REPORT

OF THE

TWELFTH MEETING

OF THE

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,

HELD AT

BRISBANE, 1909.

Sole Editor:

JOHN SHIRLEY, B.Sc.,

SENIOR INSPECTOR OF SCHOOLS, QUEENSLAND.

PUBLISHED BY THE ASSOCIATION.

BRISBANE:

BY AUTHORITY: ANTHONY JAMES CUMMING, GOVERNMENT PRINTER, WILLIAM STREET.

1910.

TABLE OF CONTENTS.

PRESIDENT'S ADDRESS.

PRESIDENTIAL ADDRESSES IN THE SECTIONS.

REPORTS OF THE RESEARCH COMMITTEES.

PROCEEDINGS OF SECTIONS.

(*An asterisk* (*) *signifies that the title only is printed.*)

SECTION A.—ASTRONOMY, MATHEMATICS, AND PHYSICS.

SECTION B.—CHEMISTRY.

Section C.—GEOLOGY AND MINERALOGY.

Section D.—BIOLOGY.

Section E.—GEOGRAPHY.

Section F.—ANTHROPOLOGY AND ETHNOLOGY.

Section Gi.—SOCIAL AND STATISTICAL SCIENCE.

Section Gii.—AGRICULTURE.

Section H.—ENGINEERING AND ARCHITECTURE.

Section I.—SANITARY SCIENCE AND HYGIENE.

Section J.—MENTAL SCIENCE AND EDUCATION.

OFFICERS FOR THE BRISBANE SESSION.

———o———

JANUARY, 1909.

———o———

Patron:

HIS EXCELLENCY LORD CHELMSFORD.

President:

PROFESSOR W. H. BRAGG, M.A., F.R.S.

Vice-Presidents:

SIR POPE COOPER, K.C.M.G.; SIR ARTHUR MORGAN, K.C.M.G.; HON. J. T. BELL, M.L.A.; J. W. BLAIR, M.L.A.; G. H. KNIBBS, F.S.S., F.R.A.S.

General Secretary:

JOHN SHIRLEY, B.Sc., New Farm, Brisbane.

Permanent Honorary Secretary:

PROFESSOR A. LIVERSIDGE, M.A., LL.D., F.R.S.

Honorary Treasurer:

HON. A. NORTON, M.L.C.

Hon. General Treasurer:

DAVID CARMENT, F.I.A., F.A.A., Sydney.

Local Secretaries:

NEW SOUTH WALES.—J. H. MAIDEN, F.L.S., Director, Botanic Gardens, Sydney.

VICTORIA.—T. S. HALL, M.A., D.Sc. University of Melbourne.

NEW ZEALAND.—G. M. THOMSON, F.L.S., F.C.S., Newington, Dunedin.

SOUTH AUSTRALIA.—W. HOWCHIN, F.G.S., and J. P. V. MADSEN, B.E., B.Sc., University of Adelaide.

WEST AUSTRALIA.—E. A. MANN, F.I.C., F.C.S., Government Analyst, Perth (Acting).

TASMANIA.—DR. ELKINGTON, Health Officer, Hobart.

Publication Committee:

Hon. A. Norton, M.L.C.
John Thomson, M.B.
A. J. Turner, M.D.
W. Cameron, B.A.
J. C. Brünnich, F.I.C., F.C.S.
John Shirley, B.Sc.

Recommendation Committee:

Professor W. H. Bragg, M.A., F.R.S.
Professor E. W. Skeats, D.Sc., F.G.S.
Professor R. W. Chapman, M.A., B.C.E.
Professor Easterfield, M.A., Ph.D.
Professor J. A. Pollock, D.Sc.
Hon. A. Norton, M.L.C.
A. H. S. Lucas, M.A., B.Sc.
John Thomson, M.B.
Peter Board, M.A.
J. H. Maiden, F.L.S.
W. H. Hamlet, F.I.C.
John Shirley, B.Sc.

Reception Committee:

His Excellency Lord Chelmsford.
Sir Pope Cooper.
Sir Arthur Morgan.
J. W. Blair, M.L.A.
Hon. A. Norton.
The Mayor of Brisbane.
The Mayor of South Brisbane.
Dr. E. Hirschfeld
Dr. John Thomson.
Dr. A. Sutton.
J. R. McConnel, B.A.
R. H. Roe, M.A.
W. B. Slade.
L. Corrie.
James Allen.
K. ff. Swanwick, B.A., LL.B.
John Shirley, B.Sc.

Members of Council Nominated by Societies:

Chas. Hedley, F.L.S.; A. H. S. Lucas, M.A., B.Sc. (Linnean Society, New South Wales).

Professor J. A. Schofield, A.R.S.M., F.I.C.; W. S. Dun (Royal Society, New South Wales).

William Benson, B.Sc. (Royal Society, South Australia).

W. H. Hamlet, F.I.C.; E. J. Goddard, B.A., B.Sc. (Sydney University Science Society).

Charles Daley (Geelong Field Naturalists' Society).

OFFICERS OF SECTIONS.

A.—Astronomy, Mathematics, and Physics.

President—PROFESSOR J. A. POLLOCK, D.Sc., Sydney University.

Vice-President—R. H. ROE, M.A.

Secretary—K. ff. SWANWICK, B.A., LL.B., Celtic Chambers, George street, Brisbane.

B.—Chemistry.

President—PROFESSOR EASTERFIELD, M.A., Ph.D., F.C.S., University College, Wellington.

Vice-Presidents—J. B. HENDERSON, F.I.C., F.C.S., Government Analyst, Queensland; A. B. CHATER, President, Pharmaceutical Society.

Secretaries—J. C. BRÜNNICH, F.I.C., F.C.S., Department of Agriculture, Queensland; GEO. WATKINS, Queen street, Brisbane.

C.—Geology and Mineralogy.

President—PROFESSOR E. W. SKEATS, D.Sc., F.G.S., Melbourne University.

Vice-Presidents—BENJAMIN DUNSTAN, Government Geologist; R. A. WEARNE, B.A., Director, Technical College, Ipswich.

Secretaries—LIONEL C. BALL, B.E., Asst. Govt. Geölogist, Brisbane; WALTER E. CAMERON, B.A., Asst. Govt. Geologist, Brisbane.

D.—Biology.

President—CHAS. HEDLEY, F.L.S., Assistant Curator, Australian Museum, Sydney.

Vice-Presidents—A. J. TURNER, M.D.; W. J. BYRAM, President, Technical College; C. W. HOLLAND, Hon. Secretary, Field Naturalists' Club.

Secretary—ROWLAND ILLIDGE, Union Insurance Co., Eagle street, Brisbane.

E.—Geography.

President—A. H. S. LUCAS, M.A., B.Sc., Sydney.

Vice-Presidents—GEO. PHILLIPS, Railway Engineer; JOHN MACDONALD, President, National Association of Queensland; A. A. SPOWERS, Surveyor-General, Queensland; C. B. LETHEM, Institute of Surveyors.

Secretary—ARTHUR EXLEY, State School, Ithaca Creek, Brisbane.

F.—Ethnology and Anthropology.

President—AUGUSTUS G. HAMILTON, Director, Dominion Museum, Wellington, New Zealand.

Vice-President—PROFESSOR S. B. J. SKERTCHLY, Corinda.

Secretary—JAS. JOHNSTON, State School, Kangaroo Point.

G (i.)—Social and Statistical Science.

President—G. H. KNIBBS, F.S.S., F.R.A.S., Commonwealth Statistician, Melbourne.

Vice-Presidents—THORNHILL WEEDON, F.S.S., Registrar-General, Queensland; ALDERMAN J. CRASE.

Secretary—J. F. BAILEY, Director, Botanic Gardens, Brisbane.

G (ii.)—Agriculture.

President—H. W. Potts, F.C.S., F.L.S., Principal, Hawkesbury College, New South Wales.

Vice-Presidents—Ernest G. E. Scriven, Under Secretary, Department of Agriculture, Brisbane; Leslie G. Corrie, F.L.S., F.Q.I.A.; F. W. Woodroffe, Secretary, Horticultural Society.

Secretary—J. F. Bailey, Director, Botanic Gardens, Brisbane.

H.—Engineering and Architecture.

President—Professor R. W. Chapman, M.A., B.C.E., Adelaide University.

Vice-Presidents—N. G. Bell, M.Inst.C.E., Deputy Ch. Engineer of Railways, Queensland; G. H. M. Addison, Architect; W. Poole, B.E., F.G.S., A.M.Inst.C.E., Director, Charters Towers School of Mines.

Secretary—Norman M. Bell, Assoc. M.Inst.C.E., Queen street.

I.—Sanitary Science and Hygiene.

President—J. Mason, M.D., Health Officer, New Zealand.

Vice-President—John Thomson, M.B., Wickham Terrace.

Secretary—Alfred Sutton, M.R.C.S. Eng., North Quay, Brisbane.

J.—Mental Science and Education.

President—Peter Board, M.A., Under Secretary, Department of Public Instruction New South Wales.

Vice-Presidents—Dr. Donaldson, Archbishop of Brisbane; J. S. Badger, General Manager, Brisbane Tramways; John Morris, President, Queensland Teachers' Union.

Secretaries—D. R. McConnel, M.A., Technical College, Brisbane; J. J. Dempsey, State School, Junction Park, Brisbane.

REPORT OF MEETING OF THE COUNCIL OF THE AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Held in the Boys' Grammar School, Brisbane, on Monday, the 11th January, 1909, at 11 a.m.

Professor W. H. Bragg, M.A., F.R.S. presided, and the following gentlemen were in attendance:—

G. H. Knibbs, F.S.S., F.R.A.S. (V.P.); John Shirley, B.Sc., General Secretary; Hon. A. Norton, M.L.C., Hon. Treasurer; D. Carment, F.I.A., F.A.A. Hon. General Treasurer; J. H. Maiden, F.L.S.; Professor J. A. Pollock, D.Sc.; R. H. Roe, M.A.; K. ff. Swanwick, B.A., LL.B,; Professor T. H. Easterfield, M.A., Ph.D., F.C.S.; A. B. Chater; J. C. Brünnich, F.I.C., F.C.S.; Geo. Watkins; Professor E. W. Skeats, D.Sc., F.G.S.; R. A. Wearne, B.A.; W. E. Cameron, B.A.; Chas. Hedley, F.L.S.; R. Illidge; A. H. S. Lucas, M.A., B.Sc.; A. Exley; Professor S. B. J. Skertchly; Jas. Johnston; Thornhill Weedon, F.S.S.; J. F. Bailey; H. W. Potts. F.C.S., F.L.S.; E. G. E. Scriven; F. W. Woodroffe; W. Poole, B.E., F.G.S., A.M. Inst. C.E.; John Thomson, M.B.; A. Sutton, M.R.C.S., Eng.; Peter Board, M.A.; J. S. Badger; John Morris; Professor J. A. Schofield, A.R.S.M., F.I.C.; W. M. Hamlet, F.I.C.; J. B. Henderson, F.I.C., F.C.S.; Dr Walter Spencer; W. T. Gray; John George, B.A.; C. H. W. Thom; Geo. Sweet, F.G.S.; W. S. Dun (Sydney); Wm. Benson, B.Sc. (Royal Society, South Australia); E. J. Goddard, B.A., B.Sc. (Sydney University Science Society); Chas. Daley (Geelong); R. L. Jack, LL.D.; Eugen Hirschfeld, M.D.; Dr. Storie Dixson; W. J. Bevington; R. Gailey.

1. Confirmation of 1907 Minutes.—

The President: The first business, gentlemen, is the confirmation of the minutes of meeting held in Adelaide in 1907, and as these have been published in the Proceedings I think we will take them as read.—Agreed to.

2. Confirmation of the Election of Sectional Officers.—

Proposed by Professor Pollock and seconded by Mr. G. H. Knibbs—That the election of sectional officers, as per printed list, be confirmed.—Carried.

(*See* list on p. xi.)

3. Resignation of Professor A. Liversidge, Permanent Hon. Secretary.—

The President read a letter from Professor Liversidge, conveying his resignation as Permanent Hon. Secretary.

Mr. Hedley moved that the letter be handed in, that the resignation be accepted with regret, and that the Council express its grateful appreciation and thanks for the services rendered by Professor Liversidge in the foundation and organisation of the Association.

Mr. Lucas: I should like to support the motion, and also that a copy of the resolution be forwarded to Professor Liversidge in England.—Carried.

4. Election of Permanent Honorary Secretary.—

Mr. Shirley: I have pleasure in moving that Mr. J. H. Maiden be elected Permanent Honorary Secretary in place of Professor Liversidge, whom we have lost. I have known Mr. Maiden for a good many years, and have been in communication with him, and I feel sure that we could not elect a man more fitted for the post than the one I have proposed.

Mr. Knibbs: I have much pleasure in seconding the motion. It must be obvious that some person must have continuous charge of the affairs of our Association to hold the position and perform the duties so ably discharged by Professor Liversidge. Might I suggest in regard to the title that it would be a little clearer if instead of Permanent Hon. Secretary the term "General" were used instead of "Honorary." The duties are all common to a general secretary, who has a clear oversight of the affairs of the Association, and will maintain unimpaired all its traditions, and be in charge of what property it possesses, and its documents. It would be an advantage to change the title, which would make the distinction clear between the local secretaries, who are called Honorary Secretaries for the States, and the General Secretary, who must be a continuous officer of the Association.

Professor Pollock: I would like to support the motion proposed by Mr. Shirley. Those of us knowing Mr. Maiden know his genius for organising, and there is the further recommendation that he was specially picked by Professor Liversidge as the one man admirably fitted to be his successor, and if he were here he would have had pleasure to propose him. I am strongly of opinion that the title should be "Permanent General Secretary."

Mr. Shirley: I would like the motion to be carried by itself, and the title dealt with by a further motion. I think it is better to unravel the title afterwards.

The President: The motion is that Mr. Maiden be elected as Permanent Honorary Secretary. Is there any amendment?

Motion put.—Carried *nem. con.*

Mr. Maiden: I am very highly honoured by your electing me to this honourable office, and all I can say is, that I will endeavour to do my utmost to carry on the work the founder, Professor Liversidge, carried on so many years. I was one of the men whom Professor Liversidge consulted in regard to the foundation of the Association, when the idea crystallised in his mind, some time in the year 1886. I attended the first meeting of the Association in 1887, and on that occasion, and on subsequent occasions, I held the office of Hon. Secretary of the Royal Society in Sydney, and of a section, and also of President of two sections. I further claim to have some estimate of the working of the Association, and my experience as Hon. Secretary of the Royal Society for eighteen years may be some guarantee to you who do not know me that I am not at all likely to run counter to the traditions of the Australasian Association for the Advancement of Science.

A Voice: How about changing the title?

The PRESIDENT: According to our rules, the office is Permanent Honorary Secretary. Furthermore, we have no power to alter it. Mr. Maiden is, therefore, elected Permanent Honorary Secretary of the Association.

Mr. KNIBBS: The office was named General Secretary in order to submit another motion.

The PRESIDENT: Then such a title was not in order.

Mr. KNIBBS: In Professor Liversidge's letter to you he mentioned that, strictly speaking, the rules do not provide for bringing in a general secretary, and he left a memo. in his papers desiring that the title be formally corrected to designate the office he held, and you will see by the resolution just submitted if the title is not "Permanent" as construed in the rules it is not quite correct. What we have carried was that a general secretary shall be appointed, and that he shall be permanent.

Mr. SHIRLEY: The best thing would be to give notice; it cannot be altered without giving notice.

The PRESIDENT: That the word "Permanent" be placed before the words "General Secretary."

5. Election of Local Secretary for New Zealand.—

Mr. SHIRLEY: I have received a letter from Mr. Thomson, Local Secretary at Dunedin, who has lately been elected to the New Zealand Parliament, resigning his position as local secretary. He has consulted with Dr. Coleridge Farr, who is willing to accept office, and I therefore propose that Dr. Coleridge Farr be elected Local Secretary for New Zealand.

Professor EASTERFIELD: I have much pleasure in seconding. Dr. Farr is a very capable man.—Carried.

6. Reports of Research Committees.—

Mr. SHIRLEY: I will propose that the reports of Research Committees be received by the Recommendation Committee at their first meeting, and that in the meantime the reports be deferred.

Professor POLLOCK: I second the motion.—Carried.

7. Balance-sheet.—

Mr. D. CARMENT: This is the balance-sheet from July, 1906, to the 30th June, 1908. In the June account there was a debit of £69 2s. 5d., but, owing to subscriptions having come in, there is a considerable difference. There is now a credit balance. The Research Committee Fund has a credit of £2,872 odd, of which the greater part is invested on mortgage, and the balance is in current account. The Mueller Memorial Fund is a separate account. This has a credit balance of £492 odd, part invested on mortgage and part in current account. There was a balance of £191 4s. 3d. in the bank in June last. All the Research Funds are invested at 4 per cent. interest. The balance-sheet will be printed in due course and audited. It is open for inspection.

Mr. Knibbs: I move that the Treasurer's report be adopted, subject to audit.

Seconded by Mr. Hamlet.—Carried.

8. Appointment of Officers for the Sydney Meeting.—

Mr. Maiden: The Council have decided to nominate as President-elect of the Sydney meeting Professor Orme Masson, Professor of Chemistry in the Melbourne University. I scarcely think it necessary to point out in a committee of scientific men the eminent and peculiar qualifications of Professor Orme Masson for an office like this. Therefore, without further ado, I nominate that gentleman as President-elect of the Sydney meeting. Perhaps I may be allowed to remind you that Sydney has been fixed by resolution, in accordance with our rules, as the next meeting place.

Professor Pollock: I beg to second it.

Mr. Shirley: I have much pleasure in supporting the motion. Professor Orme Masson was met at Adelaide by a number of Queensland members, and we are strongly in favour of his nomination. I am sure his election as President will be very popular among Queenslanders.—Carried.

Mr. Maiden: The order of the meetings has been—Sydney, Melbourne, Christchurch, Hobart, Adelaide, Brisbane, and Sydney, then followed as before by Melbourne, Hobart, Dunedin, Adelaide, Brisbane, and now we come back to Sydney again.

9. Deciding the place for the meeting next following.—

The President: We would like a Melbourne visitor to propose this.

Professor Skeats: While I have no special permission to make a proposition, I am perfectly certain that the proper organisation in Melbourne will be extremely happy to extend an invitation to the officers of the Association to meet there, following the one in Sydney—that is, the one to be held in 1913. If it is acceptable, I move it be held in Melbourne.

A Voice: Why is Perth left out?

Mr. Shirley: Simply because of the difficulties of communication.

Mr. Maiden: I received an unofficial letter from the acting local secretary in Perth. If his committee sent an official invitation it could be voted upon. So far as I am aware, no official invitation has been received.

Mr. Shirley: A proposal to hold the meeting in Western Australia was declined on one occasion. I think this was on account of the small number who would undertake the trip.

Mr. Sweet: I have much pleasure in seconding that the next meeting after the Sydney meeting be held in Melbourne, in harmony with the previous and continuous routine.—Carried.

10. Appointment of Recommendation Committee.—

Mr. HAMLET: I have much pleasure in proposing the following names as members of the Recommendation Committee:—Professor W. H. Bragg, Professor Skeats, Professor Chapman, A. H. S. Lucas, Hon. A. Norton, Dr. J. Thomson, Professor Easterfield, P. Board, Professor Pollock, John Shirley, J. H. Maiden, and the mover.

Seconded by Mr. SCRIVEN.—Carried.

11. Appointment of Publication Committee.—

Professor SKEATS: I propose the following gentlemen:—Hon. A. Norton, Dr. J. Thomson, Dr. A. J. Turner, W. Cameron, J. C. Brünnich, and J. Shirley.

Seconded by Mr. DUN.—Carried.

12. Motions.—

I. "That a separate section be formed for Botany." (Proposed by Mr. J. H. Maiden, at Adelaide.)

Mr. MAIDEN: I may say that I addressed the General Council at Adelaide on the matter, and it was remitted to the section who voted upon it, and they approved by a majority that it be remitted to Brisbane. I made a recommendation as follows:—As a rule, in the Biology section a man is either a zoologist or a botanist, and he listens (the zoologist for example) with great politeness to a paper on a subject he has very little personal interest in. I think the botanists are in the reverse direction equally polite. I submit with all diffidence, as there is an objection to multiply the sections, that some arrangement could be made to separate the two subjects. Representatives of the two sciences could meet in different rooms, and if the thing did not work well they could be consulted after a year or two, and they could meet in regard to matters of mutual concern—that is to say, in regard to general Biological questions.

Mr. HEDLEY: The sections are all round too many. We do not want to have any more Presidential addresses than we have. I would like some loose federation adopted. Alternatively a botanist or a zoologist might preside over a particular section, and alternative days could be taken by each subject. By such a means we might get all the advantages without its disadvantages.

Mr. KNIBBS: I beg to second the motion *pro formâ*. I think there is very little to be said in favour of keeping the two subjects separate. There are certain sides which are common to both, and of wider benefit if they are included under one great heading. I am not sure of the wisdom of splitting into two.

Mr. BAILEY: I think Mr. Maiden's suggestion is a very good one. Zoology is not of interest to me; but, of course, I could attend the meetings. I think it would be a very good idea to separate the two into two different sections.

Mr. WEEDON: I have no knowledge of the subject, but if we divide that, we might have other claims very shortly. It strikes me there is not so much difference between engineering and architecture as between botany and zoology. We want to guard against the danger of multiplying the sections.

Mr. Roe: Will you inform us whether the work in this section as at present constituted is overloaded with work? Is it able to deal with the work it has? Has it a surplus of papers with which it cannot deal?

Mr. Maiden: I have figured out the relative numbers of papers in the two subjects, and I find out of ninety papers for a period of nine meetings there are seventy on zoology. Therefore, there is a preponderance of zoologists' papers, but I do not think that the volume of papers is a fair test. I am willing to accept Mr. Hedley's double motion. I think it would stimulate the interest in both subjects—in fact, I have evidence at the present that both subjects are handicapped.

A Voice: I would rather the section settle its own affairs.

Mr. Maiden: We are following the wisdom of the British Association. They had to do it, but at the same time it is perfectly fair to point out that our position compared with the large number of workers in Britain and Northern Europe is not quite analogous.

Hon. A. Norton: I have a great deal of sympathy with Mr. Maiden, and I heard his address on the subject, which received a great deal of sympathy. At the same time, we are all bound to realise the difficulties which may be brought about by dividing into two sections. If such a system be adopted as suggested by Mr. Hedley, the two classes would work as twin brothers, and in that way the work which both decided to carry out might be just as effective without creating a new section.

Mr. Hedley: I move as an amendment—That in successive years this section agree to elect as President a zoologist and botanist alternatively, and that, as far as possible, zoological and botanical papers be taken on alternative days.

Seconded by Mr. Sweet.

Amendment put.—Carried by a large majority.

II. That the two divisions of Section G be made separate sections. (Proposed by Professor E. H. Rennie, at Adelaide.)

Mr. Maiden: I wrote to Professor Rennie, reminding him of this motion, and he replied he could not attend this meeting, but that he had arranged for Professor Chapman to move it in his stead. Professor Chapman is not here.

The President: Will some member move it?

Mr. Knibbs: It requires no argument to support it. I move it.

Mr. Potts: I heartily agree with the proposal. Agriculture is now assuming such vast importance that it demands a section by itself. Its importance is such that it warrants us carrying this resoluion.—Carried.

III. "That subjects be selected for discussion two years in advance." (Proposed by Mr. J. H. Maiden, at Adelaide.)

Mr. Maiden: If I had known that I should have been brought into such prominence at this meeting, I would have been more sparing in my recommendations. As I explained at Adelaide, I submit that it is undesirable to make this Association too much of a society at which papers are read after the manner of local scientific societies. Here we have members gathered from all the Australasian States, and the opportunity would be lost if we could not obtain an expression of opinion in regard to matters of particularly Australian merit. In order to illustrate my proposition, I quote one instance—that is to say, the effect of the destruction of forests on the flow of streams in Australia. This is one which might be brought forward at next meeting, should the Council see fit to entertain the proposal. I think if men from all the States were to come armed with arguments and facts in regard to a subject like that, which is attracting very considerable attention at the present time in all Australia, we should obtain information which would be of exceedingly great value to the Forestry Departments and the heads of Government in all the States. I do not think I need say any more.

Dr. Jack: I would like information as to the machinery with which it is intended to carry it into execution. Under what circumstances are discussions to take place? Will they take place at meetings specially fixed? Taking this one, what time would be set apart for discussion? To what extent would the general business of the Association be interfered with?

The President: There is nothing in our rules to guide me in making a decision. I presume it is within the power of the Council to decide what should be done.

Professor Skertchly: I second the motion, if only for the sake of eliciting information. It would be worth while to devise machinery to carry it out.

Mr. Shirley: I, like the original mover, think we should proceed by the usual method, by means of papers; that the papers be written on the subjects selected; that then these papers be read together, and a discussion follow at the end of the series of papers. If we leave the discussion without defining the number of men taking part in it, we shall waste the time of the Association. I simply make this as a suggestion.

Mr. Maiden: I would suggest that the details be left to arrangement by the local committee, but I think it might be desirable to have an afternoon meeting on subjects of great importance. My own view is that, as a rule, we come to listen to papers that through the machinery of the Association we know nothing about. We have got a number of papers here for reading to-morrow. The authors of these papers have not furnished us with any outlines. It would be incumbent upon us before bringing up any discussion to give some outlines to the local secretary on which discussion could be obtained. I do not think that a paper quite meets the case, for this reason: Suppose I, for example, take up a subject, I should want to know what other people know about this subject—not what I know. I should want to elicit information in regard to the experience in Western Australia or Tasmania.

Mr. Shirley: Could you not get that by a paper?

Mr. Maiden: Of course, that is simply a matter of opinion, I am afraid I do not think it would be an advantageous way of conducting our business.

Professor EASTERFIELD: The proposition is to some extent carried out by the British Association, although, as Mr. Maiden previously said, the conditions in Great Britain are absolutely different. Still, the fact that the system has worked well in Britain might be some guide to us. I remember ten or fifteen years ago hearing one of the most stimulating discussions I have ever heard carried on there. I consider it was one of the greatest privileges of my life to have been present on such an occasion, and I do hope that the same beneficial result will follow if such a system is adopted here for discussions.

The PRESIDENT: Would it not be best to affirm the general principle now, and consider the details later?

A Voice: I would like to make a suggestion before affirming the proposition; is not this a matter for the sections rather than the General Council?

The PRESIDENT: I think not. The motion has been proposed and seconded. I will simply put it.—Carried.

Mr. MAIDEN: It might be as well to remit it to the Recommendation Committee. You do not want to bind the Local Committee too much.

The PRESIDENT: The Recommendation Committee has power to do that.

Mr. MAIDEN: I do not know that I am quite prepared to do that. I purposely left it rather vague, so as to limit the local committees as little as possible. I wanted to establish a certain principle, and different centres might carry the scheme out in different ways.

The PRESIDENT: If there is no further motion we will simply proceed to the next business.

13. Subjects Recommended for Discussion at Sydney Meeting.—

Mr. MAIDEN: I move the following subjects be recommended for discussion at the Sydney meeting:—

I. The effect of the destruction of forests on the flow of streams in Australia.

II. The principles of scientific description in Natural History. (At Adelaide the Rev. Mr. Blackman moved the latter), Mr. Shirley seconded, Professor Skertchly supported.

Mr. LUCAS: I move as an amendment—"That the matter be postponed until the precise method in which the general subjects are to be selected and considered be determined."

Seconded by Mr. KNIBBS.

Mr. JOHNSTON: I move that we omit the following words in proposition II.—viz., "on the flow of streams," making it read "The effect of the destruction of forests in Australia."

Seconded by Mr. SWANWICK.

Mr. Johnston's amendment put—Voting = 15 for, 13 against.

Mr. Lucas's amendment put—Voting = 22 for, 2 against.

Mr. Lucas's amendment put as substantive motion, and carried.

A Voice: Has not each section the power to forward motions or suggestions to the Recommendation Committee during the course of a week?

The PRESIDENT: Certainly.

14. Motions.—

IV. That the question of publishing bibliographies in the various branches of Science be considered. (Proposed by Mr. J. H. Maiden at Adelaide.)

Mr. MAIDEN: I bring forward this subject in a representative character—that is to say, I was approached by several members, principally geologists, with the desire to spend various funds of the Association in publishing bibliographies. No doubt the scientific men who are here now can estimate whether a matter of that kind is desirable or not. Personally, I think it is very desirable. They do not propose to include the ordinary run of papers.

Mr. DUN: The matter came before the Sydney section, and there was an unanimous feeling that such a course was extremely desirable.

Mr. SHIRLEY seconded.—Carried; 3 votes against.

V. That it is desirable to publish approved monographs. (Affirmed by the Association at Adelaide.)

Mr. MAIDEN: That also arises out of the Geology section. I propose that it be reaffirmed.

Seconded by Mr. SHIRLEY.—Carried.

15. Commemoration of the Work of Darwin and Wallace.—

The PRESIDENT: There is one suggestion I would like to make: that in such a very important scientific commemoration of the work of Darwin and Wallace taking place in the old world, this Association should take some steps to share in the recognition of the work of these two great men.

Mr. HEDLEY: I give notice at the next meeting I will bring forward such a resolution.

16. Mueller Medal Committee Report.—

Mr. MAIDEN: On behalf of the Mueller Medal Committee, I have the honour to report that the committee has unanimously decided that the medal for this meeting be awarded to Professor David, in recognition of his work for the advancement of geology.

17. Deaths of Past Presidents and Appointments of Trustees.—

Mr. MAIDEN: Unfortunately, death has fallen very heavily upon our Past Presidents. I hope, Sir, that your life may be very long and happy, but within the last few years we have lost Russell, Ellery, Gregory, and, last of all, our friend Dr. Howitt, whom we hoped to have seen in the running for office as our President.

These deaths have caused some vacancies in the list of trustees. Reference to trustees is in Rule 13, which provides that all sums received for life subscriptions, &c., shall be vested in the names of three trustees; therefore I move that Mr. Shirley be a trustee in the room of Mr. Ellery.

Seconded by Mr. BAILEY.—Carried.

Mr. Weedon: Owing to the resignation of Professor Liversidge, there is another vacancy. I move that Mr. J. H. Maiden be appointed as a trustee.

Seconded by Mr. Bailey.—Carried.

18. Next Meeting of Council.—

Professor Pollock: I suggest that the next meeting of the Council be held not on Monday as provided in the programme, but on Friday. A great many of the members might not be here on Monday.

The President: The next meeting will be on Friday at 11 o'clock.

[Meeting adjourned at 12.45 p.m.]

REPORT OF MEETINGS OF RECOMMENDATION COMMITTEE.

Held in the Girls' Grammar School, Brisbane, on Thursday and Friday, the 14th and 15th January, 1909.

Professor E. W. Skeats took the chair, and the following gentlemen were in attendance:—Professor Pollock, Professor Skertchly, Messrs. Knibbs, Lucas, Maiden, and Shirley.

The Minutes of Meeting of the Committee, held on the 14th instant, were taken as read, and confirmed.

Section D.

The sub-committee appointed at the previous meeting to redraft submission from this section, as to periodicals obtained by the Scientific Societies and Libraries in the State Capitals, presented the following:—

> "The Council is aware of arrangements made by the official libraries in some of the State Capitals with the view to the systematising the selection and purchase of scientific serials to be readily available to workers, and recommends that such arrangements be adopted in all the capitals to suit local requirements."

Proposed by Mr. Lucas, and seconded by Mr. Knibbs, that the same be adopted.—Carried.

Section C.

Section submitted the following:—

> "The Association respectfully suggests to the Government of Queensland the very great desirability of imposing on the Geological Survey Department the duty of giving more attention to detailed inquiry in regard to the stratigraphy and general geological structure of the State."

Professor Skeats: The committee of this section and geologists from other States have been aware that the staff of the Queensland Geological Survey Department labours under considerable difficulties by more attention not being paid to the scientific side of its work, so that, together with the examination and recording of the economic mineral resources as now almost exclusively carried out by the survey, more detailed inquiry should be made into the stratigraphy and general geological structure of the State. In New South Wales it is the recognised practice in the administration of the Geological Survey Department of the State, that priority be given to work of an economic character—but it is expected that officers undertaking field work should spare no pains in the elucidation of the detailed geology of the district concerned. In all cases this principle has been followed, and in all examinations of districts substantial additions have been made to the knowledge of the structural geology of the State. At the same time, special attention is given to the nature and occurrence of the igneous rocks and all questions of stratigraphy. As a particular example of work of this character, combining the economic aspect of geology with the fullest details of scientifically conducted geological survey, the recently issued memoir on the Geology of the Hunter River Coalfield by Professor David may be referred to. This geological survey was the direct cause of the enormous development of coal-mining in the South Maitland Coalfield. As to geological work of purely scientific character, reference may be made to the recently completed geological survey of the Murrumbidgee Water Conservation Area, in which the field work alone occupied over eight months. In Victoria, in recent years especially, the energy of the Geological Survey staff has been mainly concentrated in the mining districts, but geological and economic work have gone on hand in hand. The work of Mr. Dunn on the Bendigo Goldfield may be specially cited as an example of a piece of work in which considerations of structural and stratigraphical geology have been employed to determine the structure of the mining field, the occurrence of the saddle reefs, and the effect which the pitch of the anticlinal axes has on the prospecting operations in the district. This paper clearly demonstrates the great economic value of careful geological work in the development of the Bendigo Goldfield. In New Zealand the Geological Survey is a separate branch of the Mines Department, and the Director is responsible to the Minister for Mines alone. The practice of the survey is to make complete examinations of districts selected by the Minister and Director. These districts are usually those in which mineral deposits are known to exist, or are supposed to be present. The actual boundaries of the areas examined coincide with those of survey blocks. Within the blocks selected complete topographical survey is done, and the whole work is performed so as to enable the officers to issue a report as complete from the scientific as from the economic standpoint. The annual appropriation for this branch of the Mines Department amounts to £12,000. I give these details of the practice of the Geological Survey Departments in the other States in the hope that the Queensland Geological Survey Department's work will be strengthened in its scientific as well as its economic value.

Proposed by Mr. Maiden, and seconded by Professor Skertchly, that the same be adopted.—Carried.

Professor Skeats: I wish to bring before this Committee another recommendation from Section C, viz.:—

(*a*) "That a Committee of the Geology and Mineralogy section, consisting of Professor David, Professor Marshall, Dr. Jensen, and myself, be appointed to investigate the alkaline rocks of Australasia."

(*b*) "That a sum of £50 be set aside for further investigation into the nature and origin of the alkaline rocks of Australasia."

There is a question about this grant. Is there any difficulty in a Committee, where a grant is set aside, awarding part of the grant to a member of the Committee? What is the practice of a research Committee?

Mr. Maiden: They have to submit vouchers for expenses. No sum of money is to be used for personal expenses on any account, except a special vote is made for that purpose.

Professor Skeats: That is very difficult in geological cases where the work is field work, and exceptional circumstances met with. The point is this: If the Committee is appointed, can it award part, or all, of the fund to a member of its committee for expenses in connection with investigation? Is there any difficulty in a member of the committee taking any money which is set aside for research purpose?

Mr. Maiden: I imagine it is a matter for the committee to make its own arrangements.

Proposed by Professor Skertchly, and seconded by Mr. Maiden, that the same be adopted.—Carried.

Section E.

"That the South Australian Government be respectfully urged to establish suitable seismographs at Port Darwin and Alice Springs, in order to complete the system of seismic records along the axis of disturbance in South Australia."

Mr. Lucas: A few years ago, when Mr. Chamberlain was in charge of the Colonial Office, the British Government approached the South Australian Government, and urged the establishment of a seismograph at Port Darwin. Later on the British Association also sent a recommendation to the South Australian Government to do the same thing. They have established a seismograph at Adelaide, which I think is working. We should follow up the action of the British Government and the British Association. It is a rather important matter.

Proposed by Mr. Lucas, and seconded by Mr. Knibbs, that the same be adopted.—Carried.

Section A.

Solar Research.

(*a*) "That the Australasian Association for the Advancement of Science records its unanimous support to the movement for the establishment in Australia of an Observatory devoted to the study of Solar Physics, which has been so strongly advocated by the International Union for Co-operation in Solar Research, by the Royal Society, and by the British Association for the Advancement of Science, and which is essential to the scheme of solar study instituted by the International Union. The practical possibilities, combined with the scientific value of solar research, make the project a matter of national as well as international importance."

Proposed by Professor POLLOCK, and seconded by Professor SKERTCHLY, that the same be adopted.—Carried.

(*b*) "That a copy of the above resolution be forwarded to the Prime Minister of Australia, with an urgent appeal that steps be taken to secure the establishment of a Solar Physics Observatory in Australia."

Proposed by Professor POLLOCK, and seconded by Mr. LUCAS, that the same be adopted.—Carried.

(*c*) "That a committee be formed to aid in the work of establishing such an Observatory, to consist of—Professor Bragg, Messrs. Knibbs, Baracchi, and Cooke, Professor Pollock, and Dr. Duffield (Secretary)."

Proposed by Professor POLLOCK, and seconded by Mr. SHIRLEY, that the same be adopted.—Carried.

(*d*) "That in view of the generous attitude of the British Association in granting £50 towards the establishment of the Observatory, a similar sum be granted to the Committee by this Association."

Proposed by Mr. SHIRLEY, and seconded by Mr. HAMLET, that the same be adopted.—Carried.

Solar Eclipse, 1910.

I. That a Committee of the Australasian Association for the Advancement of Science be appointed—

1. To organise, if possible, an expedition of Australian astronomers to witness the total solar eclipse of 1910, visible in Hobart.

2. To obtain from the Federal Government and State Governments and private companies facilities for witnessing this eclipse.

3. To arrange for the convenience of British and foreign expeditions.

4. To acquaint the leading astronomical societies of the world of such facilities and concessions as may be obtained.

II. That the Committee consist of—Messrs. Baracchi, F.R.A.S.; W. E. Cooke, F.R.A.S. (Perth); the Government Astronomer of N.S.W. (when appointed); Professor Chapman; Professor Pollock, D.Sc.; Dr. Coleridge Farr; Messrs. G. H. Knibbs, F.S.S., F.R.A.S.; R. H. Roe, M.A.; Mr. Baldwin (Melbourne University); and Dr. W. E. Duffield, F.R.A.S. (Secretary).

III. That a grant of £5 be made for postages, typing, &c.

Proposed by Professor POLLOCK, and seconded by Mr. KNIBBS, that the same be adopted.—Carried.

New Geometry.

(*a*) "That this Association requests the University of Cambridge to form a committee of experts on elementary geometrical teaching for the revision of the scheme of the New Geometry, and for the better regulation of its teaching."

(*b*) That if the Cambridge University decline the task, the Council of this Association be requested itself to constitute such a committee from amongst the mathematical professors and schoolmasters of Australasia."

(*c*) "That the presentation of this recommendation to the authorities of Cambridge University in proper form be entrusted to the President of this Association, Professor Bragg."

Proposed by Professor Pollock, and seconded by Mr. Knibbs, that the same be adopted.—Carried.

REPORT OF MEETING OF THE GENERAL COUNCIL.

HELD IN THE GIRLS' GRAMMAR SCHOOL, BRISBANE, ON FRIDAY, THE 15TH JANUARY, 1909.

Mr. G. H. Knibbs, F.S.S., F.R.A.S., Vice-President, was in the chair, and the following gentlemen were present:—

Professor J. A. Pollock, D.Sc.; Professor E. W. Skeats, D.Sc., A.R.C.S., F.G.S.; Mr. C. Hedley, F.L.S.; Mr. A. H. S. Lucas, M.A., B.Sc.; Professor P. Marshall, M.A., D.Sc., F.G.S.; Professor S. B. J. Skertchly; Professor J, A. Schofield, A.R.S.M., F.I.C.; Messrs. W. S. Dun; W. M. Hamlet, F.I.C.; J. B. Henderson, F.I.C.; G. Sweet, F.G.S.; W. Poole, B.E., F.G.S., A.M. Inst. C.E.; J. C. Brünnich, F.I.C., F.C.S.; T. Weedon, F.S.S.; R. H. Roe, M.A.; Dr. Goddard; F. B. Guthrie, F.I.C., F.C.S.; W. Cameron, B.A.; J. H. Maiden, F.L.S.; and J. Shirley, B.Sc.

The Minutes of Meeting of Council, held on the 11th instant, were taken as read, and confirmed.

The reports of Meetings of the Recommendation Committee, held on the 14th and 15th instant, were taken as read, and adopted, on the motion of Mr. HAMLET, seconded by Professor SKEATS.

ALTERATIONS OF RULES.

Mr. SHIRLEY: Professor Liversidge has written and asked me to bring before the Association the need of an additional rule, to the following effect:—

> Each Local Council shall be summoned by the Local Secretary to meet at least once annually (if possible in the month of July or September) to transact any business which may be brought before it, and to prepare for transmission to the General Council at its next Session a Report upon the local work of the Association since its last session.

This is a very important motion. As a rule, in the several States, after the Session of the Association, the Association dies in that State, and has to be born again after a period of twelve to fourteen years. By this motion it is intended to give it continuity, so that some action may be taken each year to keep it before the public. I propose that it be recommended for adoption at the next meeting of the Council.

Mr. HAMLET: I second it, because there should be a perfect understanding of work to be undertaken in each State.

Professor MARSHALL supported.—Carried.

Professor POLLOCK: I move that it be a recommendation to the next meeting of Council that Rule 9 be altered to read as follows:—

> The President, five Vice-Presidents, a General Treasurer, a Permanent General Secretary, and Local Secretaries shall be appointed by the Council.

Mr. SHIRLEY: I would like to point out that you cannot get five vice-presidents among past presidents. I second the recommendation for consideration at next meeting of the Council.—Carried.

JUBILEE OF "ORIGIN OF SPECIES."

Mr. Hedley: I move that—

This Association offers to Dr. Alfred Russel Wallace its congratulations on the attainment of the jubilee of "Origin of Species," jointly introduced by Dr. Darwin and himself.

I think a motion of this sort needs no further recommendation.

Dr. Spencer: I second the motion.

Mr. Maiden supported.—Carried.

VOTES OF THANKS.

Professor Pollock: I beg to propose a vote of thanks to His Excellency the Governor. His Excellency has shown, not only during the meetings, but previous to the meetings, a great interest in the work of the Association, and during the meetings he has given us encouragement by his presence at and by addressing the meetings. I should also like to include the name of Lady Chelmsford in my motion.

Professor Marshall: I have much pleasure in seconding.—Carried.

Mr. Knibbs: I need hardly say that we feel extreme gratitude to the Hon. the Premier and the Parliament of Queensland for grants in aid of the work of the Association. They clearly perceive that the work we are doing is of profound interest to Australia from the economic and higher standpoints. I move that the thanks of this Association be accorded to them.

Dr. Goddard: I have much pleasure in seconding.—Carried.

Mr. Hamlet: I beg to move a vote of thanks to His Grace the Archbishop of Brisbane (Dr. Donaldson) for his cordial invitation to a Garden Party taking place to-morrow afternoon.

Mr. Hedley: I second the motion.—Carried.

Professor Pollock: I rise with very great pleasure to propose a vote of thanks—more than as a mere matter of form—to the General Secretary, Mr. Shirley, who has made a splendid Secretary. I have attended most of the meetings, and we all feel sure that this has been one of the most successful. Personally, it has been to me the happiest meeting I have ever attended. We all know how much of success depends upon the efforts of the Secretary, and that in this connection we ought to pass an extra cordial vote of thanks to Mr. Shirley for the great efforts he has made and for the success it has been.

Mr. Guthrie: I cordially second and support the motion.

Mr. Knibbs: I think we all appreciate and recognise how very much we are indebted to the arduous labours of Mr. Shirley for the success of this meeting.—Carried.

Professor Skertchly: I have very great pleasure in moving a vote of thanks to the Local Secretaries. We know their tasks are difficult ones, and that they have carried them out with the greatest care and attention.

Dr. Goddard: I second the motion.—Carried.

Mr. Knibbs: I move that a hearty vote of thanks be accorded to the lecturers, who have done so much to occupy our time and give us pleasure.

Dr. Spencer: I second the motion.—Carried.

Mr. Lucas: I move that a hearty vote of thanks be accorded to the Minister and Commissioner for Railways, who have granted to us very liberal facilities for seeing the country, and making the trip from the South much less expensive, and for giving us an opportunity of going to Gympie, Toowoomba, Warwick, Killarney, and the Barrier Reef so easily.

Professor Pollock: I second the motion.—Carried.

Mr. Hamlet: I move that a hearty vote of thanks be accorded to Mr. Badger, of the Brisbane Tramways Company, for placing cars at the disposal of members for morning and evening rides around the city.

Mr. Daley seconded.—Carried.

Mr. Maiden: I move that a hearty vote of thanks be accorded to the trustees of the Brisbane Grammar Schools, coupled with the name of Mr. Roe. The kindness of the trustees has been of a most substantial character. Mr. Roe has not only supported the Association in every possible way in his official character, but has been very kind to us, and has done his best to make us feel at home.

Professor Schofield seconded.—Carried.

Mr. Maiden: I move that the thanks of the Association be accorded to the Press for the services rendered us during the session. I wish that some of our members had been a little more considerate in providing them with abstracts of their papers, but notwithstanding this the Press has performed great service in recording the daily proceedings of the session.

Mr. Knibbs: The Queensland Press has been noted for its intelligence, and it has undoubtedly distinguished itself with regard to the space made available for the reports of this Session. It would be well, indeed, if we could get the same space given to us in the other States.

Mr. Shirley: I cannot allow this motion to pass without saying something in its support. We have had the help of the Press right through from the beginning, since we began to organise; they were only too anxious to publish what we were doing. From November, 1907, until we got nearer the Session, the space devoted to our Association grew larger and larger. We are greatly indebted to the Press for its assistance.—Carried.

Mr. Shirley: I have to propose a vote of thanks to the Editor of the Official Daily Journal, Mr. John George, for his work which was done well and done promptly. He has considerately taken work off my hands, and relieved me of much trouble.

Seconded by Professor Pollock.—Carried.

Professor Pollock: I have great pleasure in moving that a special vote of thanks be given to Miss Shirley, for the great courtesy shown to us all, and for the work done by her during this Session. She has attended at all the meetings, and rendered us great assistance.

Seconded by Mr. Guthrie.—Carried.

BALANCE-SHEET OF THE AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.—SOUTH AUSTRALIA.

	£ s. d.	£ s. d.
Balances—		
From Adelaide Volume, 1907—		
Bank of Australasia	31 16 7	
Less Cheques Outstanding ..	12 11 1	
		19 5 6
Savings Bank		2 6 1
Cash in Hand		0 2 4
Subscriptions—		
Brisbane Meeting, January, 1909—		
16 Members at £1	16 0 0	
5 Associates—3 at 10s., 2 at 10s 6d.	2 11 0	
		18 11 0
		£40 4 11

	£ s. d.	£ s. d.
1st December—		
S.A. Paper Bag Co.	..	4 2 7
31st December—		
Bonython and Co., J. L.	..	1 3 4
1st January—		
Thomas and Co., W. K.	..	1 3 4
5th February—		
Graves and Co.	..	1 12 5
1st March—		
Hussey and Gillingham	..	0 10 6
5th March—		
Henderson H. B.	..	2 1 4
Henderson, H. B. (Clerical Work) ..	..	5 0 0
Good, Toms, and Co.	..	0 7 6
Postages—		
Reprints to Authors	2 4 5	
Volumes to Members	12 7 6	
Sundry Postages	1 4 1	
		15 16 0
Sundries	..	0 6 7
Bank of Australasia, Fee	..	0 5 0
Remitted to Treasurer, Sydney ..	..	7 0 0
Cash in Hand (W. Howchin) ..	..	0 16 4
		£40 4 11

H. B. Henderson.

Certified correct this twentieth day of May, 1909.

EDWARD H. RENNIE, Chairman Local Committee.
WALTER HOWCHIN, Secretary Local Committee.

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,—WESTERN AUSTRALIA.

Receipts.	£	s.	d.
1908.			
Subscriptions, Brisbane Meeting—			
17th June—			
A. Gibb Maitland	1	0	0
17th November—			
A. L. Tilly	1	0	0
2nd December—			
J. Bernard Allen	1	0	0
14th December—			
Miss A. Collison	1	0	0
1909.			
9th January—			
E. S. Simpson	1	0	0
	£5	0	0

Expenditure.	£	s.	d.
1908.			
21st June—			
Envelopes	0	0	6
Postages	0	3	1
Printing Circulars, Receipt Account	0	7	6
Account Books	0	1	6
11th December—			
Telegram—Shirley, Brisbane	0	1	2
1909.			
17th May—			
Postage—Maiden, Sydney	0	0	2
20th May—			
Stationery, &c., Receipt B.	1	8	6
1st June—			
Cost of Money Order 6d., and Postage 2d. ..	0	0	8
Balance Transmitted	2	16	11
	£5	0	0

1st June, 1909.

A. GIBB MAITLAND, Local Secretary, Western Australia.

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, GENERAL BALANCE-SHEET, SYDNEY OFFICE.

General Account, 1st July, 1906, to 30th June, 1908.

Dr.			£ s. d.	Cr.	£ s. d.
To Subscriptions			152 2 0	By Balance at 30th June, 1906	69 2 5
,, Share of Legal Expenses *re* Mortgage, Paid by Royal Society			8 8 0	,, Clerical Assistance	41 5 0
,, Sales of Volumes			17 15 5	,, Printing and Stationery	13 3 9
,, Balance			74 8 11	,, Expenses *re* Sales of Volumes	24 13 2
				,, Petty Cash and Expenses	28 9 6
				,, Bank Charges and Exchange	1 10 4
				,, Furniture and Fittings	35 3 6
				,, Advertisements	6 0 0
				,, Rent	33 6 8
			£252 14 4		£252 14 4

Research Fund.

Dr.	£ s. d.	£ s. d.	Cr.	£ s. d.
To Balance at 30th June, 1906		121 8 11	By Amount Lent on Mortgage at 30th June, 1908	2,668 0 0
,, Mortgage at 30th June, 1906	1,400 0 0		,, Balance at Current Account	204 17 3
,, Fixed Deposits	1,134 0 0			
		2,534 0 0		
,, Interest on Mortgage	182 5 11			
,, Interest on Fixed Deposits	70 6 10			
Less Interest on Overdraft	35 4 5			
		217 8 4		
		£2,872 17 3		£2,872 17 3

Mueller Memorial Fund.

Dr.	£	s.	d.	£	s.	d.
To Fixed Deposit at 30th June, 1906	400	0	0			
,, Current Account	26	16	1			
				426	16	1
,, Interest on Fixed Deposit for 2 years, ending 12th July, 1906 ..	32	0	0			
,, Interest on £432 lent on Mortgage, at 4 per cent., from 12th July, 1906, to 30th June, 1908 ..	33	19	10			
				65	19	10
				£492	15	11

Cr.	£	s.	d.
By Amount Lent on Mortgage	432	0	0
,, Balance at Current Account	60	15	11
	£492	15	11

D. Tannent.
31st December, 1908.

RICHARD TEECE, }
ROBERT A. DALLEN, } Auditors.

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.—VICTORIA.

Statements of Receipts and Payments for period 31st May, 1907, to 7th April, 1909.

Dr.	£	s.	d.
To Balance in Bank, 31st May, 1907	6	19	9
,, Subscriptions for Brisbane Meeting	22	1	0
,, Interest	0	3	7
	£29	4	4

Cr.	£	s.	d.
By Remittance to Hon. Treasurer, Sydney Office	23	0	0
,, Postages	0	12	6
,, Printing	0	5	6
,, Exchange	0	1	6
,, Bank Charge	0	5	0
,, Balance in Bank, 7th April, 1909	4	19	10
	£29	4	4

T. S. HALL, Local Secretary.

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE—NEW ZEALAND.

Statement of Receipts and Expenditure.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance in Hand (February, 1907)	0	4	7	By Stamps and Telegrams	0	5	4
„ Subscription Outstanding (February, 1907) ..	1	0	0	„ Stationery (Fergusson and Mitchell)	1	17	6
„ Twelve Subscriptions for 1908 (as per list) ..	12	0	0	„ Remittance to Brisbane	10	15	0
				„ Post Office Order	0	2	6
				„ Cash in Hand	0	4	3
	£13	4	7		£13	4	7

GEO. M. THOMSON, Local Secretary.

OBJECTS AND RULES OF THE ASSOCIATION.

OBJECTS OF THE ASSOCIATION.

The objects of the Association are to give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the Australasian States and in other countries; to obtain more general attention to the objects of Science, and a removal of any disadvantages of a public kind which may impede its progress.

RULES OF THE ASSOCIATION.

Members and Associates.

1. Members shall be elected by the Council.

2. The subscription shall be £1 for each Session, to be paid in advance.

3. A member may at any time become a Life Member by one payment of £10, in lieu of future annual subscriptions.

4. Ladies' tickets (admitting the holders to the General and Sectional Meetings, as well as the Evening Entertainments) may be obtained by full Members on payment of 10s. for each ticket. Ladies may also become Members on the same terms as gentlemen.

Sessions.

5. The Association shall meet in Session periodically for one week or longer. The place of meeting shall be appointed by the Council two years in advance, and the arrangements for it shall be entrusted to the Local Committee.

MANAGEMENT OF THE AFFAIRS OF THE ASSOCIATION.

Council.

6. There shall be a Council consisting of the following:—(1) Present and former Presidents, Vice-Presidents, Treasurers and Secretaries of the Association, and present and former Presidents, Vice-Presidents, and Secretaries of the Sections. (2) Members of the Association delegated to the Council by Scientfic Societies; (3) Secretaries of Research Committees appointed by the Council.

7. The Council shall meet only during the Session of the Association, and during that period shall be called together at least twice.

Local Committees.

8. In the intervals between the Sessions of the Association, its affairs shall be managed in the various States by Local Committees. The Local Committee of each State shall consist of the members of Council resident in that State.

Officers.

9. The President, five Vice-Presidents (elected from amongst former Presidents), a General Treasurer, one or more General Secretaries and Local Secretaries shall be appointed annually by the Council.

Reception Committee.

10. The Local Committee of the State in which the Session is to be held shall form a Reception Committee to assist in making arrangements for the reception and entertainment of the visitors. This Committee shall have power to add to its number.

Office.

11. The permanent office of the Association shall be in Sydney.

Money Affairs of the Association.

12. The financial year shall end on the 30th June.

13. All sums received for life subscriptions and from the sales of back numbers of Reports shall be invested in the names of three Trustees appointed by the Council, and the interest arising from such investment shall be reserved for grants in aid of scientific research.

14. The subscriptions shall be collected by the Local Secretary in each State, and be forwarded by him to the General Treasurer.

15. The Local Committees shall not have power to expend money without the authority of the Council, with the exception of the Local Committee of the State in which the next ensuing Session is to be held, which shall have power to expend money collected or otherwise obtained in that State. Such disbursements shall be audited, and the balance-sheet and the surplus funds be forwarded to the General Treasurer.

16. All cheques shall be signed either by the General Treasurer and the General Secretary, or by the Local Treasurer and the Secretary of the State in which the ensuing session is to be held.

17. Whenever the balance in the hands of the banker shall exceed the sum requisite for the probable or current expenses of the Association, the Council shall invest the excess in the names of the Trustees.

18. The whole of the accounts of the Association—*i.e.*, the local as well as the general accounts—shall be audited annually by two Auditors appointed by the Council; and the balance-sheet shall be submitted to the Council at its first meeting thereafter.

Money Grants.

19. Committees and individuals to whom grants of money have been entrusted are required to present to the following meeting a report of the progress which has been made, together with a statement of the sums which have been expended. Any balance shall be returned to the General Treasurer.

20. In each Committee the Secretary is the only person entitled to call on the Treasurer for such portions of the sums granted as may from time to time be required.

21. In grants of moneys to Committees or to individuals, the Association does not contemplate the payment of personal expenses to the members or to the individual.

Sections of the Association.

22. The following Sections shall be constituted:—

A.—Astronomy, Mathematics, and Physics.

B.—Chemistry.

C.—Geology and Mineralogy.

D.—Biology.

E.—Geography.

F.—Ethnology and Anthropology.

G.—Economic Science and Agriculture.

H.—Engineering and Architecture.

I.—Sanitary Science and Hygiene.

J.—Mental Science and Education.

Sectional Committees.

23. The President of each Section shall take the chair and proceed with the business of the Section not later than 11 a.m. In the middle of the day an adjournment for luncheon shall be made, and at 4 p.m. the Sections shall close.

24. On the second and following days the Sectional Committees shall meet at 10 a.m.

25. The Presidents, Vice-Presidents, and Secretaries of the several Sections shall be nominated by the Local Committee of the State in which the next ensuing Session of the Association is to be held, and shall have power to act until their election is confirmed by the Council. From the time of their nomination, which shall take place as soon as possible after the Session of the Association, they shall be regarded as an Organising Committee, for the purpose of obtaining information upon papers likely to be submitted to the Sections, and for the general furtherance of the work of the Sectional Committees. The Sectional Presidents of former years shall be *ex officio* Members of the Organising Committees.

26. The Sectional Committees shall have power to add to their number.

27. The Committees for the several Sections shall determine the acceptance of papers before the beginning of the Session. It is therefore desirable, in order to give an opportunity to the Committees of doing justice to the several communications, that each author should prepare an abstract of his paper, of a length suitable for insertion in the published Transactions, Reports, or Proceedings of the Association, and that he should send it, together with the original paper, to the Secretary of the Section before which it is to be read, so that it may reach him at least a fortnight before the Session.

28. Members may communicate to the Sections the papers of non-members.

29. The author of any paper is at liberty to reserve his right of property therein.

30. No report, paper, or abstract shall be inserted in the volume of Transactions, Reports or Proceedings, unless it be handed to the Secretary before the conclusion of the Session.

31. The Sectional Committee shall report to the Publication Committee what papers it is thought advisable to print.

32. They shall also take into consideration any suggestions which may be offered for the advancement of Science.

33. In recommending the appointment of Research Committees all members of such Committees shall be named, and one of them who has notified his willingness to accept the office shall be appointed to act as Secretary. The number of members appointed to serve on a Research Committee should be as small as is consistent with its efficient working. Individuals may be recommended to make reports.

34. All recommendations adopted by Sectional Committees shall be forwarded without delay to the Recommendation Committee; unless this is done the recommendation cannot be considered by the Council.

Official Journal.

35. At the close of each meeting of the Sections, the Sectional Secretaries shall correct, on a copy of the Official Journal, the list of papers which have been read, and add to them those appointed to be read on the next day, and send the same to the General Secretary* for printing.

Recommendation Committee.

36. The Council at its first meeting in each Session shall appoint a Committee of Recommendations to receive and consider the reports of the Research Committees appointed at the last Session, and the recommendations from Sectional Committees. The Recommendation Committee shall also report to the Council, at a subsequent meeting, the measures which they would advise to be adopted for the advancement of Science.

37. All proposals for the appointment of Research Committees and for grants of money (see Rules 19-21) must be sent in through the Recommendation Committee.

Publication Committee.

38. The Council shall each Session elect a Publication Committee, which shall receive the recommendation of the Sectional Committees with regard to publication of papers, and decide finally upon the matter to be printed in the volume of Transactions, Reports or Proceedings.

Alteration of Rules.

39. No alterations of the Rules shall be made unless due notice of all such additions or alterations shall have been given at one meeting and carried at another meeting of the Council held during a subsequent Session of the Council.

* Or Editor of Official Journal.

INAUGURAL ADDRESS

BY

PROFESSOR W. H. BRAGG,

M.A., F.R.S.,

ADELAIDE UNIVERSITY, S.A.,

BRISBANE, MONDAY, 11th JANUARY, 1909.

THE LESSONS OF RADIO-ACTIVITY.

Before I address myself to the subject on which I would speak to you this evening, there is one matter to which it is my duty and my sad privilege to refer.

Since the last meeting of our Association at Adelaide, in 1906, the occupant of the presidential chair at that gathering, Dr. A. W. Howitt, the man on whom we had been proud to confer the highest honour in our power, has passed away; and there is a deep sadness in the fact that he is not here to-night to perform the last duties of his office. Those of us who were present at the meeting of three years ago will remember with what vivid interest we looked up to our old and venerated president, as he spoke to us of the great work of his life, and told us of the difficulties and trials of exploration in a time gone by. It was an inspiration to have before us a veteran of the old pioneering days, one of the greatest of those famous old bushmen to whose labours we owe so much of the development of our country. Our Association will for ever treasure his memory; he was a man whom all Australasians honoured, and a scientist whose methods and aims we would all emulate.

My choice of the subject of this evening's address has been prompted by many considerations. The wonderful science of radio-activity must be, and is, a centre of deep interest to all lovers of knowledge, inasmuch as it is at the same time lighting up new paths of deeply interesting inquiry, and throwing a fresh illumination on that with which we are already more or less familiar. Moreover, it is a fundamental science, on which other sciences ultimately rest; and every scientific worker has more than a kindly interest in its progress, for he knows that his own work may be, indeed must be, profoundly affected by the new knowledge which we are acquiring. And, again, new as the science is, its advance is startlingly rapid, and it is well to review at comparatively short intervals the positions which have been attained by recent experiment.

Besides these general considerations, I think it is not out of place to mention one which is of more particular interest to this meeting of Australasians. I doubt if there are many here present to-night who realise that a very considerable share in the development of the new science is due to men born and educated in this country. Easily first of these stands Ernest Rutherford, the New Zealander, now Professor of Physics at Manchester. To him the world owes many of the fundamental conceptions of the subject; and no investigations have been so powerful and so brilliant as his. Perhaps it is only the student of radio-activity who can fully appreciate the excellence of his work, yet when he recently received a Nobel prize I am sure there was no member of the scientific world who did not appreciate the justice of the award. But he does not stand alone; there are other Australasians born and bred who have made worthy contributions to radio-active science. Dr. Pollock is to address one of our sections to-morrow, and besides his name I may mention Kleeman, Laby, Madsen, and Durack. When we consider the sum total of the work done by all these men, we have good reason to be proud of our country's product; and we may well take a special interest in the subject which they have helped to investigate.

With your permission, therefore, I propose to devote some time this evening to an examination of the great facts of the new science, and of the lessons which they teach. It is no easy task which I set myself, but I hope that the interest of the subject will to some extent hide my own inadequacy. I have just one more preliminary remark to make. I would warn you, before I begin, that I mean to stretch the compass of my address until it includes, with what plausibility it may, some reference to the general condition of research work in this country.

As is implied by its name the new science deals with certain radiations of which those due to the constant activity of radium and uranium may be taken as typical. They differ, in some important respects, from the longer known radiations of light and heat. Their existence was practically unknown to us a few years ago, and the science of radio-activity may be considered to have come into existence when Becquerel first experimented on the action of uranium on a photographic plate in 1896. This is true in spite of the fact that the cathode rays and the Rontgen rays have been investigated for many years past, and are of the same type as those emitted by the radioactive substances; for the extension of knowledge which has followed on the discovery of the latter has been so great that previous investigations can rank only as an introduction to the new science. Nevertheless, novel as the new radiations are in their origin and properties, it is important to observe that the recent investigations can be looked upon as the latest stage of a long inquiry of first importance, relating to radiation in general. For ages men have asked themselves, "What is light?" When the ancient writer recorded as one of the great acts of creation the command of God, "Let there be light!" he testified truly of its importance to mankind, and bore witness to the extent to which the seers of his day had grasped that importance. When men bowed to sun and moon and stars, they did but recognise their debt to the radiation on which their whole lives seemed to depend. And though we can now look past these creatures of light and heat, yet still we recognise their vast importance in the universal scheme. Not only are they necessary to our life upon the earth, but they alone bring us intelligence from the infinities of space, and help our thoughts to rise from the earth and stretch themselves to worthier and greater comprehensions. It is no matter of surprise that the study of the character and properties of radiation has at all times filled the thoughts of men.

There are two sides of this study to which I would particularly call your attention. We examine the properties of radiation in order to discover on the one hand the nature of radiation itself, on the other the nature and constitution of the atoms or molecules which emit it. For such information as we can obtain of the nature of atoms is of the utmost value since it is one of the main purposes of science, having once recognised the atomic composition of all material substances, to seek how to account for the properties of bodies in bulk from a knowledge of the properties of the atoms of which those bodies are composed. We, therefore, try to judge the atom by that radiation which proceeds from it. We can never hope to see an atom in the sense in which we see objects generally; we must form our estimates by indirect means. Yet the direct and the indirect are not so entirely different as might at first appear. We draw our conclusions as to the form, colour, and position of the objects which we see in this room by the aid of the radiation emitted by the artificial light. The radiation is reflected, scattered, and modified by the surfaces on which it falls; and our seeing is really no more than the perception and interpretation of these effects. In fact, the objects in the room are emitting radiation, borrowed, it is true, and thereby we judge them. In this case our perceptions deal immediately with the objects themselves, not the atoms of which they are composed. Can we ever perceive effects upon radiation due to individual atoms as apart from the effect due to their action in bulk? The answer is, of course, in the affirmative. We may pass a ray of white light through coloured glass or any substance which shows selective absorption, so that the rays of certain wave lengths are removed, and the rest pass on. The result is the sum of separate actions by the billions of atoms of which the body is composed, so that the light which emerges may be considered as representative of light proceeding from each atom after modification therein. Here, then, is a way by which we may hope to learn something of the individual atom. These absorption effects have indeed been closely studied, and have, as is well known, yielded results of the utmost importance not only to pure scientific research but also to commerce and industry. But, as regards the matter we are especially considering, they serve more to open our eyes to the complexity and richness of the inquiry than to yield us laws of any precision or generality.

In experiments of this kind we make use of sources of radiation external to the atoms, and permit the atoms to modify the original rays. We can, however, force the atoms to become themselves the primary sources of radiation; and, in doing so, we avail ourselves of a much more fruitful means of investigation. We may raise substances to incandescence by placing them in a flame, or subjecting them to the more intense heat of the electric arc or discharge; or we may turn our instruments to the heavens, where glowing suns form furnaces which far exceed in temperature anything we can find on earth. The atoms are now addressing themselves to us directly; each kind sends us radiation peculiar to its nature and condition. If we could but read the messages! But we are overwhelmed by the complexity and infinite variability of the effects which we observe. From a bewildering wealth of results we are able to disentangle a few fundamental truths, just enough to make us impatient of our inability to do more: the work required to elucidate one law successfully seems at the same time to add to the pile of facts yet unclassified and unexplained. The science of spectrum analysis grows year by year. It has taught us of the natures and motions of the stars, and revealed to us fundamental laws of physics; it has been a keen weapon of chemical research, and given powerful aid to industrial development. But, as to the constitution of the atom, it tells us too much at once; there is a roar of sound from which we can hardly disentangle separate sentences. Not only are the radiations emitted by each atom of exceeding complexity, but they vary, in a broad sense at least, with the condition of the atom and with its electrical state, with the temperature and the pressure of the gas of which the atom forms part, and so forth. We are staggered by difficulties of interpretation, and crave for some simple method of attacking the great problem. Spectrum analysis speaks a language which we barely understand as yet.

Now you will understand the welcome which we give to a new science like radio-activity, which addresses us in simple phrases. We are here still concerned with radiations emitted by atoms, either directly or in a secondary sense; and still we try to gain from an examination of the radiations some knowledge of the atoms from which the radiations proceed. But we work under totally different conditions. Nothing marks the change more forcibly than the disappearance, complete or almost complete, of all dependence on physical and chemical conditions. The radio-active substances exercise their marvellous powers at a rate which cannot be hastened or delayed by any known agency, such as heat or cold or pressure; not even if they are made to form chemical compounds with other substances. And, again, when the radiations which they emit pass through material substances, and are scattered or absorbed, as we find to be the case, the scattering and absorption are independent of the physical or chemical condition of those substances. We have, as it were, gone below the foundations of physics and chemistry to the simpler primordial conditions on which the more complex sciences are built. There are radio-active phenomena which go so far as to take no account of those fundamental distinctions between atoms on which chemistry is based. The most penetrating gamma rays, in passing through substances, recognise no other property than that of mass; four atoms of aluminium affect them no more and no less than one atom of silver, because the former weigh as much as the latter, and the names "silver" and "aluminium" no longer convey a distinction.

It is clear that we are dealing with the most fundamental characteristics of the atoms, with the building material, and not with the structure; with the inner nature of the atom, and not its outside show; and it is this which differentiates radio-activity from the older sciences. You will remember how Jules Verne in one of his bold flights of imagination drives the submarine boat far down into the depths of the sea. The unrest of the surface, its winds and waves, are soon left behind; the boat passes through the teeming life below, down into regions where only a few strange and lonely creatures can stand the enormous pressure, and, diving still, reaches at last black depths where there is a vast and awful simplicity. Here, where no man "hath come since the making of the world," the silent crew gazes on the huge cliffs which are the foundations and buttresses of the continents above.

It is with the same feeling of awe that we examine the fundamental facts and lessons of the new science.

First and foremost of the lessons we must place the revelation that this underworld exists, the fact that there are processes in Nature which are utterly beyond the intervention of man so far as we have yet been able to learn. It may be said that this holds true in many ways already known; but there is a radical difference between the older and the newer knowledge. It is true, for example, that man cannot stay the action of the sun upon the waters of the globe, and prevent the vapours from mounting into the clouds; but he can shelter any particular quantity of water from the sun's rays, and check the evaporation of that quantity at least. He cannot understand how the seed grows to be a tree, much less manufacture a seed of the simplest plant; but he can keep water away from the seed, and render its latent powers abortive. On the other hand, the disintegration of the radium atoms proceeds at a rate which is entirely beyond man's control, in the sense that the rate cannot be affected by any disposition which he may make, or, at any rate, has been able to make as yet. We know of only one other phenomenon in Nature of the same simplicity. The action of gravity is also most extraordinary in being independent of physical and chemical conditions; and we are unable, except in the refreshing pages of a certain popular novelist, to hinder the mutual attraction of two bodies by any arrangements of material such as the interposition of a screen between them. Hitherto gravity has stood alone. It is surely a most significant fact that we have now found other phenomena which resemble those of gravity in all these respects; and a fact of additional significance that the most penetrating radiations of which we have knowledge, the so-called hard gamma rays of radium, take exactly the same cognizance of the various atoms as gravity does; the "mass" is the one and only feature which is of importance in either case. This, then, is the first great lesson of radio-activity: the revelation of the existence of phenomena which are not to be classed with the most of physical and chemical effects, but rather belong to a class of which gravity has hitherto been the only representative.

Let us proceed to consider a second. We have only to move one step forward, and we are at once face to face with the wonderful theory of radio-active change which we owe to Rutherford and Soddy. Surely there never was a stranger or more unexpected realisation of an idle dream. The old alchemist laboured to bring about the transmutation of metals, and failed. Now we know that we can actually watch the process taking place. There is, however, no clear evidence as yet that we can be anything more than spectators; and this is a very important point. Sir William Ramsay does indeed describe certain experiments in which the radium emanation seems to have played the part of the philosopher's stone, but the matter is so new that science has not yet uttered her final decision on the point. It is strange enough, however, that the transmutation should take place at all; and that we should have definite proof that the atom is not absolutely stable. Up to the present we are sure of the transmutation in one direction only, the break-up of larger atoms to form smaller ones. We have found no instance of the reverse process, but we may well imagine that it merely awaits discovery. Surely it must exist.

This, then, is the second lesson—the instability of the atom. I will not discuss it at greater length, because it has already received such interested and full discussion in recent years; its importance has been recognised from the earliest times in the history of our new science.

The third lesson which may be drawn from the study of radioactivity follows naturally on the previous discussion. If such transmutations of atoms take place, there must be a certain uniformity of structure, or rather of building materials. This view is strongly supported if we consider the character of the radiations from the various radio-active substances. Where uranium passes through one or two intermediate forms into radium, and this again disintegrates step by step to polonium, and the process continues to an extent as yet not wholly known, a number of substances of widely varying properties have existed each for its allotted time. But the various fragments which have been shed by the disintegrating atoms, and which constitute the radiation, are found to be of two forms only, known as alpha particles and beta particles. Rutherford has shown clearly that the former are atoms of helium, and owe their positive charge to the fact that each has lost two negative electrons. The latter have long been known to be negative electrons simply. Therefore, that which began as an atom of uranium proceeds to become atoms of other substances in succession, by an operation of which the main feature is the dropping of one or more of such particles; we conclude that these particles are integral portions of the atom—parts which go to the building of the whole. The helium atom is doubtless further divisible; but for some reason it seems to exist as a more or less self-contained portion of large atoms. Though this principle is clear in the case of the radio-active substances only, it seems illogical to deny it in the case of others. Thus we are led to recognise a certain sameness in the materials of construction which was vaguely thought of a few years ago, but has only now acquired some degree of precision. The idea has recently received further support from the remarkable experiments of J. J. Thomson on positive rays. It seems that these rays, when formed in the vacuum tube, consist of atoms of helium and atoms of hydrogen, no matter what other materials the tube contains, and even if hydrogen and helium have been carefully excluded in the manufacture of the tube. This suggests that helium, as before, and now hydrogen also, are building materials used in the construction of atoms. But we cannot go much further as yet; if we try to do so we find ourselves in the midst of great uncertainties. We see that the alpha particle appears to be a frequent subdivision of the atom; and we know further that every atom contains electrons; but the number of the latter is doubtful, and is indeed greatly debated at the present time. On the one hand J. J. Thomson concludes that the number is nearly the same as the atomic weight; on the other it is said that this estimate must be thousands of times too small. When the atom is put together it has a certain mass; the uncertainty arises principally from ignorance as to how to allow for this mass. It is possible to explain mass as an electrical phenomenon, every negative electron has so much mass of this kind. Is this, then, the only source of atomic mass? If so the electrons must be many. But perhaps there may be mass which is not an electrical phenomenon, as we always used to think vaguely; then a smaller number of electrons will be necessary. It seems unlikely, however, that there should be two sources of mass, one electric and one not. Or, again, the positive electricity in the atom may also be responsible for some of the mass in the same way as the negative electrons; but it is well known that electrical charges must be condensed into extremely minute centres before they can show "electrical" mass: and there is a general tendency at present to suppose that the positive electricity in the atom is not condensed into centres so small as is the negative electricity, but is probably much more diffused.

It is, indeed, one of the greatest puzzles of the subject that so little should be known of the positively charged constituents of the atom. The negative electron is comparatively a familiar acquaintance. The cathode rays of the vacuum tube, the beta rays of radium, the delta rays which issue from all atoms under the influence of any of the radiations we are discussing, are all negative electrons exactly like each other, but endowed with different velocities. For years the negative electrons have been handled and investigated with ease. But no one has succeeded in handling the positive electron, if it exist, in the same manner. It is perhaps instructive to consider to what causes we may ascribe our power to isolate the negative. If we do so, we see that it depends on certain relations between the speed mass and electrical charge. The delta ray is the slowest moving negative electron that can maintain an independent existence; it is scarcely set free before its electrical forces attract it to some neighbouring atom to which it becomes attached. The cathode rays have usually a far higher speed, and can pass through many atoms without becoming entangled therein. The beta rays of radium move faster still, and can penetrate millions of atoms; in the open air they may move through comparatively long distances without being deflected, perhaps 2 or 3 feet on the average. The speed of the delta ray is of the order of a few hundred miles a second; that of the beta ray, 150,000 miles a second. Now, if the mass of the negative electron were less, if it were more easily turned aside, still higher speeds would be necessary to preserve it from incorporation into the atom. It might be, therefore, that the positive electrons are lighter than the negative, and that their separate existence requires a greater speed than can be given them in such a process of expulsion from the atom as occurs when a delta ray is expelled, or can be communicated to them by artificial means. We know that the positive electricity exists; and exists in any atom to an amount just sufficient to neutralise the negative charge. It seems arbitrary to assert that the positive cannot be subdivided to as great an extent as the negative, and that we cannot conceive of so small an amount of positive electricity as is sufficient to neutralise one negative electron. It is convenient to make one other observation at this stage. Just as the electron is known to be a constituent of all atoms, yet is never obtained isolated, unless it is moving with sufficient speed, so the electron together with enough positive to neutralise it, the neutral pair or electrical doublet may be found in the atom, and may exist separately under suitable conditions, *e.g.*, when endowed with sufficient speed, failing which it becomes incorporated.

It will be seen, therefore, how scanty is our knowledge of the positive constituent of the atom. When it is necessary to adopt some hypothesis as a basis of calculation, it is only possible to choose one which is simple, and, probably, therefore crude. Thomson presumes a uniform sphere of positive electricity in which the negative electrons move freely; through which it must also be supposed that other similar spheres are able to pass, since, for example, the alpha particle traverses atoms of all substances, and the alpha particle is an atom of helium.

To sum up, we may take as the third lesson that there is a certain sameness in the materials of construction of the atoms; and we realise, as we do so, that this is not going very far, for we know very little as yet of the way in which these materials are put together.

So far, we have been considering the phenomena that attend the origination of the radiations. Let us now turn our attention to the behaviour of the radiations during their passage through material substances. The so-called absorption effects are most extraordinary, and teach us further lessons of great interest.

Let us, therefore, imagine ourselves able to project streams of one or other of the new radiations through various substances, and to watch the result. And, before going further, I had better explain briefly how the watching is to be done. The fact is that as an alpha or beta ray passes through a gas it leaves behind a trail of electrons loosened from the atoms which it has traversed, and that it is a comparatively simple matter to gather up these electrons, and so to follow up the track of the ray. The loosened electrons are the delta rays, and the mode of their unloosening is apparently just the same, no matter to what agent it is due. I may repeat that the delta rays start out from the parent atom with barely enough speed to enable them to get clear away. Inasmuch as they are electrons in motion, they are just the same as the beta rays of radium or the cathode rays in the X-ray tube, but their speed is too small to give them the distinguishing properties of these latter rays.

When we consider the absorption effects we find that, in the first place, there is the most remarkable rectilinear propagation of radiations which are known to be material. A pencil of alpha or beta rays projected in a certain direction can maintain that direction, in a general sense, after having traversed many centimetres of a gas at ordinary pressure. But a straight line 10 centimetres long, placed in a gas, passes through something like a million molecules. If a stream of particles maintains its general direction after such a course, it follows that the particles have had no difficult passage through the atoms which they have met. They cannot have gone round them, that is to say, been ricochetted to and fro, and yet kept the main direction in view; that would only be possible if a guiding force acted all the time, or if the particles were endowed with intelligence. We do indeed find that a scattering of the particles occurs; it has long been known that beta particles can be turned out of the main stream and shot into new directions, and Geiger, working at Manchester, has shown recently that the alpha particles, although enormously more massive than the beta, are also liable to be swung out of their course. But such deviations cannot be likely to happen frequently to a particle in going such a distance, for a general direction is maintained throughout, as we have seen. We have but to picture in our minds the radiation of the boughs and twigs of a tree to realise that a very few successive deviations at random are sufficient to destroy all connection with an original direction. But if the alpha and beta particles recoiled or were deflected in striking the exterior of the atoms which they met, they would experience perhaps a hundred thousand such deviations in the first centimetre. The particles, therefore, cannot have encounters with atoms as a whole; they must penetrate them, and usually without any deflection. Only occasionally they must come into encounter with parts of atoms, but probably this does not happen in the case of a beta particle once in a hundred or thousand atoms traversed. The actual figure depends upon its speed, because the so-called encounter of the flying particle with the part of the atom really consists in an approach so close as to permit a sufficient mutual action; and the faster the particle the nearer the approach has to be in order to produce a given deflection. The problem is exactly that of a comet flying round a sun; the course of the comet is the more altered the nearer the two bodies approach each other.

All this amounts to saying that the atoms must be very empty things; something like solar systems in miniature, a few significant points or parts, and in between a relatively large amount of almost unmeaning space. We are almost out of sight of the original view of the atom, a circumscribed body, into whose interior nothing else could penetrate, occupying so much space to the exclusion of everything else. Such a view was all that was needed in order to explain to us the ordinary physical and chemical effects, such as, for example, the collision of the molecules of a gas. But now the interior of the atom is no longer a forbidden country, the new radiations pass through the atoms with ease. We may look on such transits as journeys of exploration, and hope to learn something of the nature of the interior of the atom from the way in which the motion of the particles has been altered in going through. In the older physics all the actions which we studied depended on the external presentments of the atoms to each other, and we, therefore, learnt only of their external characteristics. Now for the first time we can, as it were, insert something material into the interior of the atom and prove its contents.

It may be useful to put the matter in a slightly different way. The molecules of a gas move rapidly to and fro, changing their directions and speeds at each mutual encounter. Each molecule of the air in this room moves on the average about one hundred thousandth of a centimetre between successive encounters. This distance we call the mean free path. Now, in the same way, it becomes clear that these particles, the motion of which constitutes the new radiation, move rapidly to and fro, only their velocities are enormously greater than the velocities of the gas molecules. The molecules collide with each other with very little interpenetration, if any; these particles take no account of molecular boundaries, but penetrate within, and their collisions are with parts of atoms, not with the atoms as wholes. The mean free path of a molecule of an ordinary gas is a minute fraction of a centimetre. The paths of these particles between successive encounters at which the direction of their motions are violently changed, is immensely greater, varying from a millimetre or so in the case of cathode rays to a metre in the case of the beta rays, whilst the gamma rays can penetrate hundreds of yards of ordinary air without being turned aside.

To some extent, we had already learnt to recognise the penetrability of the atom before the discovery of radio-activity. Hertz and Lenard had shown us that cathode rays could penetrate extremely thin metal sheets. But the new facts are a revelation to us in this direction. The beta rays, which move five to ten times as fast as the cathode rays, have a thousand times the penetrating power. And more singular still is the penetration of atoms by the alpha particle, itself an atom. That two atoms can for a moment occupy the same space is certainly a novel and instructive conception. Of course, the singular penetrating power is due to enormous speed. In helium, at ordinary pressures and temperatures, the atoms do not penetrate into each other at all; it is only the helium atom which is ejected from radio-active atoms at terrific speeds which does not respect the atomic boundaries.

Equally striking is the penetrating power of the Rontgen or gamma ray, whatever view may be taken as to its nature. The older hypothesis gives it the nature of a pulse or irregular disturbance of the æther. It has been modified in order to fit recent experiments; J. J. Thomson now conceives of it as a tiny "bundle of energy," possessing almost all the properties of a material particle. I have, myself, ventured to take the simpler view that it really is a material particle, as I will explain a little later. For the present I will anticipate only so far as to assume what is consistent with either hypothesis—viz., that the ray consists of something in motion in a straight line, possessing energy, and having boundaries which must be far more restricted than those of an atom, and must, probably, be comparable with those of an electron. Now imagine such an entity passing in a straight line through all the molecules in, say, a hundred yards of air without suffering deflection, indeed without suffering any loss of energy at all, as can easily be shown to be the case. What can it have met with on the way? It cannot have had an encounter with anything forbidding it admission into any region; it can hardly have pushed things out of the way, or it would have lost energy. If there were any centres at all in any of the atoms which were impenetrable, the ray would have met not one but many of them. Extraordinary as it may be, it really seems that penetration to the uttermost is only a matter of degree, that there is nothing, not even of the minutest kind which occupies a definite portion of space to the exclusion of everything else. Of course, a statement like this suffers from the vagueness which is almost unavoidable when new ideas are put into old words. But I am trying to show that we must put aside the older conception of the properties of matter. At one time two bodies could not fill the same space; with the recognition of atomic composition came the understanding that there was space between the atoms of which bodies were composed; later came the idea of the penetration of the atom, and there were only certain electrons within the atoms which kept portions of space to themselves. We have always been pushing the limits back, it does not seem unlikely now that there are no limits at all, and that we might conceive of radiation having any desired penetration. At the present time the hard gamma rays are the most penetrating of those that we know. As I have already said, they fly on the average through great thicknesses of matter, hundreds of yards of air, or inches of lead, before suffering serious deflection at some encounter with a part of the internal structure of the atom. Only an encounter is not merely a geometrical relation between spaces occupied by the two encountering particles.

It is impossible to pass by the conception of penetrating radiation without considering two other problems which have led, or might lead, to the assumption of its existence. A long time ago the Genevan philosopher, Lesage, filled all space with a penetrating radiation moving in all directions for the express purpose of accounting for gravitation. The attraction of two bodies for one another was to be ascribed to the shelter which each gave to the other from the driving streams. Since the whole of a body counts in the attraction which it exerts, the inside of the body must contribute to the sheltering as well as the outside, and this requires a radiation of extreme penetration. Some fraction of the radiation is to be turned aside by any body through which it is passing, or there would be no sheltering, but it must be a very minute fraction indeed. It is not an impossible theory, and leads to results which are numerically accurate. But it has never been widely accepted. It requires not only the excessive penetration, but also a velocity of radiation which is enormously greater than that of light, for astronomical calculations show that the actions between the heavenly bodies do not take an appreciable time to cross the space between them. Moreover, the energy of the radiation must reach an appalling amount. It is interesting to observe, however, that the penetration is no longer the difficulty that it used to be; and still more interesting, perhaps, is the fact that the more penetrating the new radiations are, the more nearly are their effects on different atoms proportional to those of gravity. In the case of the most penetrating gamma ray, the proportionality is almost exact, failing perhaps a little for the heavier atoms. When we take less penetrating gamma rays the effect is only exact in the case of the light atoms. If we were to surround a number of small bodies with radium they would be driven together by the gamma rays in such a way that every pair would seem to exert an attraction on each other proportional to the product of their masses, and inversely to the square of their distances apart, which, of course, agrees with the law of gravitation. It certainly is very curious that we should actually be able to prove the existence to a small amount, at least, of radiation which fulfils the properties of Lesage's radiation on a small scale. It is useful in that it illustrates the great difference between the new radiations and those of light and heat, and the closer resemblance which they have to the more fundamental phenomenon of gravitation. But I need hardly say that this is not enough to prove Lesage's theory.

And, again, there is another problem in which the existence of a very penetrating radiation has been considered as an aid to its solution. It is now generally held that the energy which is set free when the various radiations are ejected from the radio-active atoms is derived from a store internal to the atom. It is a most important conception, for it is naturally extended to the case of all atoms, and we have a glimpse of the existence of great quantities of energy existing within the atoms, and unutilised. Yet we have no warrant, as yet, for the hope that we may some day succeed in unlocking these storehouses. For, in the first place, the substances which liberate the energy of their own accord are few and rare, and other substances, though they doubtless possess it, do not set it free. In the second place, the action is beyond our control in the few cases in which we know it to exist.

A different view as to the origin of the energy was put forward by several great physicists in the early days of the science, notably by

Lord Kelvin. The energy was supposed to come from without, and the radio-active substances were merely transforming agents. But this view became discredited chiefly, I think, because it was found impossible to stay the radio-active action by surrounding the radium with screens which might be expected to ward off the action of the external agent. That objection can hardly be held to be final now. The gamma rays, though turned aside by all substances generally in proportion to their mass, yet are specially affected by heavy atoms, with an excessive transformation of energy. May there conceivably be a very penetrating radiation which is practically not to be observed by ordinary means, but acts especially upon the radio-active atoms? The idea has its fascination, but there are many difficulties in the way of its acceptance.

We have now considered, very briefly, the circumstances of the origin and progress of these new radiations. We see that they are ejected from certain atoms, of the disintegration of which they are the accompaniment; that they have no regard for physical conditions; that they move with tremendous speeds, and that they penetrate atoms with ease. Let us go on to consider, as far as we can, what happens to them in the end. Again, only a little is known, but that little is very interesting.

Take the alpha particles first. Their special peculiarity may, perhaps, be best expressed by saying that something happens to them before they have made more than, perhaps, one collision causing deflection, perhaps none at all; so that after this event they are lost to view. Prior to it, their tracks through gases are abundantly clear on account of the clouds of delta particles which they leave behind. In consequence, the particles move straight through the gas for some distance, and then seem to disappear. This distance I have called the range; and I have shown that each radio-active substance sends out alpha particles of special range, so that it is possible to distinguish the different substances by the ranges of their particles. I find it possible to measure the range, which varies from about 3 to 8 centimetres in the known cases, with a precision of about $\frac{1}{4}$ per cent. The ranges in different gases depend for some obscure reason nearly on the square roots of the atomic weights; and it is to be observed that the range in a gas (or solid) containing a complex molecule is to be calculated from the knowledge of the ranges in gases containing simpler molecules formed of the same atoms. This, again, illustrates the absence of dependence of radio-active effects upon chemical conditions. With the aid of Dr. Rennie and Dr. Cooke, of the Adelaide University, I have spent some time in the attempt to verify this important fact with exactness. Our divergences from the law are under 1 per cent. so far, and it is not unlikely that, small as they are, they are due to some disturbing influence in the experiment. Now, the remarkable thing is that Rutherford has shown that the alpha particle, when it reaches the end of its range, is still possessed of enormous speed, some thousands of miles per second, about half what it started with. Then what has happened to it? Why can we no longer follow it? The best suggestion is that of J. J. Thomson, that it becomes neutralised by the attachment of an electron, and that when neutral it does not excite delta rays. But this only suggests a further question of interest: What are now its properties, and what its final end? Somehow its speed is reduced, for Rutherford finds helium in the tubes containing radium in the quantity to be expected if it is derived from the alpha particles. Sometimes, perhaps, it is incorporated into an atom, helping to raise its atomic weight, and causing a process the reverse of the known process of disintegration. It is very curious that this loss of power occurs to the alpha particle, when its velocity has fallen to the same amount, no matter what gas it is moving through.

Next let us consider the beta or cathode particle. In this case we can follow many deflections from an original track, so that the particle behaves more like a molecule of an ordinary gas. But, apparently, it loses energy at every deflection, and, as it does so, deflections become more numerous and more serious, and we can imagine that after a very few scatterings it loses its speed and becomes incorporated in an atom or molecule, forming the ordinary *ion* of which Dr. Pollock will speak to you to-morrow. But there is also something else that can happen to it. Like the alpha particle, it may disappear from view, and in its place may appear a ray of different kind. When the cathode rays are driven against the metal plate in the Rontgen ray tube, the most of them dive into the metal and disappear; a few swing out and hit the glass wall of the tube, which they do not penetrate, but, in the case of a very few, we find their replacement by the famous Rontgen or X rays. So, also, I think we may argue, from analogy, that beta rays may disappear and be replaced by gamma rays, even though the actual effect has never been observed. For, I think, it is easy to show that the effect is too small to find. Not only is the number of particles in a beta ray stream small compared to that in the cathode stream of the X ray tube, but also the gamma rays which they produce are very penetrating, and escape without being made to reveal their existence.

This transformation is, of course, a very remarkable thing. But the interest is increased when we find that the reversed transformation can also take place. For, when we come to consider the life history of the Rontgen or gamma rays, we find that, like the cathode or beta rays, from which they may be transformed, they move in straight lines through many atoms, and yet may be deflected at last. The penetration is, however, enormously greater. Also, as in the case of the flying electron, these rays may be modified by the act of deflection, and become less penetrating than before. The changes have been studied by Barkla in the case of X rays, and by Madsen in the case of the gamma rays. And, again, as in the case of the electron, the rays may disappear altogether; the reversed transformation then takes place, the X ray being replaced by a cathode ray, the gamma by a beta. It is to be remarked that when cathode rays are replaced by X rays, and in turn these disappear to be replaced by cathode rays, the last have nearly the velocity of the original cathode rays. Putting all these facts together, we have some idea of the life history of these rays, which we see cannot be considered separately. Of an original bundle of cathode rays some, after a number of deflections, lose their energy altogether, some are for a time replaced by X rays, but presently cathode rays reappear of rather less energy than before; and, finally, we have no longer a stream of cathode particles flying at high speed, but a number of negatively charged molecules scattered through the gas.

This very curious alternation of forms leads us to ask of what nature the Rontgen and gamma rays must be to make the transformation possible?

The orthodox view, due to Sir George Stokes, is, that they consist of æther pulses; that they are the disturbances of the æther which spread away from the places where the motion of electrons is altered. In the original form of the theory the disturbance was supposed to disperse its energy over widening surfaces, as the energy of the splash where a stone enters the water distributes itself in spreading ripples. But this view has necessarily been abandoned. It could hold only so long as the appearance of cathode rays from atoms struck by X rays was supposed to be due to radio-active explosions of the atoms, precipitated by the X rays. This was imagined in order to explain why the cathode rays, which arise in this way, have precisely the same speed, no matter how much the pulses have spread before they originate the rays. But it is found (1) that the rays have the same speed no matter from what atoms they arise, and we could not expect such uniformity as the result of explosions of widely different atoms; (2) that the rays, at least in the case of the gamma and beta sequence, move off at first in continuation of the line of movement of the gamma rays. For these and other reasons it is no longer thought possible that the energy of the electrons, which arise in this way, can come from the atoms themselves; it is simply derived from the Rontgen or gamma rays, as the case may be.

But if the energy is derived from this source, we cannot allow that the Rontgen rays spread as thought at first. The energy of a Rontgen ray must move in a straight line without loss by the way, so that when it strikes the fatal atom it may have an undiminished amount to give to the electron which takes its place, and the velocity of the latter may not depend on the distance the ray has travelled from the tube. The X ray, in fact, behaves like a material particle, in that it moves from point to point, carrying a certain store of energy which does not diffuse over a larger space in the transit. Now, the æther, which is supposed to fill all space, and which has been postulated in order to carry the light and heat radiations, has hitherto been supposed to be quite uniform and isotropic. A disturbance which has its origin at any point spreads in widening spheres, diffusing and weakening as it goes. Our conception of the æther must be materially amended if we are to suppose it capable of carrying a pulse along a line without allowing it to spread. Thomson has not shrunk from making this very serious change, and has imagined the æther to possess a sort of fibrous or tubular structure; in other words, he has filled all space with lines or tubes, along which the æther pulse is to travel undiffused. This carries with it corresponding changes in our conception of light and heat. We must replace our spreading waves by clouds of minute bundles of energy, tiny entities which move like material particles, but with the speed of light. It is a curious and most interesting return in the direction of the old Newtonian corpuscular hypothesis—a kind of compromise between two theories which were so long at war.

But the question arises at once: Is the amended hypothesis able to explain all the facts? In our ignorance of the nature of the æther it might, perhaps, just as well have such a constitution as not. Recent experiment has, however, added largely to our knowledge of the circumstances under which the energy of a moving electron is converted into the energy of a pulse and back again, and it is right to ask whether they are in agreement with the amended theory. So far as I am able to judge, no satisfactory agreement is possible; but it is only fair to say that the experimental results to which I refer have been obtained so recently that there has not been time for the advocates of the pulse theory to make any serious attempt to explain them.

I will describe some of these experimental results presently. Meanwhile, I would ask you to consider the Rontgen and gamma rays from a somewhat different point of view in order that I may be able to suggest an alternative hypothesis as to their nature. Let me take you back to the history of scientific research in the last century. The wave theory of light had completely triumphed over the corpuscular theory which Newton had advocated; and the progress of physical science for scores of years consisted in a long series of successful explanations of new discoveries in terms of the undulatory theory. When, therefore, new radiations were discovered, it was natural that determined efforts should be made to explain them in terms of the winning hypothesis. For a long time many physicists claimed that the cathode rays were æther pulses, and Sir William Crookes had to fight hard for his idea of a fourth state of matter. The later investigations of J. J. Thomson established firmly the material view, and laid the foundation of the electronic theory. When Becquerel first experimented with the rays of uranium, some of his earliest tests were made in order to discover whether the new radiation possessed the characteristic properties of æther waves. Pioneering work is always difficult; Becquerel's experiments led him to false conclusions. He announced that he had found reflection, refraction, and polarisation; it was, therefore, concluded that the rays were of the nature of light, and this view was accepted by most physicists for some years. Finally, Rutherford, in 1899, repeated the experiments, and reversed Becquerel's conclusions. Thanks mainly to his labours, we now know that two at least of the three forms of radiation which radium and uranium emit are material. The alpha rays are positively charged atoms of helium, the beta rays are negative electrons. There remain the gamma rays, and with these must be classed the Rontgen rays, which resemble them so closely. Many years ago Sir George Stokes, as I have already said, applied the pulse hypothesis to explain the properties of the newly-discovered X rays; and later it was naturally applied to the gamma rays also. But it is a very striking fact, I think, that the more closely these various radiations are examined the clearer does it become that there is a strong family likeness between the properties of them all. If for no other reason, we are forced to inquire whether they are not more nearly allied in Nature than is compatible with the classification into corpuscular and pulse radiations. The differences between the various rays—alpha, beta, gamma, and Rontgen rays—are rather differences in the degree to which various properties are exhibited; there is no very radical difference between the properties themselves. The most obvious difference at all stages of the inquiry has been, perhaps, the fact that the alpha and beta rays can be deflected by electric and magnetic fields, whilst the gamma and X rays cannot. This shows that the former are charged electrically, and, since pulses cannot carry charges, we conclude that the rays are material. The gamma and X rays are not acted on by electric and magnetic fields; they are therefore uncharged. This does not prove them to be immaterial—to be pulses, in fact; they may be material particles without charge. The simplest conception of such a material particle would be one negative electron with its positive counterpart.

Again, it is important to remember that when X rays were first discovered nothing was known of material radiations capable of passing through matter in straight lines, and the remarkable power of penetration which the rays were found to possess was sufficient to put out of court any suggestion that they might be material. That objection has vanished now. Even the electrified beta rays possess the property of penetration; some of the electrons in a stream of such rays, projected against a metal sheet, are found to have passed through, apparently without being affected in any way. When we remember that such electrons as have been swung aside out of the stream owe the effect to the strong influence of their electrical charges, it is natural to suppose that if the charges were neutralised by the attachment of the corresponding positives, the penetrating power would be greatly increased. Thus, the same simple hypothesis which explains the independence of electric and magnetic fields explains also the extraordinary penetration of the gamma and Rontgen rays. Nor does it stop short here. The movement of the rays in straight lines, without dispersion of their energy, is at once made clear; the rays resemble material particles in their behaviour simply because they are such, and there is no need to invent a special æther to cover the case. And, again, the ease with which the energy of the cathode ray may change into that of the Rontgen ray, and back again, is understood. It is simply that the negative electron picks up its positive counterpart, and again puts it down. The electron of the cathode stream is driven against the surface of the anti-cathode, and penetrates the atoms there. If the atom consists, as is generally supposed, of a number of similar electrons embedded in a quantity of positive electricity of little massiveness, it is easily to be imagined that in one of these deflections its temporary entanglement may be so great that it may pick up the neutralising amount of positive before emerging. Thus, instead of the negative cathode particle we now have a neutral pair, incapable of deflection by electric or magnetic fields and endowed with far more power of penetration than the original cathode particle. Yet the neutralising positive may be torn away again from the electron in some other transit across an atom, and the Rontgen ray become once more a cathode particle, probably with less energy than at first, since some loss of energy might well occur at each change.

And, again, the neutral pair has the further properties of the Rontgen ray in that it is incapable of regular reflection, refraction, or polarisation of the ordinary kind. Yet, as I have pointed out elsewhere, it can be made to exhibit the peculiar polarisation which Barkla has shown to be a property of the Rontgen rays.

It is true that it can hardly be supposed to move with the velocity of light, and that a famous experiment by Marx seems to have shown that Rontgen rays and light rays do actually move with the same speed. But I have pointed out that the quantitative conclusions of Marx' experiment are incorrect; and the whole experiment has recently been seriously questioned by Franck and Pohl. Again, a very small diffraction effect is said to have been found by Haga and Windt as the result of a most difficult and delicate experiment. An effect of this kind might be expected if the rays were æther pulses. But this experiment has also been questioned by Walter and Pohl, who have been unable to confirm it.

It is often said that the X rays, like alpha and beta rays, cause electrons to be shed by the atoms through which they pass; but the statement is not logically correct. The X rays disappear as they pass through matter whether sold, liquid, or gaseous, and cathode rays appear in their place: the latter certainly cause electrons to be set free. Unless it can be shown that the actual number liberated is more than can be accounted for as the result of the action of the secondary cathode rays, it is not right to assert that any of them are due to the direct action of the X rays themselves. The question may be settled by experiment; but I have not, so far, found it easy to obtain a decisive result. All that can be asserted is that the number of electrons set free when Rontgen rays pass through a gas is so near to the number which would be set free by the cathode rays formed by the gas as the result of the passage of the Rontgen rays, that the burden of proof rests with those who would say that any are due to the Rontgen rays themselves. As a final result we have, therefore, a fairly simple picture of the progress associated with the Rontgen ray tube. The cathode particles impinge on the metal anti-cathode; some of these pick up the positive necessary to neutralise them, and so become X rays. In this form they cross the glass walls of the tube, the air outside, and any other substances which they may meet. The stream is continually weakened, since pairs are always dropping out of it; because they are broken up into the negative electron and its positive counterpart. The former is the secondary cathode ray, and perhaps is responsible for all the action in the gas by which we trace the progress of the X rays. The latter we may suppose to remain in the atom where the break-up of the pair has occurred. It is too light to assume an independent existence.

Simple as this conception is, it correlates the facts in a remarkably effective way. Moreover, it has led to new discoveries, as I will now explain.

I have said that the radiations which are known to be material are capable of being scattered or deflected in passing through the atoms. It is most easy to examine the effect in the case of the beta rays. The flying electron which passes close to a centre of force within the atom is only deflected through a large angle when the degree of approach is very close indeed. Since close approaches are relatively rare, if a stream of electrons passes through a sheet of material so thin that any one electron is not likely to experience more than one deflection or so, then we find that the number of electrons which are only slightly deflected, and, therefore, appear on the further side of the plate, is much greater than the number which are so much deflected as to be turned right back and emerge again on the side of the plate at which the original stream entered. The fact might be anticipated; but it has actually been shown very clearly by Dr. Madsen in some experiments of which the account is to be read at this meeting.

Now a certain proportion of a stream of X rays or gamma rays is scattered in passing through a plate; and the æther pulse theory has hitherto been held to show that there should be equality on the two sides of the plate in respect to the proportions scattered. Thus the two theories lead to different conclusions in this respect.

When the experiment is made it is found that the X rays and the gamma rays behave like the material beta rays, and not in the manner to be expected on a pulse theory. Madsen has recently shown that when gamma rays are passed through a plate, the scattered rays on the far side of the plate are sometimes five or six times as important as those which are to be found on the near side, that at which the original stream enters. I have myself found the effect to be clearly shown by X rays, though to a smaller degree.

And, again, when the gamma rays are replaced by beta rays the experiments of Madsen and myself show that the latter must at first travel straight on in the original direction of the former. This is easily understood on the neutral pair theory, since we may suppose the removal of the positive from the pair to be effected without seriously interfering with the motion of the negative. The effect was not anticipated on the pulse theory. It is now proposed to modify that theory, so as to explain a certain amount of dissymmetry, but it seems to me that it will be very difficult to explain the completely unidirectional movement of the beta ray. On the whole, therefore, it seems proper to class the gamma and the Rontgen rays with the alpha and beta, the nature of which is more certain; and to ascribe a material character to them all. In this way they would stand entirely differentiated from the radiations which we call light and heat; and the absolute difference in the properties of the two classes of radiation would imply an absolute difference in their natures. In one we should see the travelling to and fro through space of those æther waves which we have been investigating for centuries; in the other a continuous dance of atomic particles. Just as the theory of gases teaches us to think of the gaseous molecules moving rapidly from collision to collision with each other, and the seemingly quiet air to be the seat of the most vivid movement, so the lessons of radio-activity show us a continuous movement far finer still in which the parts of atoms torn from their normal places fly about at inconceivable speeds encountering only each other. Though there is a strong family likeness between all in their properties, yet there is also a most interesting variety in their natures and histories. Some may be set in motion in the vacuum tube under the action of electric forces, but the alpha, the beta, and the gamma rays arise from the disintegration of the atom. Certain forms are interchangeable as we have seen. The life of each ray is very short, and it may be that as the appearance of the ray is the sign of an atomic breakdown, so in some cases the disappearance is really contributory to atomic growth. Some of the rays as they move through a gas cause the appearance of delta rays, and throw the gas for a time into a state of "ionisation."

If we now ask to what extent this radiation exists, whether, for example, it is prevalent and influential enough to affect the events of our existence, it is not easy to give a satisfactory answer at present. Of the great scientific importance of our new knowledge there can be no doubt; of the magnitude of the part which it plays in the working of the universe our knowledge is insufficient as yet. We can see importance enough in a science which deals with the evolution and destruction of the atoms of which all materials are made. We can grasp the significance of the fact that radio-active material exists in our earth and air in sufficient quantities to have great influence on the temperature of the globe and on the electric state of the atmosphere. But it also seems likely that in a thousand ways yet unsuspected the strange motions which we have recently discovered are concerned with the working of the great machine, and with our very lives upon the earth.

Such, then, are some of the conclusions to which the study of radio-activity leads us. No student of science woud deny their interest and importance, and I am sure that you will understand why I have wished to attempt their exposition. I trust that you will not think it inapposite if now in the short time remaining to me I ask you to turn your thoughts in a different direction. The discussion of any pure scientific research before an Australasian audience like this naturally brings forward the question as to how far Australasians are themselves justified in spending their time and money on such work. Or, is there any other research work which they should attempt in preference? And, again, if there is work which should be done, who is to do it? To all these questions I do not propose to attempt a full answer. But it seems to me that certain of them call for a very serious consideration at this present time, and, therefore, that as President of an Association for the Advancement of Science I ought to discuss them. For I am addressing not only those who are directly engaged or interested in scientific work, nor only our kind Queensland hosts who honour and delight us with their presence this evening, but also all Australasians who care to listen.

First, then, as regards the study of pure science, the one all-important thing to remember is that pure science lies at the root of all applied science. The former throws up and nourishes the stems which bear the latter as their fruit. It is said that when an Indian durbar is to be held in some uncultivated spot the natives create in a single night the semblance of an established garden with its trees and shrubs, beds of bright annuals and winding paths. But it is only the garden of a day; even the flowers have been cut from plants grown on other soil, and are but stuck in the ground; there is no root and no power to grow. Just so, if we are content in this country to import always the flowers of European or American thought, and to use them in the establishment of our industries and to grow nothing of our own, then we must continually be replenishing our ideas from abroad in order to maintain our position. That is neither an honourable nor an economical arrangement. We must ourselves encourage the spirit of pure research amongst our own peoples, and provide opportunities for research within our own borders, if the science of our crafts and industries is to have life and power to grow.

There is another aspect of the question which I may illustrate from our own experience. In the history of every new country there is a phase—it has not yet passed away in Australia—when the prospector and the surveyor traverse the land through and through mapping its features, investigating its riches and its possibilities. Their labour is absolutely necessary, though they set out on their quest in ignorance of what they shall find. Just so the workers of science cover the new fields of research; they are prospectors who must do their part before the new country can be made to contribute to the enrichment of mankind. Now it is true that there are branches of scientific research which have a more or less obvious relation to Australasian progress. But we may also aspire to do work which does not appear to advantage our own country more than the world at large. Indeed, if we wish to take our place amongst the progressive peoples of the world, to gain the strength and inspiration which come from sharing in a common advance, and to shun the soul starvation which would follow on a selfish concentration on our own immediate advantage, we must play our part in this sense also, and play it enthusiastically and well. Pure scientific research is necessary not only to Australasia but in Australasia; to bring in the spirit of the patient and reverent search for truth, to illustrate the searcher's methods, to open up new fields, and to answer the questions that arise and will arise to an ever-increasing degree if the progress of the country is to be sound.

Now as to research with more obvious application to the work of the country it is surely unnecessary to plead for it at length. Everyone will admit the urgent need; and I will only point out that the present position is consequent not only on the increasing use of scientific methods which is made by all mankind, but also on the change of status of our own country. We did not feel the want in the early days. When gold was first discovered in Australia little science, though plenty of pluck, was required by the workers in the alluvial fields. But when the first pockets were worked out, and the greater though less obvious wealth of the quartz reefs was made plain, then all the resources of chemistry and physics, mineralogy and mechanics were called in to assist; and now the student of the mining school receives a training which would have been beyond the power of the old digger to conceive much less appreciate. Just so with the other industries of the country; it is a fact of first rate importance that they must all pass through the same stages, though it may not always be so obvious. Is not, for example, the old farming passing away, yielding to the absolute necessity for more scientific methods? And are there not, in consequence, a host of agricultural questions pressing for investigation, the need of which has been revealed by the adoption of the new procedure? I do not for a moment overlook the fact that State Governments have given serious attention to agriculture, or that much excellent work has not been done by the men whom they have appointed. But no one is better aware, I am sure, than the directors of agriculture of how much there is to be done at once which may reasonably be expected to return a rich harvest to the State. To one of them I am indebted for the information that there are still great opportunities for research in the field of wheat-breeding, especially in Australasia; that we have, as yet, very insufficient knowledge of the rusts and other cryptogamic pests, of the process of nitrification in the soil under Australasian conditions, of the inoculation of our soils with bacteria, of wheat diseases like "take-all," of soil investigation, of pests like the lucerne-flea, and the parasitic insects which can be called in to war with the pests, and so on. We may take a few illustrations from other great industries. How much is known of coast disease in sheep? What great gaps are there not still in our knowledge of the fishes of our seas? Is there not a great field of inquiry as to tropical diseases, into which the school of tropical medicine to be found in your State is making honourable entry? Is there not still much profitable work to be done in connection with Australian forestry, indeed should I not in this case use much stronger terms? How little do we know of some orchard diseases, like bitter pit, in apples; how much there is to learn in respect to Australian viticulture, and so on. I am sure that if you ask any of those able men in the various States who are brought face to face with these questions it will be your experience, as it has been mine, that he will tell you of numberless opportunities of useful scientific inquiry waiting only for the men to take advantage of them.

We may indeed assume without hesitation the existence of work to be done. The question I would particularly bring to your notice to-night is this, "Who is to do it?"

It will be said that there are universities to do pure scientific work, and Government experts to take up the questions of applied science. But to this it is to be answered that the reapers are utterly insufficient for the harvest. Those who would lend enthusiastic service in the scientific work which the country demands are quite unable to cope with all that they see before them. It is possible, of course, to suggest that the number of experts might be increased; but it is also possible, I think, to adopt means which will increase greatly the effective value of those we already possess, and, at the same time, provide the capacity of further growth. The point I would particularly press upon your notice is this:—I think that we are falling far short of what we might do in the way of using the scientific powers of our own young people. Every year we are throwing away the services of highly trained university graduates who might do good work under the direction of older men, and who might at the same time relieve the experts of certain routine duties, setting their brains and time free for better work. Froude quotes a saying of Goethe to the effect that "once a man has done a good piece of work to the satisfaction of the world, then the world takes good care that he shall have no opportunity of repeating his performance." Goethe was certainly not speaking of Australasian conditions, to which nevertheless his words are singularly applicable. Is it not usual to find the scientific expert so loaded with routine duties, and with work which is not really scientific, that the country is being deprived of the best part of his powers?

Let us see whether we cannot help him. My own experience of Australian university life has convinced me of several things which bear upon the question. In the first place there is good material to be had. In most of the States there is a more or less effective educational ladder from the primary school to the university which is much used already, and might be made more popular still. In the second place the training which is given in the universities is well suited for students who may afterwards take up research work under proper direction. And, again, there is generally nothing to keep the young graduates in their universities; most of them must at once set to work to earn bread and butter, and they soon scatter far and wide. A very large proportion of our best students leave Australia altogether, tempted by travelling or research or other scholarships tenable elsewhere. And, lastly, the young graduate may be of inestimable help to the professor or technical expert who is trying to do research work. All such work involves a great deal of attention to details, long hours and days spent in observations or manipulations which are almost mechanical in themselves and yet must be closely followed by some one with enthusiasm and intelligence. The research which is almost a drudgery when the worker is alone, which moves with a halting gait, brightens up and begins to run when there is a willing assistant. And there is another most important consideration. The assistant soon becomes the separate worker, if opportunity allows. No better way has ever been devised of training young men into the spirit and methods of research than that of allowing them to work with those of greater experience.

To what then does all this tend? In what direction shall we move?

In the first place, since I am speaking in a State in which the university movement has not yet reached its goal, I would break down the few barriers that still stand in the way. You must have a university in this State with a staff of men whose first quality shall be that glowing enthusiasm from which the students catch fire, and the second, a profound knowledge and the power to use and impart it. You need the final court of appeal in scientific matters; the example of research; the training ground of the young and eager minds whose services will be of more and more value to you as thought and knowledge are brought to bear on your industries. I speak only of the scientific side of university work because it is directly related to my subject. I must be silent in respect to other sides about which I could gladly speak with equal earnestness.

Having provided the means of training, let us keep our best students for a while from the need to go out immediately into the commercial world. A moderate number of research scholarships would involve no great expense, and the country would be amply repaid if only in the greater effectiveness of the professional men under whom the research students would work. In our own country the Government of Victoria has already shown the way, in the provision of scholarships at the University of Melbourne. If we look abroad we can find other examples from which we can learn; for some countries have already realised the position which I am trying to explain, and made provision to meet its requirements. When I was trying to decide a few months ago as to what I should say to you on this subject, the scientific papers brought the text of Professor Kipping's address to the Chemistry Section of the British Association meeting in Dublin. Professor Kipping discusses with great ability the need to encourage young research students in England, in order to meet the tendency of certain branches of chemical industry to leave English for German soil, and he had found in the preparation of his address that he was able to draw lessons from American experience. In the University of Kansas it is a practice for manufacturers, who require the solution of some problem of importance to their work, to maintain a special and temporary research fellowship at the State University. The results of the fellow's investigations are the property of the manufacturer, but are also communicated to the university, which may publish them for the benefit of the world after three years have expired. Fuller details of the scheme may now be found in a new book by Professor Duncan, of the University of Kansas, "The Romance of Chemical Industry."

This is a very interesting and useful illustration, drawn from a scheme already in operation. You will see that it shows the university in touch with industrial life. I consider that this is a lesson of fundamental importance; of all the mistakes that could be made in the management of the universities in these States I do not think there could be a greater than that of allowing them to shut themselves up, or to drift away, or to be cut off from the daily life and tasks of the people. Not that the so-called "utilitarian" side of university life should be encouraged to abnormal growth; very much the contrary. The point is that pure science and technical science draw life each from the other, and must on no account be separated. Technical problems are most naturally and successfully attacked when there is constant touch with the professors and the methods of pure science; for the very novelty of the technical problem implies that some law of pure science has not been obeyed, or is perhaps yet undiscovered; and, on the other hand, the advances of pure science are often due to attempts to solve the problems which arise in industry and commerce. I know there are those who think that our universities should be kept free from the touch of sordid industry, and that their professors should teach only that which is "useless," to use a historic phrase. I am convinced that this is not the noble view, but the narrow one. If the State university is to live its full life, it must not separate itself into the wilderness, like the hermit of old; but must mingle with the people and draw strength and inspiration from the attempt to minister to their needs.

Let us then do all that we can to keep our universities in touch with the applied science of the country. If I were to define too exactly my suggestions as to how this should be done, I might defeat my own purpose, since the circumstances are too varied to admit of uniform treatment. But in the first place let me repeat that research scholarships will induce young graduates to take up work for a while under the direction of those who are face to face with the problems to be solved, whether they are university professors or Government experts. The young men are in general only too glad of the chance to win their spurs. Again, let us try to keep the State expert in touch with the university; sometimes it may be desirable that he should actually be a member of the university staff, sometimes that the connection should be less rigid. For example, he might from time to time give special courses of lectures on subjects of interest and importance which he has met with in the course of his work. In some way the results of his own first-hand observations should be made to illustrate and give point to the subject of the university curriculum, and the student should become interested in what he is doing.

Or, again, the university may aim at becoming a court of appeal, or in forming standards of reference in certain industries. For example, some of our universities are considering schemes for the formation of electrical testing laboratories; so that the tests of the electrical companies may be carried out cheaply and efficiently, the students may gain experience, the companies and the students may become acquainted with each other, and pure science may benefit by the consideration of problems of special difficulty and interest.

Whatever the means adopted, the end is clear. If I may sum it up, the scientific research work of the country is growing inevitably; and the country's welfare demands that we should grapple with it boldly and with enthusiasm. It is true that much has already been done by public and private enterprise, yet it is possible and desirable to do very much more. I have tried to show that we can make our research army a better fighting machine, by throwing into its ranks some of our own young men, trained in our own universities.

I would assert the value of the help which such assistants can give to those already engaged in research, and the advantage which the country derives from the encouragement of research amongst its own people. Lastly, I would urge that the scientific expert work of the country should be kept in close touch with the universities as the centres of that pure research on which all technical work ultimately depends. It is rather the recognition of a situation for which I would plead than the expenditure of large sums of money. For I am confident that if we once understand our position and use the simple means of advance which lie immediately to our hands, we shall find ourselves entering on a course from which we can hardly stray.

Section A.

ASTRONOMY, MATHEMATICS, AND PHYSICS.

ADDRESS BY THE PRESIDENT,

J. A. POLLOCK, D.Sc.,

Professor of Physics in the University of Sydney.

THE IONS OF THE ATMOSPHERE.

As one of the results of the recent development of electrical science, it is considered that throughout the air in its normal state, and in other gases in a similar condition, there exist a small number of molecules, or groups of molecules, which are distinguished from the vast host of their fellows in being electrified. Each of these electrified entities, whatever its structure, is called an ion, and of ions there are two main classes, the one containing those which are positively, the other those which are negatively electrified. The notion of the ion, in this connection, arises from attempts to reach a simple description of the facts associated with the conduction of electricity through gases, and the hypothesis admirably fulfils its purpose.

The number of ions in the air can be greatly increased by exposing it to the influence of Rontgen rays, or to the radiations from radium or other radio-active bodies, and it is from investigations connected with this artificially-produced ionisation that most of our present knowledge of ions is derived. For the most interesting account of these researches I refer you to the Address delivered before this Section at Dunedin in 1904 by the present distinguished President of the Association. For my immediate purpose I have to remind you of one result: in an electric field, in addition to the motion of molecular agitation shared by all the constituents of a gas, the ions, in virtue of their charge, acquire a velocity whose average value depends on the electric intensity and on the resistance which is offered to the movement; under the influence of the electrical forces the ions drift, as it were, in a definite direction, the positives travelling to the negative electrode, and *vice versâ*, a motion in which the uncharged molecules have no part. Other things being equal, it is assumed that this drift velocity of the ions is directly proportional to the electric intensity, and, following the suggestion of M. Langevin, the term "mobility" has been adopted for the average velocity acquired by an ion under the influence of unit electric force. At the present time the mobility of a class of ions is its most readily determined property, and it is principally to observations of the mobility of the ions in different gases and under various conditions that we must look for a clue to the nature of the ionic structure. In all cases

I shall state the value of the mobility as that of the velocity, in centimetres per second, due to an electric force represented by a potential gradient of one volt per centimetre.

Two types of ion are recognised as existing naturally in the air, the small ion, with a mobility of about 1·5 under normal conditions, and another, discovered by M. Langevin,* and called by him the large ion, which is characterised by the very small mobility of only 1/3000. To these I now add a third, which has a mobility of about 1/100 under normal circumstances. It may be called, for the present at least, the ion of intermediate mobility, or the intermediate ion.

M. Bloch† finds in air bubbled through water ions of mobility of the order of 0·1 or 0·2; these seem to form a fourth class of ions, and it would be interesting to know if they exist in air not specially treated.

The small atmospheric ions are identical with those artificially produced in air by ionising agents which have been made the subject of such numerous researches as described by Professor Bragg in his address. There is now considerable knowledge, resumed in the beautiful kinetic theory of gases, of molecular movements and dimensions, and when it is thought that an ion moves more slowly in an electric field than would a single molecule if charged, as the ion must be made of the stuff of the gas in which it is formed, what more natural than to consider it a cluster of a few molecules? This idea has been generally adopted. The small ions are thus assumed to be of somewhat greater size than their fellow molecules; but, as the mobility notably increases with decrease of pressure, and with rise of temperature, their diameter is apparently not a constant quantity.

The direct argument, which is used to support this view, considers that in the numerous collisions which occur between the charged and uncharged molecules, in many cases the kinetic energy of the latter will not be great enough to carry them away, after impact, from the attraction of the charge. The charged molecule will thus collect other molecules around it; but, as the effect of the charge on the outer members of the cluster diminishes as the collection of molecules increases, the growth will cease when the size is such that the attraction of the charge at the surface of the cluster, in grazing impact of ion and molecule, is just insufficient to hold the latter as a permanent member of the ionic system. The principle involved, in calculating the value of the limiting radius, is similar to that which determines whether a comet, in its close approach to the sun, shall become a permanent member of the solar system or wander into the space from which it came. The calculation of the ionic size which has been made on these lines assumes the ions as charged, the molecules as uncharged conducting spheres, and taking the radius of the molecules as 10^{-8} centimetres, reaches the conclusion that the radius of the ion cannot exceed three times this value.

---

* Langevin. C.R., t. 140, p. 232, 1905.

† Bloch. C.R., t. 145, p. 54, 1907.

To account for the change of mobility associated with alteration of the pressure or temperature conditions, it is supposed that the clusters of molecules forming the ions consist of fewer members at low pressures and at high temperatures than under ordinary circumstances. As the temperature rises, for instance, the ion may be imagined as shedding one by one its component molecules. The mobility, however, varies continuously, and not by jumps; it may, therefore, be considered, in addition, that a cluster at any temperature does not always consist of the same number of molecules. In the numerous collisions, to which an ion as a constituent of a gas is subjected, a molecule of the cluster may be lost at one, to be gained at another impact, the cluster acting on the whole as if it contained the average number of members; it is this average number which, from this point of view, must be taken as decreasing continuously with rise of temperature.

From a consideration of the slow movement of the ions in an electric field compared to that which it is assumed a single charged molecule would have in the same circumstances, it is possible, with the aid of the principles of the kinetic theory, to make an estimate of the number of molecules which go to make an ion. The argument is given in Mr. Phillips' paper on "Ionic Velocities in Air at Different Temperatures,"* and he calculates from his results that the positive ion at − 179° C. consists, on the average, of about four and a half molecules (4·63), while at + 138° C. the average number is only about one and a half (1·52). For the negative ion slightly smaller figures are obtained.

Such an idea of the small ion, based, either on the direct argument in its restricted form already noted, or on the calculation just mentioned, cannot be considered satisfactory, and it is now shown to be unnecessary by two workers at opposite sides of the world, Mr. Wellisch, at Cambridge, and Mr. William Sutherland, at Melbourne.

In this connection it is interesting to recall another physical problem which apparently also required for its explanation a shrinkage of the molecules with rise of temperature, that of the relation between the temperature and the viscosity of a gas. The solution of the problem was finally reached in 1893 by Mr. Sutherland, from a consideration of the influence of molecular force in bringing about collisions which would otherwise not occur, the investigation being published in his paper on "The Viscosity of Gases and Molecular Force."† The result of mutual attraction, only sensible at small distances, is to make the molecules, considered forceless, behave as if they had a diameter greater than the true value. As the molecular force is less effective in causing collisions the greater the velocity with which two molecules approach each other, the apparent diameter to which it gives rise is less the higher the temperature. It is now shown by the writers I have mentioned that there is a similar effect due to the ionic charge. Owing to the influence of the electrical attraction, collisions between ions and molecules take place which

* Phillips. Proc. R.S. A, 78, p. 167, 1906.

† Sutherland. Phil. Mag. 36, p. 507, 1893.

would otherwise be avoided, and consequently the ions act as molecules of greater than the normal size, the apparent diameter decreasing as the temperature rises.

For the movement of an ion through a gas, M. Langevin* has given for the mobility, k, and the coefficient of diffusion, D, the equations—

$$k = eL/MV\,;\; D = LV/3$$

where e denotes the ionic charge, L the mean free path of the ion, M its mass, and V its mean velocity of thermal agitation. Mr. Wellisch, in his investigation, calculates the mean free path of the ion, taking into account the effect of the ionic charge in increasing the collision frequency, and substituting in the above equations reaches general expressions for the two quantities under consideration. If the mass and dimensions of the ion are taken as the same as those of the molecule, the expression for the mobility becomes at 0° C.

$$k = \frac{A\eta}{\rho_1 p}\left\{1 + \frac{(K_1 - 1)\,\pi\, A^2\eta^2}{2\rho_1\, p_1^2}\right\}^{-1}$$

and that for the coefficient of diffusion at the same temperature

$$D = \frac{\eta}{\rho}\left\{1 + \frac{(K_1 - 1)\,\pi\, A^2\eta^2}{2\rho_1 p_1^2}\right\}^{-1}$$

where A (= $1{\cdot}30 \times 10^{10}$ electro-static units), is the product of the number of molecules per cubic centimetre and the ionic charge, η the coefficient of viscosity of the gas, K its specific inductive capacity, ρ the density and p the pressure in dynes per cm^2., the symbols with subscripts referring to values under the standard conditions as to temperature and pressure.

To test the theory Mr. Wellisch gives the following table of comparison between the observed and the calculated values, the observed mobilities, except in the case of air, hydrogen, nitrogen, and oxygen, being the results of a series of determinations recently made by him.

Gas or Vapour.	Formula.	Molecular Mass.	$\rho_1 \times 10^5$.	$\eta \times 10^6$.	$(K_1 - 1) \times 10^5$.	k_{760} Calculated.	Observed. +	−
Air	...	...	129	177	59	1·25	1·36	1·87
Hydrogen	H_2	2	9	85	26	6·32	6·70	7·95
Carbon Monoxide ..	CO	28	125	163	69	1·16	1·05	1·10
Nitrogen	N_2	28	125	163	59	1·31	1·6	mean
Oxygen	O_2	32	143	191	54	1·25	1·36	1·80
Carbon Dioxide ...	CO_2	44	196	141	96	·87	·77	·81
Nitrous Oxide ...	N_2O	44	196	141	107	·81	·79	·86
Ammonia	NH_3	17	76	96	770	·21	·70	·76
Ethyl Alcohol ...	C_2H_6O	46	205	83	940	·19	·32	·26
Sulphur Dioxide ...	SO_2	64	286	122	993	·13	·42	·39
Ethyl Chloride ...	C_2H_5Cl	64·5	288	93	1554	·11	·32	·30
Ethyl Ether ...	$C_4H_{10}O$	74	330	69	742	·24	·28	·30
Carbon Tetrachloride	CCl_4	153·8	686	153	426	·20	·29	·30

* Langevin. Ann. de Chimie et de Physique, V, 28, p. 289, 1903.

Mr. Wellisch further shows that if d denotes the coefficient of interdiffusion of a molecule through the gas,

$$\frac{D}{d} = \left\{ 1 + \frac{(K_1 - 1)\,\pi A^2 \eta^2}{2\rho_1\, p_1^2} \right\}^{-1},$$

and by the following table indicates the nature of the agreement between the calculated and observed values.

Gas.	$\frac{(K_1-1)\,\pi A^2\eta^2}{2\rho_1\, p_1^2}$	d* Observed.	D Calculated.	D Observed.†	
Air	3·70	·150	·032	·028	·043
H_2	5·39	1·31	·205	·123	·190
O_2	3·56	·189	·041	·025	·040
CO_2	2·52	·109	·031	·023	·026

Both in the case of the mobility and in that of the coefficient of diffusion the agreement between the calculated and the observed values is, on the whole, quite satisfactory, the conclusion being that the behaviour of the ion can be explained on the supposition that it consists of a single molecule associated with a charge equal to that carried by the monovalent ion in electrolysis.

Mr. Wellisch read an account of this investigation of the mobility and diffusion of the ions before the Cambridge Philosophical Society at its meeting held on the 9th November, 1908, and communicates a paper on the same subject to this Section.

Mr. Sutherland, to our regret, is unable to be present at this meeting of the Association, but he allows me to communicate to the Section a letter of his on the theory of the small ion written to me on the 6th February, 1908, and permits me to mention the results of his investigation at this stage of our proceedings.

Amplifying the discussion developed in his Viscosity paper by the addition, in the energy expression, of a term representing the electrical potential energy of ion and molecule when in contact, Mr. Sutherland, in his letter, proceeds to investigate the relation between the mobility and temperature, and deduces for the mobility of the ion the simple expression—

$$k = \frac{A\,\theta^{\frac{1}{2}}}{1 + \dfrac{C'}{\theta - \theta'}}$$

where A is a constant, θ the absolute temperature, θ' the absolute boiling point, under the experimental pressure, of the substance of the gas in which the ions are formed, and C' a constant similar to that represented by C in his now well-known viscosity formula.

* *See* Jeans, Dynamical Theory of Gases, p. 253.

† Townsend, Phil. Trans. A 193, p. 129, 1900.

To test the theory, Mr. Sutherland applies the equation to the experiments of Mr. Phillips* on the negative ion, taking A = 0·1764, C′ = 150·5 and θ′ = 70, with the following results:—

θ	411	399	383	373	348	333	285	209	94
k calculated	2·48	2·42	2·33	2·27	2·13	2·05	1·75	1·22	·235
k observed	2·49	2·40	2·30	2·21	2·125	2·00	1·78	1·23	·235

As will be noticed, the comparison of the mobility calculated from the above expression with the results of Mr. Phillips' valuable series of observations shows an accordance well within the limits of experimental error, over the whole range of temperature from 95° to 411° absolute. The apparent decrease in the size of the ion with rise of temperature, as discovered by Mr. Phillips, is thus shown to be due to an effect of the ionic charge similar to that of molecular force which accounts for the apparent shrinkage of the molecules in the viscosity problem.

Mr. Sutherland shows, in addition, how his investigation enables an estimate to be made of the diameter of the ion, and concludes from his determination that most probably the small gaseous ion is the ordinary ion of electrolysis.

Mr. Sutherland's expression for the mobility of the ion, by containing a symbol representing the boiling point of the gas substance at the pressure of the experiment, indicates a dependence of the mobility on the pressure of the gas; the comparison of the values given by it have yet to be compared with the results of experiment.†

The idea of the small ion as a cluster of a few molecules, founded on insecure assumptions, was perhaps chiefly characterised by its numerical vagueness; its replacement by a definite theory cannot but be regarded as marking a great advance in our knowledge of ionic structure.

Turning now to the consideration of the larger ions in the air, it may be said at once that our knowledge is as yet but represented by the mere collection of the results of experimental investigations. The large ions were discovered by M. Langevin‡ in 1905, who found that their movement, in an electric field with a potential gradient of one volt per centimetre, is only at the rate of one three-thousandth of a centimetre per second, but that, under natural conditions, their number is about fifty times as great as that of the small ions. In a later communication MM. Langevin and Moulin§ describe an instrument for automatically registering the ionisation of the atmosphere caused by the small and the large ions, with which they have experimented during the past few years; from the use of such an apparatus most important information will be derived.

For some time observations of these large ions, in the air at normal pressure, have been made at the Physical Laboratory of the University of Sydney. In this investigation I have been joined, at times, by students whose names will be given in connection with the

---

* Phillips *loc. cit.*

† Langevin. Ann. de Chimie et de Physique, t. 28, p. 289, 1903,

‡ Langevin. C.R., t. 140, p. 232, 1905.

§ Langevin and Moulin. Le Radium, 4, p. 218, June 1907.

mention of results they have obtained, and throughout have been most ably helped by my assistant, Mr. Carl Sharpe. Owing to the variable character of the natural ionisation, the work has proved extremely tedious, as it is only on somewhat rare occasions that a series of observations is accordant enough to give a definite measure of the mobility. The ionisation is more uniform after sunset, and we now observe mainly in the night time.

All our observations have been made with apparatus constructed after the pattern of that used with such success by Professor Zeleny* in his determination of the mobility of the small ions. In such an instrument a uniform stream of air flows through a metal tube which forms the outer conductor of a cylindrical condenser, the ions drifting on to an inner axial electrode, due to the forces in the electric field established between the tube and the axial rod. The theory of the method of finding the mobility with such an apparatus, as given by Professor Zeleny, is well known; it has been followed without modification in calculating the results of the present series of experiments. Greater uniformity in the ionisation is obtained if the air, before reaching the measuring tube, is drawn through a considerable length of piping. We have not noticed any effect on the nature of the ions due to the somewhat prolonged contact of the air with the metal of the pipes, and in most of our experiments several metres of iron or of galvanised iron piping have been employed. In all cases Dolezalek electrometers have been used to measure the ionisation currents.

During the investigation some definite results have been obtained, of which I propose to give a general account.

In thinking of M. Langevin's discovery the idea must have occurred to many, and is, indeed, suggested by Professor Rutherford in his book on Radio-active Transformations, that the large ions may be due to the presence of water vapour. My efforts to elucidate this point have resulted in finding that there is a definite relation between the mobility of the ion and the amount of moisture in the air.

When a current of air is passed over hygroscopic substances, without mechanical filtration, Mr. S. G. Lusby finds that large ions are absorbed, and has noticed a loss in number amounting to 55%, after the air had flowed over a tray containing phosphorus pentoxide. I find, in addition, that after leaving the drying agent, those large ions which still exist in the air decrease in mobility with time, and that when the relative humidity changes from 80% to 4%, at a temperature of 19° C., they are not in equilibrium with the new vapour pressure conditions until after the lapse of about twelve minutes. Owing to the variable nature of the natural ionisation, and perhaps to other causes, the calculated mobilities exhibit considerable irregularities, but show in an unmistakable manner, when the equilibrium state is established, a dependence of the mobility on the amount of water vapour in the air, the reciprocal of the mobility being a linear function of the humidity between the limits of the absolute humidity represented by 0·5 and 19·0 (grms/m^3), corresponding to relative humidities of 4% and 100%. The mean mobilities for these values of the humidity, from results so far obtained, are 1/1280 and 1/3370 respectively. In other words, the mobility for an absolute humidity of

* Zeleny. Phil. Trans. A, 195, p. 193, 1900.

2·4 is twice as great as that for a humidity of 15·4. The observations are not regular enough to show if there is any difference between the mobilities of the positive and negative ions. Owing to ionisation being caused by phosphorus, it is not advisable to use phorphorus pentoxide as the drying agent in such experiments, and calcium chloride has been employed in all cases.

The intermediate ion has been under observation for only a comparatively short time; the measures so far made, however, show that the mobility is largely affected by change of the humidity of the air, the magnitude varying from 1/15 to about one-tenth of that value as the absolute humidity alters from 0·5 to 15 at a temperature of about 22° C. To this statement there is a limitation, the extent of which I do not as yet fully know: in air in its natural state with the absolute humidity between 14 and 16 at 22° C., when the ionisation due to this class of ions is relatively weak, the mobility, at least of the positive ions, is of the order of 1/65, while with strong ionisation the value is only about half as great. Unless the limitation just mentioned provides an exception, on further investigation, no definite difference between the mobilities of the positive and negative ions of this class can be deduced from the observations.

The facts just described prove that there is a definite connection between the ions and the water vapour of the air, and open up an interesting field for speculation as to the development and structure of electrified clusters, and as to the nature of the resistance which they experience in drifting through the crowd of molecules. The basis of the structure is, of course, the molecular ion, which, it is well known, originates from effects associated with radio-active transformations occuring in the air, the ionisation being primarily due to the presence of radium and thorium in the material of the earth's surface. The growth to more complex structure apparently occurs by the collection of water molecules round the molecular ion owing to the influence of its charge.

Seemingly from a consideration of the experimental results, we must recognise at least two forms of electrified molecular aggregation in the air which are stable under ordinary conditions. As the mobilities depend on the humidity it might not unreasonably be supposed that the intermediate and large ions represent stages in the development of the small ions into visible drops of water, which occurs if the air becomes sufficiently supersaturated. It seems, therefore, curious that the large ions are not separately apparent as condensation nuclei in cloud experiments.

Mr. C. T. R. Wilson* has shown that in such experiments the presence of a moderate electrical field prevents the formation of drops if the expansion ratio does not exceed the value 1·27. This proves that the nuclei for these small expansions are ions which can be removed by the field before the expansion takes place. I have carefully repeated the observations, with an apparatus similar to that described by Mr. Wilson, in order to determine if the effect of the electric field varies with the time it is on before expansion, and find the full effect whether the interval is one second or twenty minutes. With the fields used it takes several minutes to remove all the large

* Wilson. Phil. Mag., June, 1904.

ions, on account of their small mobility, whereas the small ions disappear in less than a second, so the nuclei for the drops formed with expansions below 1·27 are small, not large ions. To test whether the large ions become visible at a lower humidity than that at which the small ones appear, Mr. E. P. Norman, at the Sydney University Laboratory, has repeated Mr. Wilson's experiments on the supersaturation required for condensation,* with natural air over mercury. Commencing with a humidity between 60% and 70%, after removing the "dust," no condensation occurs, not only below saturation, but not until the supersaturation becomes four-fold, as in the earlier experiments over water. In all our experiments the observations have been repeated with air which had remained undisturbed in the apparatus over night, in order that time might be available for the reproduction of the large ions if they had been initially withdrawn, but the results of the first expansion in the mornings appeared in no case different to those of the later ones. Now Mr. Lusby finds, using two Zeleny tubes in series, joined by earthed piping whose length can be varied, that if all the large ions are removed from a stream of air by the first tube, they are fully reproduced in number in about twenty-two minutes. Our failure to detect the large ions is not, therefore, because they were removed with the "dust," unless, indeed, large ions are not produced in closed vessels, a matter which it would be difficult to determine.

Considering that in natural air the large ions are fifty times more numerous than the small ones, it is hard to reconcile the fact that the separate existence of the former has never been suspected in condensation experiments with the idea of the large ion as representing a stage in the growth of the small one to a condition of visibility, and the experimental evidence as to the position of the large ion in this connection seems as yet in an unsatisfactory state.

MM. Langevin and Moulin† describe the small and the large ions as playing different parts in the formation of natural clouds, but the statement is merely one of suggestion.

As all the ions have the same charge, the electrical state of the atmosphere is conditioned by the numbers of the ions of each class which exist at the time. Should the numbers of positives and negatives be equal the air is electrically neutral; if, however, one kind greatly outnumbers the other the air is thereby highly electrified.

The number per cubic centimetre, or the specific number as it may be called, of each class of ions in the air is an extremely variable quantity, particularly in the day time. From measurements in other parts of the world it is considered that the specific number of the small ions varies between 500 and several thousands. Between this estimate and that given by my own experience there is an amazing discrepancy. In a series of 128 observations, taken at Sydney in the early part of the year 1907, the maximum specific number is 157, the minimum zero, the mean number for the positives being 39, and that for the negatives 38. The European determinations are based on observations taken with Dr. Ebert's well-known ion counter, the principle of the apparatus being that of the Zeleny tube. With our

* Wilson. Phil. Trans. A., 189, p. 265, 1897.

† Langevin and Moulin *loc. cit.*

present knowledge of the existence of the intermediate ions, it can readily be shown that the inner electrode of the instrument is altogether too long. The apparatus, as ordinarily employed, catches not only the small ions, but a proportion of the others as well. Calculating with my own measures of the mobilities and specific numbers, it appears that the determination of the specific number of the small ions from the indications of the Ebert instrument must be from two to four times too great. As for the remaining part of the discrepancy, having used Dolezalek electrometers in my own observations, I may, perhaps, be prejudiced in thinking that the metal leaf electroscope of the Ebert apparatus is an unreliable appliance for use in such determinations; in any case the matter must be made the subject of a special inquiry, but in the meantime I have the utmost confidence in my own measures.

With regard to the other ions, from the very limited series of observations which I have as yet made of the intermediate ones, in air in its natural state, what I have previously called relatively strong ionisation is represented by about 1000 per cubic centimetre, while for the relatively weak ionisation the number is about 200.

For the specific number of the large ions, a series of 117 observations gives 5,500 as the maximum, and 600 as the minimum, the mean for the positives being 1,914, and for the negatives 2,228.

The numbers given, with the exception of those for the intermediate ion, are the results of measures with air drawn directly into the testing apparatus without the intervention of any pipes; later observations give, on the whole, much higher values for the specific number of the large ions in air led through a considerable length of piping.

It is now well known, since Lord Kelvin's memorable work on the subject, that a potential difference exists between the earth's surface and the upper layers of the atmosphere. In the electrical field which is thus indicated the ions in the air move more or less steadily in a vertical direction, the negatives ordinarily travelling upwards, the positives downwards to the earth. Such a movement constitutes a vertical electric current in the air, the magnitude at any time depending on the air's specific conductivity and the value of the potential gradient at the moment. The specific conductivity is represented by the sum of the continued product of the specific number, the mobility, and the charge for each class of ion. An instrument designed by Dr. Gerdien, in which an electroscope is used as in the Ebert apparatus, has been universally employed for such determinations as have been made of this important quantity. It measures the sum of the conductivities due to each type of ionisation, and the calculation of the result from observations with the apparatus is not affected by the discovery of a new class of ions. The complexity of the natural ionisation, however, prevents the instrument being used to accurately determine the specific number of the small ions. The average value of the specific conductivity of the air in other parts of the world, as given by the Gerdien apparatus, is about 10^{-4} in electrostatic units*. The magnitude of this quantity can be calculated from the measures of the mobilities and specific numbers of the ions, and the average

Gerdien. Gessell. Wiss. Gottingen, Nachr., Math-Phys. Klasse, 1, p. 77, 1907. Dike. Terr. Magn. and Atmcs. Elect., Sept., 1908.

specific conductivity of the air at Sydney, so determined, is only about one-tenth of the value just stated. Here again, there is a considerable discrepancy between my own and other measures which has yet to be investigated.

With increasing knowledge we can look forward to developments of importance to meteorology in connection with ionic observations; just now it is doubtful, I think, if valuable effort is not being wasted as a result of over-confidence in the present state of the art.

Such is a sketch of our present knowledge of the ions of the atmosphere. With the publication of Mr. Wellisch's and Mr. Sutherland's investigations we have reached a definite idea of the small ion in air—a molecule, which, as the attraction of its charge brings about collisions which would otherwise not occur, acts as if it were one of more than the normal size—the conception enabling our experience to be not only simply but exactly described. Of the larger ions, no such definite picture can as yet be drawn. Ions similar in character have been observed in gases from flames and in other cases, and it is to be hoped that the material which is now being collected may soon prove sufficient, in the hands of those specially skilled in the methods of the Kinetic Theory of Gases, for a discussion of the life history of these molecular clusters. The study of the natural ions has a special interest, as a wider determination of the facts of the ionisation of the air means an advance towards a more comprehensive knowledge of atmospheric electricity.

REPORT OF THE COMMITTEE ON SEISMOLOGY.

By the Secretary, P. BARACCHI, F.R.A.S.

To the President of Section A—

Sir,—I have the honour to present the attached reports from the Observatories of Sydney, Adelaide, Perth, and Melbourne, showing what had been done in Australia, in regard to Seismology, during the period, 1st January, 1907, to 31st December, 1908; and to direct attention to two important matters, as follows, viz.:—

(*a*) At present no organised service exists in Australia for obtaining earthquake records from localities outside of the capitals. It would not be difficult to recruit in each State a large number of voluntary observers, not necessarily to be provided with any special instrumental equipment, to report seismic phenomena in accordance with some uniform plan.

I would suggest that the Council be asked to bring this matter before the State Governments, recommending that the existing observatories be given facilities and some little extra means (say, £100 per annum) for the purpose.

(*b*) Professor Milne, as secretary of the Seismological Committee of the British Association, collects and publishes the seismic records obtained at many observatories in every part of the world, including Australia and New Zealand, and an International Seismological Association also deals with similar seismic records. There appears to be an unnecessary complexity and some doubt as to the desirability of such an arrangement, and, as some of the Australian Observatories, whose records are supplied to Professor Milne, have been asked to co-operate with the other abovementioned association, it would be expedient for us to know more clearly than we know at present the exact relations and objects of these two bodies.

I would suggest that the Council be recommended to take steps with the object of obtaining definite information and opinions from the proper authorities in England and Germany on this question.

SEISMOLOGICAL REPORT FROM THE SYDNEY OBSERVATORY.

Sydney Observatory, 23rd December, 1908.

Dear Sir,—I trust you will overlook my seeming dilatoriness in answering your two letters, dated 14th October, 1908, in which you ask for a brief account of the seismological and magnetical work carried on at the Sydney Observatory since January, 1907. My excuse is that I have delayed matters so long in order to be able to supply you with records quite up to date. With regard to seismology, with the exception of four short stoppages, extending over about a day at each period, our Milne siesmograph has been recording continuously. During the year 1907 ninety-six tremors were experienced, and, classing them in order of intensity, they are as follows:—

1	tremor	over 15 m/m amplitude, 18th December ...	1%
2	,,	between 7 and 8 m/m	2%
1	,,	,, 6 ,, 7 ,, ...	1%
3	,,	,, 5 ,, 6 ,, ...	3%
2	,,	,, 3 ,, 4 ,, ...	2%
6	,,	,, 2 ,, 3 ,, ...	6%
13	,,	,, 1 ,, 2 ,, ...	14%
68	,,	under 1 m/m	71%

The numbers of the above recorded monthly were:—

January ...	6	tremors.	July	16	tremors.
February ...	4	,,	August ...	11	,,
March ...	3	,,	September ...	9	,,
April ...	6	,,	October ...	13	,,
May ...	12	,,	November ...	9	,,
June ...	4	,,	December ...	3	,,

From 1st January to 12th December, 1908, eighty-two tremors have been recorded on our instrument, as under:—

2	tremors	between 6 and 7 m/m amplitude	2%
1	,,	,, 5 ,, 6 ,, ,, ...	1%
1	,,	,, 4 ,, 5 ,, ,, ...	1%
1	,,	,, 3 ,, 4 ,, ,, ...	1%
3	,,	,, 2 ,, 3 ,, ,, ...	4%
14	,,	,, 1 ,, 2 ,, ,, ...	17%
60	,,	less than 1 m/m	73%

MONTHLY RECORD OF EARTH TREMORS.

January ...	3	tremors.	July	9	tremors.
February ...	4	,,	August ...	11	,,
March ...	8	,,	September ...	13	,,
April ...	7	,,	October ...	5	,,
May ...	5	,,	November ...	5	,,
June ...	11	,,	December ...	1	,,

You will thus observe that, during the period under review, more than 70 per cent. of the disturbances are only thickenings of the light line.

Complete detailed measurements of all the records are appended hereto.

MAGNETICAL.

Although a magnetometer has been established at our branch observatory, Red Hill, Pennant Hills, under the charge of Mr. J. W. Short, for several years, owing to certain defects in the instrument, no systematic observations were taken till late in 1907, when a new collimator magnet was received from the National Physical Observatory, Kew, London, and placed in position.

I forward you the results for February to November, 1908, those being the only observations on which any reliance can be placed.

I have, &c.,

WM. E. RAYMOND, Officer in Charge.

The Government Astronomer, Observatory, Melbourne.

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH.

As early as possible after 30th June and 31st December of each year, the Recorder is requested to fill up the sheets, and post the same to the Secretary of the Earthquake Committee, British Association, Burlington House, London, England.

These should be accompanied by copies of important seismograms. Remarks exceeding six words should be entered on separate sheets.

At the end of each Register the equivalent of 1 mm. of amplitude should be stated in seconds of arc.

P.T. = Preliminary Tremors. L.W. = Large Waves. Time is Greenwich Civil Mean Time; it is to be given in hours, minutes, and decimals of minutes; 0 or 24 H = midnight.

Register from Sydney Observatory—W. Graham, Observer.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
	H. M.	H. M.	H. M.	H. M.	MM.	H. M.	
1907.							
1 January...	0 23·2	0 23·6	0 28·4	1 18·2	1·5	0 55·0	
1 ,, ...	22 43·5	22 43·7	22 52·2	23 13·7	1·25	0 30·2	
2 ,, ...	12 2·4	12 14·0	12 33·4	15 36·2	6·7	3 34·8	
4 ,, ...	4 58·7	5 25·5	5 27·7	7 53·6	5·85	2 54·9	
Thickening of line on 8th January from 5 41·8 to 6 55·8.							
14 ,, ...	9 56·9	9 57·4	9 58·2	10 11·2	1·5	0 14·3	
3 February	5 55·8	5 58·3	6 2·3	6 22·1	0·5	0 26·3	
3 ,, ...	19 43·2	19 44·6	19 49·2	20 53·8	7·2	1 10·6	
16 ,, ...	21 21·5	21 22·1	21 30·3	22 15·5	1·85	0 54·0	
27 ,, ...	9 17·8	9 23·4	9 26·8	9 39·4	0·55	0 11·6	
29 March ...	20 53·7	21 0·4	21 11·3	21 41·0	1·1	0 47·3	
31 ,, ...	15 5·7	15 7·5	15 8·0	15 23·3	0·5	0 17·6	
31 ,, ...	22 4·3	22 9·5	22 14·3	22 39·3	1·0	0 35·0	

Machine under repairs from 23 30 on 2nd April to 6 0 on 3rd April.
Thickening of line on 10th April from 17 4 to 18 16·5.

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH—*continued.*

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
	H. M.	H. M.	H. M.	H. M.	MM.	H. M.	

1907.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
18 April ...	1 32·8	1 34·5	1 35·3	1 44·7	5·1	0 11·9	
18 ,, ...	20 15·7	20 18·2	20 31·9	21 2·5	2·5	0 46·8	
19 ,, ...	0 9·0	0 15·2	0 25·3	1 20·7	3·3	1 11·7	
19 ,, ...	10 20·8	10 22·0	10 25·8	10 41·5	0·7	0 20·7	

Thickening of line on 24th April from 23 13·7 to 23 37·6.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
4 May ...	5 57·6	6 4·7	6 12·8	6 47·6	3·55	0 50·0	
4 ,, ...	8 54·0	...	8 56·4	9 19·5	0·7	0 25·5	

Thickening of line on 12th May from 7 55 to 8 43.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
13 ,, ...	21 5·2	21 8·5	21 16·2	22 3·4	2·4	0 58·2	
17 ,, ...	1 10·3	1 13·1	1 23·5	1 31·5	0·85	0 21·2	

Thickening of line on 20th May from 8 7·3 to 10 7·0.
Thickening of line on 23rd May from 16 41·6 to 21 11·3.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
25 ,, ...	12 5·1	12 21·6	12 23·8	12 49·7	0·7	0 44·6	
25 ,, ...	14 22·4	14 22·4	14 22·4	15 0·7	1·0	0 38·3	Max. amplitude at commencement of tremor
26 ,, ...	11 8·2	11 12·0	11 15·4	11 38·2	0·5	0 30·0	
27 ,, ...	5 11·3	5 12·7	5 17·5	5 25·3	0·55	0 14·0	
31 ,, ...	12 49·6	12 51·0	13 24·3	14 12·9	1·0	1 23·3	

Thickening of line on 2nd June from 14 59·7 to 21 39·1.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
13 June ...	12 3·3	12 6·0	12 8·8	12 13·5	0·3	0 10·2	
21 ,, ...	3 55·1	3 58·8	4 2·3	4 22·6	0·8	0 27·5	

Clock stopped on 24th June at 12 43·8; repaired and restarted on 26th June at 5 13·0.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
27 ,, ...	22 31·5	22 34·2	22 45·0	23 56·7	2·8	1 25·2	
1 July ...	13 29·7	13 40·1	13 40·9	13 47·5	0·3	0 17·8	

Thickening of line on 5th July, 21 55 to 6th July, 5 59.
Thickening of line on 7th July from 19·48 to 21·4.
,, ,, 8th July from 15·30 to 21·33.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
9 July ...	19 9·5	19 14·2	19 30·5	20 2·6	0·5	0 53·1	

Thickening of line on 10th July from 0·41 to 8 24·0.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
12 ,, ...	17 30·8	17 53·4	17 55·2	22 18·2	0·35	4 47·4	
13 ,, ...	14 17·8	14 44·5	14 47·6	15 44·8	0·25	1 27·0	
13 ,, ...	16 15·5	16 34·5	17 15·8	18 59·4	0·4	2 43·9	

Thickening of line on 13th July from 20 54·2 to 22 43·5.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
20 ,, ...	5 42·9	...	5 43·9	5 49·2	0·45	0 6·3	
20 ,, ...	13 47·0	13 53·5	13 57·0	14 42·1	2·0	0 55·1	
23 ,, ...	17 58·7	18 10·4	18 17·3	21 29·4	0·35	3 30·7	
29 ,, ...	19 43·1	19 54·6	19 59·1	20 30·0	1·1	0 46·9	
30 ,, ...	15 29·7	15 47·5	15 51·3	18 1·9	0·7	2 32·2	
30 ,, ...	19 59·9	20 13·3	20 23·3	21 55·9	0·4	1 56·0	
7 August ...	2 30·7	2 31·7	2 32·5	2 50·4	0·3	0 19·7	
7 ,, ...	3 10·1	3 16·1	3 29·6	4 12·6	0·45	1 2·5	
7 ,, ...	6 17·6	6 25·8	6 27·6	7 11·1	0·25	0 53·5	
13 ,, ...	2 19·9	2 36·7	2 38·1	3 6·4	0·5	0 46·5	
13 ,, ...	4 1·5	4 20·1	4 27·0	7 9·4	0·35	3 7·9	
13 ,, ...	21 54·4	21 58·5	22 0·8	22 54·9	2·5	1 0·5	

Thickening of line on 17th August from 17 45·5 to 22 1·9.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
18 ,, ...	17 32·9	18 4·4	18 7·9	18 23·9	0·3	0 51·0	
18 ,, ...	20 20·5	20 29·5	20 37·0	20 58·7	0·5	0 38·2	
23 ,, ...	13 30·9	13 32·2	13 36·9	13 42·9	0·8	0 12·0	
26 ,, ...	19 14·8	19 17·1	19 19·4	19 46·3	0·35	0 31·5	

Clock stopped from 14·10 on 1st September to 23·48 on 2nd September.

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
4 September	20 8·0	20 41·0	20 53·9	21 41·5	0·45	1 33·5	
6 ,,	0 43·8	1 18·6	1 23·0	1 30·0	0·35	0 46·2	
9 ,,	10 10·9	10 27·9	10 39·5	11 9·2	0·5	0 58·3	
9 ,,	22 57·1	23 34·1	23 40·1	...	} 0·7	5 17·6	
10 ,,	...	...	...	4 44·7			
11 ,,	3 4·0	4 17·6	5 51·7	18 25·2	0·5	5 21·2	

Lamp went out on 22nd September at 3·20. Relighted at 23·30 on same day.

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH—*continued.*

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
	H. M.	H. M.	H. M.	H. M.	MM.	H. M.	
1907.							
24 September	0 29·3	0 50·1	0 58·7	4 13·3	0·3	3 44·0	
24 ,,	5 59·6	6 4·6	6 7·0	8 48.6	0·4	2 49·0	
25 ,,	...	13 27·9	13 31·6	13 42·9	0·6	0 15·0	
30 ,,	23 45·9	...	...	..	0·5	7 35·0	
1 October ...	...	0 42·9	0 44·5	7 20·9			
2 ,, ...	1 28·0	1 29·2	1 33·1	1 40·5	1·9	0 12·5	
2 ,, ...	1 50·9	1 51·9	1 58·5	2 28·4	2·7	0 37·5	
Thickening of line on 3rd October from 7 44·3 to 16 53·5.							
4 ,, ...	10 47·8	10 59·2	11 1·5	11 36·5	0·5	0 48·7	
8 ,, ...	6 34·0	6 41·0	6 51·0	7 11·8	0·5	0 37·8	
9 ,, ...	15 4·2	15 11·4	15 12·9	16 19·2	0·4	1 15·0	
10 ,, ...	21 52·4	21 55·7	21 57·6	22 59·9	5·0	1 7·5	
11 ,, ...	14 35·0	14 36·7	14 46·3	16 5·2	7·8	1 30·2	
11 ,, ...	20 37·8	20 39·4	20 40·3	21 19·5	0·9	0 41·7	
17 ,, ...	4 5·5	4 8·7	4 10·3	4 16·1	1·0	0 10·6	
17 ,, ...	19 5·4	19 10·6	19 11·9	19 20·4	0·7	0 15·0	
21 ,, ...	4 42·0	4 48·3	5 10·0	6 32·0	0·9	1 50·0	
28 ,, ...	0 22·4	0 22·7	0 22·8	0 27·2	0·75	0 4·8	
3 November	19 47·6	19 58·1	20 19·1	21 45·7	1·9	1 26·6	
12 ,, ...	7 8·8	7 16·3	7 20·1	7 49·3	0·65	0 40·5	
19 ,, ...	5 2·0	5 10·3	5 12·0	5 18·4	0·6	0 16·4	
19 ,, ...	21 46·6	21 48·1	21 53·8	22 0·9	1·25	0 14·3	
21 ,, ...	9 12·5	9 15·5	9 19·8	9 26·6	0·4	0 14·1	
21 ,, ...	20 23·7	20 39·2	20 50·2	21 28·7	0·9	1 5·0	
24 ,, ...	14 15·7	14 26·5	14 29·9	14 59·7	0·6	0 44·0	
26 ,, ...	3 2·6	3 5·9	3 6·6	3 51·6	0·7	0 49·0	
28 ,, ...	19 14·7	19 17·5	19 20·9	19 35·2	0·7	0 20·5	
18 December	17 42·6	17 51·5	17 52·4	19 23·7	15·6	1 41·1	
Thickening of line on 27th December from 3·16 to 15·49.							
30 ,, ...	5 37·4	5 44·2	5 47·4	7 21·3	0·6	1 43·9	
1908.							
11 January ...	3 43·2	3 44·7	3 48·2	4 48·4	0·75	1 5·2	
19 ,, ...	7 23·8	7 25·2	7 26·8	7 48·4	1·0	0 24·6	
29 ,, ...	20 22·9	20 31·1	20 34·8	21 5·2	0·6	0 42·3	
2 February	14 24·7	14 27·9	14 33·0	15 7·8	1·15	0 43·1	
13 ,, ...	16 53·3	16 57·9	16 58·8	17 11·3	0·3	0 18·0	
20 ,, ...	15 36·8	15 39·5	15 40·3	15 53·6	0·35	0 16·8	
24 ,, ...	23 48·8	23 53·3	23 54·2	...	2·2	0 26·7	
25 ,, ...	...	...	...	0 15·5			
5 March ...	2 27·9	2 31·9	2 36·2	4 0·9	5·6	1 33·0	
15 March ...	9 14·6	9 23·1	9 28·1	10 10·8	0·9	0 56·2	
15 ,, ...	11 10·4	11 13·3	11 14·4	11 30·6	0·35	0 20·2	
16 ,, ...	13 28·3	13 29·0	13 29·9	13 34·7	0·6	0 6·4	
19 ,, ...	3 4·0	3 14·7	3 19·0	3 27·2	0·35	0 23·2	
21 ,, ...	4 9·1	4 30·8	4 33·1	4 57·4	0·5	0 48·3	
23 ,, ...	12 30·5	12 42·9	12 49·7	13 49·9	6·0	1 19·4	
26 ,, ...	23 23·5	23 40·8	23 45·5	...	1·5	2 10·0	
27 ,, ...	...	...	...	1 33·5			
7 April ...	1 22·9	1 25·6	1 28·2	1 47·4	0·7	0 24·5	
9 ,, ...	23 57·8	...	...	...	...	...	
10 ,, ...	...	0 6·8	0 8·6	1 10·4	6·3	1 12·6	
11 ,, ...	16 33·6	16 35·2	16 36·9	16 42·2	0·6	0 8·6	
12 ,, ...	19 15·7	19 21·1	19 23·2	19 49·4	2·0	0 33·7	
23 ,, ...	0 1·0	0 13·1	0 24·3	1 32·0	1·1	1 31·0	
24 ,, ...	18 13·2	...	...	21 54·0	..	3 40·8	Thickening of line
25 ,, ...	13 59·0	...	18 12·0	20 58·5	0·5	6 59·5	,, ,,
5 May ...	6 25·1	6 31·7	6 50·3	7 46·8	1·7	1 21·7	
7 ,, ...	17 55·3	...	19 21·0	22 35·6	0·5	4 40·3	,, ,,
17 ,, ...	8 0·4	8 9·2	8 11·6	9 28·3	1·6	1 27·9	
25 ,, ...	11 30·7	...	20 14·8	21 58·4	0·35	10 27·7	,, (25 May–12 June)
31 ,, ...	3 20·4	...	3 21·9	3 31·2	0·5	0 10·8	
3 June ...	10 51·9	...	19 21·6	21 58·0	0·55	11 6·1	
10 ,, ...	0 56·6	...	3 17·1	10 43·2	0·4	9 46·6	
10 ,, ...	17 13·8	...	...	...	0·4	12 27·8	
11 ,, ...	...	...	4 53·1	4 41·6			
12 ,, ...	0 42·4	...	4 58·4	6 13·4	0·5	5 31·0	
17 ,, ...	12 30·1	12 33·1	12 34·8	12 56·6	0·7	0 26·5	

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH—*continued.*

Date.	P.T. Commence.	L.W. Commence.	Max.	End.	Max. Amplitude.	Duration.	Remarks.
	H. M.	H. M.	H. M.	H. M.	MM.	H. M.	
1908.							
17 June ...	14 16·9	...	20 31·7	22 30·9	0·6	8 30·9	Thickness of line
19 ,, ...	4 17·0	...	4 19·3	4 26·2	0·4	0 9·2	
19 ,, ...	14 2·7	...	15 46·7	18 58·8	0·4	4 58·8	
21 ,, to	21 36·7	...	...	...	0·5	41 17·4	Intermittent thickening of line for nearly two days
23 ,, ...	...	...	4 3·9	14 54·1			
30 ,, ...	14 6·4	...	14 22·6	14 53·6	0·2	0 47·2	Thickening of line
30 ,, ...	19 53·1	...	21 14·3	22 55·8	0·4	3 2·7	
1 July ...	15 56·4	...	20 49·4	21 50·4	0·5	5 54·0	
6 ,, ...	8 20·1	8 25·2	8 30·1	8 47·3	1·65	0 27·2	
10 ,, ...	16 25·1	...	19 29·4	22 8·1	0·5	5 43·0	,, ,,
15 ,, ...	23 59·0	...	...	...	1·0	0 36·0	
16 ,, ...	...	0 2·7	0 4·0	0 35·0			
21 ,, ...	18 56·1	...	...	...	0·3	11 43·2	
22 ,, ...	...	...	0 38·6	6 39·3			
22 ,, ...	18 4·6	...	21 18·1	22 41·8	0·6	4 37·2	
24 ,, ...	11 36·0	...	19 12·8	21 32·7	0·5	9 56·7	,, ,,
26 ,, ...	16 25·3	...	16 40·3	18 21·8	0·2	1 56·5	
29 ,, ...	15 49·9	...	21 19·3	22 42·9	0·5	6 53·0	
2 August ...	16 43·2	...	18 34·6	22 29·1	0·3	5 45·9	
9 ,, ...	16 9·7	16 16·2	16 17·2	16 36·0	1·0	0 26·3	
12 ,, ...	15 53·5	15 57·8	16 1·0	3 3·0	1·2	1 9·5	
13 ,, ...	18 53·5	19 3·2	19 13·5	20 2·1	2·3	1 8·6	
15 ,, ...	11 8·8	...	11 13·6	11 34·5	0·3	0 25·7	
16 ,, ...	2 27·6	...	3 24·0	9 17·2	0·55	6 49·6	,, ,,
16 ,, ...	23 37·9	...	...	...	0·35	7 44·6	
17 ,, ...	...	...	2 53·8	7 22·5			
17 ,, ...	10 52·3	11 25·0	11 45·8	13 11·1	1·7	2 18·8	
22 ,, ...	19 18·2	19 24·2	19 39·8	20 17·5	1·1	0 59·3	
25 ,, ...	13 42·2	...	17 28·7	22 38·0	0·4	8 55·8	,, ,,
28 ,, ...	4 59·6	5 1·5	5 2·6	5 6·5	0·5	0 6·9	
1 September	21 35·2	...	...	...	0·3	10 35·1	,, ,,
2 ,, ...	...	...	3 4·7	8 10·3			
13 ,, ...	0 18·7	...	...	13 50·4	0·3	13 31·4	
19 ,, ...	18 36·3	18 44·1	18 58·1	19 26·6	0·55	0 50·3	
19 ,, ...	22 21·4	...	22 50·9	...	0·4	12 8·2	
20 ,, ...	...	...	...	10 29·6			
20 ,, ...	12 59·6	...	13 49·6	15 9·6	0·25	2 10·0	,, ,,
20 ,, ...	16 44·5	...	...	...	0·5	17 27·4	
21 ,, ...	...	...	7 20·7	10 11·9			
21 ,, ...	15 5·1	15 9·7	15 12·6	15 36·2	1·5	0 31·1	
24 ,, ...	8 14·7	...	9 46·7	10 3·0	0·2	1 48·3	,, ,,
24 ,, ...	23 23·9	...	...	...	0·35	7 54·5	
25 ,, ...	...	...	4 14·4	7 19·4			
25 ,, ...	13 27·6	...	20 44·3	23 6·2	0·25	9 38·6	,, ,,
26 ,, ...	5 29·7	5 31·3	5 34·3	6 31·9	4·0	1 2·2	
26 ,, ...	19 21·6	...	19 37·8	20 39·9	0·2	1 18·3	,, ,,
27 ,, ...	23 9·9	...	23 13·9	...	0·3	1 33·8	
28 ,, ...	...	...	...	0 43·7			
7 October ...	0 57·5	1 3·3	1 6·1	2 2·5	3·2	1 5·0	
8 ,, ...	3 18·9	...	4 44·9	6 26·0	0·4	3 7·1	
8 ,, ...	23 40·0	...	...	...	0·3	9 11·1	,, ,,
9 ,, ...	...	..	1 56·8	8 51·1			
19 ,, ...	4 46·2	...	11 37·1	14 19·5	0·25	9 33·3	
19 ,, ...	21 0·6	...	...	...	0·4	9 32·5	
20 ,, ...	...	...	2 6·2	6 33·1			
2 November	5 34·0	5 50·7	5 52·0	7 9·5	1·1	1 35·5	
10 ,, ...	18 55·1	18 56·1	18 57·4	19 11·6	0·3	0 16·5	
11 ,, ...	21 29·1	21 30·7	21 33·4	21 59·7	0·4	0 30·6	
15 ,, ...	1 51·0	1 57·0	2 2·3	2 24·9	0·25	0 33·9	
18 ,, ...	13 14·6	...	13 15·6	13 18·9	0·4	0 4·3	,, ,,
10 December	12 14·4	...	12 15·1	12 20·6	0·3	0 6·2	

Mean Displacement Value 0·55″ of arc per m/m. Boom Period 13·5.″

SEISMOLOGICAL REPORT OF THE MELBOURNE OBSERVATORY.

Observatory, Melbourne, Victoria, 1st January, 1908.

The instrument employed at this observatory is a Milne horizontal pendulum, constructed by the firm of R. W. Munro, London. It is located in a dry and well-ventilated underground room in the main building. It records photographically. The average period of the boom ranges from 16 s. to 17 s., the time scale is 60 mm. per hour, and the angular value of an amplitude of 1 mm. on the records is 0·4″.

The instrument has been kept in constant use throughout the period from 1st January, 1907, to date, and has registered satisfactorily.

All seismograms have been measured, classified, and registered in appropriate ledgers, and the results will be sent shortly to Professor Milne for publication in the reports of the British Association, according to a standing arrangement.

Unfortunately, the last record of the year 1908 is that of the disastrous Sicilian Earthquake of 28th December.

P. Baracchi.

SEISMOLOGICAL REPORT FROM ADELAIDE OBSERVATORY.

The Observatory, Adelaide, 30th November, 1908.

Dear Sir,—In reply to your letter of the 14th ultimo, asking for an account of seismological work at the Adelaide Observatory from January, 1907, to date, I send you herewith a list of reports received from country stations during that period.

A Milne horizontal pendulum seismograph has been mounted this year at the observatory, in a building specially erected for the purpose, but the fitting and furnishing of the seismograph-room and developing-room have not yet been completed. It is hoped, however, that this will be done by the end of the year, and work will then be commenced with the instrument.

The seismograph is of the latest pattern, and embodies several improvements on its predecessors. It has been set up with the boom in the meridian, the free end of the boom being to the north.

Yours faithfully,

G. F. Dodwell,
Acting Government Astronomer.

Date.	Name of Place.	Time of Beginning of Shock, Ade. S.T. 9.30 E. of G.	Apparent Direction.	Apparent Duration.	Effect—Remarks.
1907.				Seconds.	
30 May ...	Naracoorte	8·28 a.m.	E. to W.	20	Sharp. Crockery knocked down and doors shook. People alarmed: rushed outside. No damage reported. Loud rumbling noise.
29 July ...	Jamestown	12.15 a.m.	S.W. to N.E.	...	A rather severe shock. Many residents were awakened by the low rumbling noise that immediately preceded it, and doors and windows were distinctly shaken by the vibration.
14 December	Carrieton ...	7·20 p.m.	N.E. to S.W.	12	Sharp. Crockery rattling; no damage.
1908.					
10 April ...	Eurelia ...	1·57 a.m.	N.E. to S.W.	10 to 15	Windows and doors and movable articles rattled.
10 ,, ...	Hookina ...	2·5 a.m.	S.W. to N.E.	About 1 minute	Houses trembled and cracked. Crockery, &c., moved rapidly. A long rumbling sound before actual shock, and rumble afterwards. Three distinct shocks within the tremor.
				Seconds.	
10 ,, ...	Clare ...	1·55 a.m.	...	5	Small. Utensils on dressing-table shaken.
10 ,, ...	Yunta ...	1·57 a.m.	...	50	Severe. Windows rattled and houses shook; also hotel fixtures noisy.
10 ,, ...	Carrieton ...	1·55 a.m.	N.W. to S.E.	30	Crockery rattled.
10 ,, ...	Yongala ...	1·50 a.m.	S.W. to N.E.	10	Beds were shaken, and crockery and windows rattled.
10 ,, ...	Waukaringa	2·5 a.m.	N.E. to S.W.	8	Doors and windows shook, crockery rattled, iron on roof trembled. Sound previous to shock resembled steam for several seconds.
29 October	Second Valley	6·10 a.m.	S.W. to N.E.	...	Slight shock.
6 ,,	Eudunda ...	5·10 a.m.	...	20	It was accompanied by a loud rumbling noise like a heavy wagon passing over hollow ground.
6 ,,	Sutherlands	5 p.m.	...	...	The vibration caused windows, furniture, and crockery to rattle. It was accompanied by a loud rumbling noise like thunder.
6 ,,	Mount Mary	5·10 p.m.	E. to W.	...	It shook buildings and made iron roofs rattle.

SEISMOLOGICAL REPORT FROM THE PERTH OBSERVATORY, WESTERN AUSTRALIA.

My Dear Baracchi,—The Perth seismograph was erected in September, 1901. It is of the Milne horizontal pendulum type. It is mounted on brick pillars with a marble table-top, and the pendulum is pointing true north. Both kerosene and electric lamps have been used at different times, and we now adopt an 8 c.p. electric lamp, covered with an opaque screen, in which is a small hole. The instrument is placed on a concrete floor in the basement of the astrograph building, about 8 ft. underground, and 200 above sea level.

The instrument has worked uninterruptedly and satisfactorily since 1st January, 1908, with the following exceptions:—Five times the light went out. Once the paper was caught on the cylinder.

The results are sent every six months to Professor Milne, and published in the circulars of the British Association.

Accompanying this is a list of our earthquakes for 1908. You will find all the previous records in the printed circulars. As to distinguishing between those recorded elsewhere, &c., you can probably do this better than I, as we only have the local Press reports to go by.

I have, &c.,

7th December, 1908. W. E. Cooke.

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH.

As early as possible after 30th June and 31st December of each year, the recorder is requested to fill up the sheets, and post the same to the Secretary of the Earthquake Committee, British Association, Burlington House, London, England.

These should be accompanied by copies of important seismograms. Remarks exceeding six words should be entered on separate sheets.

At the end of each Register the equivalent of 1 mm. of amplitude should be stated in seconds of arc.

P.T. = Preliminary Tremors. L.W. = Large Waves. Time is Greenwich Civil Mean Time; it is to be given in hours, minutes, and decimals of minutes; 0 or 24 H = midnight.

Register from Perth Observatory—W. E. Cooke, Director.

No.	Date.	P.T. Commence.		L.W. Commence.		Max.		End.		Max. Amplitude.
	1908.	H.	M.	H.	M.	H.	M.	H.	M.	MM.
1	11 January ...	3	52·7	3	56·4	4	29·0	5	2·7	1·0
2	19 ,, ...	7	21·6	7	23·5	7	27·0	7	54·8	1·5
3	29 ,, ...	20	34·8	20	54·3	20	57·8	21	22·3	0·5
4	2 February ...	14	30·0	14	33·0	{14 {14	37·0} 42·0}	14	57·0	{1·0 {1·0
5	20 ,, ...	15	50·2	15	52·2	15	55·2	16	7·2	1·0
6	25 ,, ...	0	3·5	0	8·5	0	11·5	0	15·5	1·0
7	5 March ...	2	25·2	2	30·7	2	43·2	3	39·7	3·0
8	23 ,, ...	12	28·7	12	33·7	12	40·7	13	51·7	4·75
9	26 ,, ...	23	23·5	23	28·0	0	30·0	...		4·0
	27 ,, ...	...		...		0	36·5	2	2·0	4·75
10	9 April ... 10 ,, ...	23 ...	54·5	23 ...	58·5	} 0	3·5	1	2·0	4·0
11	11 ,, ...	16	27·5	16	29·0	16	31·5	16	48·5	0·75
12	23 ,, ...	0	2·8	0	6·6	0	17·8	1	41·0	4·5
13	5 May ...	6	24·4	6	29·9	6	36·9	7	45·0	4·5
14	5 ,, ...	11	35·0	11	51·4	11	57·4	12	24·7	1·5
15	11 ,, ...	14	0·8	14	2·8	14	7·8	14	22·6	1·0
16	20 ,, ...	7	46·6	7	51·9	7	58·6	8	56·6	5·25
17	26 July ...	16	14·5	16	19·5	16	37·3	16	56·5	0·5
18	26 ,, ...	17	26·0	17	29·5	17	41·5	18	18·0	0·75
19	9 August ...	16	13·0	16	19·5	16	20·0	16	33·0	1·0
20	12 ,, ...	15	53·1	16	8·6	16	15·6	16	51·4	3·25
21	12 ,, ...	18	51·6	18	55·8	19	4·4	20	0·0	2·75
22	17 ,, ...	11	0·0	11	2·2	11	24·5	13	22·0	3·0
							29·5	...		3·0
							33·8	...		3·75
							36·7	...		3·0
							40·3	...		2·75
23	22 ,, ...	19	22·8	19	45·8	19	48·3	20	17·1	0·75
24	9 September	20	28·2	20	29·7	20	35·0	20	58·2	0·75
25	26 ,, ...	5	34·7	5	37·5	5	44·7	6	39·7	1·25
26	7 October ...	1	5·2	1	9·2	1	16·5	1	51·2	2·5
						1	19·1	...		2·25
27	2 November	5	24·2	5	28·7	5	38·2	8	12·7	3·75
						5	56·2	...		4·0
28	10 ,, ...	...		13	33·1	13	54·3	14	33·1	1·25
29	15 ,, ...	1	39·7	1	45·7	1	48·7	2	21·5	0·75
30	23 ,, ...	12	53·8	12	56·3	13	9·8	13	36·1	1·0

REPORT OF THE COMMITTEE ON TERRESTRIAL MAGNETISM.

To the President of Section A—

Sir,—I have the honour to report as follows on behalf of the Committee on Terrestrial Magnetism, viz.:—

The magnetic observatory of Christchurch, New Zealand, and the Melbourne Observatory are the only stations within the scope of the Association where systematic registration of the magnetic elements has been and is being carried out. Some isolated absolute measurements have been made at Sydney Observatory during the last two years.

The report from the Christchurch Observatory will very probably be presented to the section directly by Mr. Henry F. Skey, B.Sc., the director.

An abstract of the Sydney observations, supplied by the officer in charge of the observatory, is appended.

At Melbourne the usual routine work has been continued as in preceding years, and the measurement and reduction of the full series of records, comprising the period 1868-1908, have been practically completed, and the results are now being prepared for publication.

It will be remembered that at the Sydney meeting of the A.A.A.S., in 1898, at the request of Section A, the Council urged upon the Government of Victoria to give means and facilities to the Melbourne Observatory for undertaking this important work, which were obtained in due course; and, if its progress has been unavoidably slow, yet, considering that it involved the measurement and tabulation of hourly ordinates of more than 40,000 day-curves, it should be gratifying to all concerned to know that such a task has now been brought up to its final stage.

It is expected that the results of the whole series will be ready in manuscript within the present year.

The magnetic committee was created in 1898, with the special object of promoting the following undertakings, viz.:—

(*a*) The execution of a magnetic survey of New Zealand, and the establishment of a permanent magnetic observatory in that country.

(*b*) The reduction of the Melbourne series of magnetic records.

As these objects have now been accomplished, should a magnetic committee be re-elected? and, if so, on what grounds?

This question should be very carefully considered. It would not be difficult to suggest new undertakings of first importance, and even urgency, for the advancement of our knowledge of terrestrial magnetism, such as the establishment of permanent magnetic observatories at Sydney, Brisbane, Adelaide, Perth, and Port Darwin, and the initiation of a magnetic survey of Australia and Tasmania. The assistance required for this kind of enterprise is, however, of the order of that which might be expected from a Carnegie institution, and, under present circumstances, it is extremely doubtful whether we in Australia could advance such proposals with any probable chance of success.

I have, &c.,

P. BARACCHI.

REPORT ON TERRESTRIAL MAGNETISM BY THE OFFICER IN CHARGE OF THE SYDNEY OBSERVATORY.

Magnetic Elements Observed at Red Hill Observatory during the Year 1908.

—	Declination.	Dip.	Intensity.	B. A. W.	C. G. S. W.
			Total	...	...
January ...	...	...	Vertical	...	...
			Horizontal ...	...	...
			Total	12·707	·5859
February ...	9 24 7	63 7 41	Vertical	11·335	·5226
			Horizontal ...	5·743	·2648
			Total	12·735	·5872
March	9 23 52	63 5 12	Vertical	11·356	·5236
			Horizontal ...	5·764	·2658
			Total	12·621	·5819
April	9 24 13	63 5 52	Vertical	11·255	·5190
			Horizontal ...	5·710	·2633
			Total	12·660	·5838
May	9 24 7	63 5 26	Vertical	11·289	·5205
			Horizontal ...	5·731	·2643
			Total	12·649	·5832
June	9 24 9	63 6 0	Vertical	11·280	·5201
			Horizontal ...	5·723	·2639
			Total	12·618	·5818
July	9 24 4	63 5 55	Vertical	11·253	·5189
			Horizontal ...	5·709	·2633
			Total	12·614	·5816
August	9 24 7	63 7 9	Vertical	11·251	·5188
			Horizontal ..	5·703	·2630
			Total	12·612	·5815
September ...	9 23 32	63 7 38	Vertical	11·250	·5187
			Horizontal ...	5·701	·2629
			Total	12·656	·5836
October ...	9 28 23	63 7 46	Vertical	11·289	·5206
			Horizontal ...	5·720	·2638
			Total	12·663	·5839
November ...	9 24 9	63 6 23	Vertical	11·294	·5207
			Horizontal ...	5·728	·2641
			Total	...	...
December ...	...	...	Vertical	...	...
			Horizontal ...	...	...

The officer in charge adds—"Although a magnetometer has been established at our branch at Red Hill, Pennant Hills, under the charge of Mr. J. W. Short for several years, owing to certain defects in the instrument no systematic observations were made till late in 1907, when a new collimator magnet was received from the National Physical Observatory, Kew, London, and placed in position. I forward you the results for February to November, 1908, those being the only observations on which any reliance can be placed." (These results are those shown in above table.)

PAPERS READ IN SECTION A.

1.—ON THE QUATERNION EXPRESSION FOR THE CO-ORDINATES OF A SCREW RECIPROCAL TO FIVE GIVEN SCREWS.

By Sir ROBERT BALL, F.R.S., Lowndean Professor of Astronomy and Geometry, University of Cambridge.

One of the most fundamental principles in the theory of screws is that which asserts that, if five screws are not contained in a system of order less than five, then one screw, but only one, can be found which is reciprocal to each of the five screws. We shall now prove this by the quaternion representation, and we shall obtain the co-ordinates of the reciprocal screw in terms of the co-ordinates of the given screws.

Let the co-ordinates of four screws be respectively—

$$\mu_1\,\lambda_1\,;\quad \mu_2\,\lambda_2\,;\quad \mu_3\,\lambda_3\,;\quad \mu_4\,\lambda_4\,;$$

and let x_1, x_2, x_3, x_4 be any four scalars. Then the 4-system will be found by giving all values to $x_1\ x_2\ x_3\ x_4$ in the co-ordinates—

$$x_1\,\mu_1+x_2\mu_2+x_3\mu_3+x_4\mu_4,\ \ x_1\lambda_1+x_2\lambda_2+x_3\lambda_3+x_4\lambda_4 \qquad \text{(i.)}$$

For if $\mu\,\lambda$ be the co-ordinates of a screw reciprocal to each of the four screws, then (see Joly's Manual of Quaternions, p. 204)—

$$S(\lambda\mu_1+\mu\lambda_1)=0\,;\ S(\lambda\mu\ +\mu\lambda_2)=0\,;\ S(\lambda\mu_3+\mu\lambda_3)=0;\ S(\lambda\mu_4+\mu\lambda_4)=0,$$

and consequently—

$$S\{\lambda(x_1\mu_1+x_2\mu_2+x_3\mu_3+x_4\mu_4)+\mu(x_1\lambda_1+x_2\lambda_2+x_3\lambda_3+x_4\lambda_4)\}=0. \qquad \text{(ii.)}\,;$$

so that μ, λ is a screw reciprocal to every screw of the type (i.) It is thus shown that all screws which are reciprocal to the original four screws are also reciprocal to every screw of the type (i.), and hence the latter must be the general representation of the screw of a 4-system.

It is well known that if λ_1, λ_2, λ_3, λ_4 be any four vectors whatever,

$$\lambda_1 S\lambda_2\lambda_3\lambda_4-\lambda_2 S\lambda_3\lambda_4\lambda_1+\lambda_3 S\lambda_4\lambda_1\lambda_2-\lambda_4 S\lambda_1\lambda_2\lambda_3=0 \qquad \text{(iii.)}\,;$$

let us make in (ii.)—

$$x_1=S\lambda_2\lambda_3\lambda_4\,;\ x_2=-S\lambda_3\lambda_4\lambda_1\,;\ x_3=S\lambda_4\lambda_1\lambda_2\,;\ x_4=-S\lambda_1\lambda_2\lambda_3\,;$$

then from (ii.) and (iii.) we have

$$S\lambda(\mu_1 S\lambda_2\lambda_3\lambda_4-\mu_2 S\lambda_3\lambda_4\lambda_1+\mu_3 S\lambda_4\lambda_1\lambda_2-\mu_4 S\lambda_1\lambda_2\lambda_3)=0.$$

The interpretation of this equation is that every screw μ, λ which is reciprocal to the four given screws must also be at right angles to the vector—

$$\mu_1 S\lambda_2\lambda_3\lambda_4-\mu_2 S\lambda_3\lambda_4\lambda_1+\mu_3 S\lambda_4\lambda_1\lambda_2-\mu_4 S\lambda_1\lambda_2\lambda_3 \qquad \text{(iv.)}$$

We know that the locus of screws which are reciprocal to four given screws is a cylindroid, and hence we obtain the following theorem :—

Given four screws $\mu_1\lambda_1$; $\mu_2\lambda_2$; $\mu_3\lambda_3$; $\mu_4\lambda_4$; *then the axis of the cylindroid reciprocal to these four screws is parallel to the vector.*

$$\mu_1 S\lambda_2\lambda_3\lambda_4-\mu_2 S\lambda_3\lambda_4\lambda_1+\mu_3 S\lambda_4\lambda_1\lambda_2-\mu_4 S\lambda_1\lambda_2\lambda_3$$

If μ, λ be reciprocal to the five screws—

$$\mu_1, \lambda_1; \ \mu_2, \lambda_2; \ \mu_3, \lambda_3; \ \mu_4, \lambda_4; \ \mu_5, \lambda_5;$$

then it must be at right angles not only to vector (iv.) but also to any similar vector obtained by taking any other combination of four screws out of the five—*e.g.*,

$$\mu_2 S\lambda_3\lambda_4\lambda_5 - \mu_3 S\lambda_4\lambda_5\lambda_2 + \mu_4 S\lambda_5\lambda_2\lambda_3 - \mu_5 S\lambda_2\lambda_3\lambda_4 \qquad \text{(v.)}$$

Hence λ must be parallel to the vector part of the product of these two vectors (iv.) and (v.), for which we have the expression—

$$\left.\begin{array}{l} V\mu_1\mu_2(S\lambda_2\lambda_3\lambda_4 S\lambda_3\lambda_4\lambda_5) \\ + V\mu_2\mu_3(S\lambda_3\lambda_4\lambda_1 S\lambda_4\lambda_5\lambda_2 - S\lambda_3\lambda_4\lambda_5 S\lambda_4\lambda_1\lambda_2) \\ + V\mu_3\mu_4(S\lambda_4\lambda_1\lambda_2 S\lambda_5\lambda_2\lambda_3 - S\lambda_1\lambda_2\lambda_3 S\lambda_4\lambda_5\lambda_2) \\ + V\mu_4\mu_5(S\lambda_2\lambda_3\lambda_4 S\lambda_1\lambda_2\lambda_3) \\ + V\mu_5\mu_1(S\lambda_2\lambda_3\lambda_4 S\lambda_2\lambda_3\lambda_4) \\ + V\mu_1\mu_3(S\lambda_2\lambda_3\lambda_4 S\lambda_4\lambda_2\lambda_5) \\ + V\mu_3\mu_5(S\lambda_2\lambda_3\lambda_4 S\lambda_4\lambda_2\lambda_1) \\ + V\mu_5\mu_2(S\lambda_2\lambda_3\lambda_4 S\lambda_3\lambda_1\lambda_4) \\ + V\mu_2\mu_4(S\lambda_3\lambda_1\lambda_4 S\lambda_5\lambda_2\lambda_3 - S\lambda_1\lambda_2\lambda_3 S\lambda_3\lambda_5\lambda_4) \\ + V\mu_4\mu_1(S\lambda_2\lambda_3\lambda_4 S\lambda_5\lambda_3\lambda_2) \end{array}\right\} \text{(vi.)}$$

At present this expression does not seem symmetrical, though it is obvious that the vector parallel to the screw reciprocal to five screws must be symmetrical in regard to these five screws. We can give the expression in the desired form by the following Lemma:—

If $\alpha, \beta, \gamma, \delta$, and θ be any five vectors, then—

$$S\alpha\gamma\theta \cdot S\beta\delta\theta = S\alpha\beta\theta S\gamma\delta\theta - S\alpha\delta\theta \cdot S\gamma\beta\theta;$$

this can easily be verified by substituting for α and β from the equations—

$$\alpha = A\gamma + B\delta + C\theta; \quad \beta = A'\gamma + B'\delta + C'\theta;$$

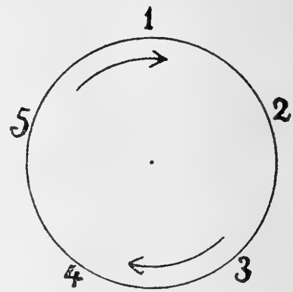
when A, B, C, A', B', C' are scalars. Thus we find that—

$$\begin{array}{l} S\lambda_3\lambda_4\lambda_1 . S\lambda_4\lambda_5\lambda_2 - S\lambda_3\lambda_4\lambda_5 S\lambda_4\lambda_1\lambda_2 = S\lambda_2\lambda_3\lambda_4 \ S\lambda_5\lambda_1\lambda_4 \\ S\lambda_4\lambda_1\lambda_2 \ S\lambda_5\lambda_2\lambda_3 - S\lambda_1\lambda_2\lambda_3 S\lambda_4\lambda_5\lambda_2 = S\lambda_2\lambda_3\lambda_4 \ S\lambda_5\lambda_1\lambda_2 \\ S\lambda_3\lambda_1\lambda_4 \ S\lambda_5\lambda_2\lambda_3 - S\lambda_1\lambda_2\lambda_3 S\lambda_3\lambda_5\lambda_4 = S\lambda_2\lambda_3\lambda_4 . S\lambda_1\lambda_5\lambda_3 \end{array}$$

Introducing these values into (vi.) and dividing out by the common factor $S\lambda_2\lambda_3\lambda_4$ (we assume that no three of the five given screws are complanar), we obtain for λ, the vector parallel to the screw reciprocal to the five given screws, the symmetrical expression—

$$\lambda = \left.\begin{array}{l} + V\mu_1\mu_2 S\lambda_3\lambda_4\lambda_5 \\ + V\mu_2\mu_3 S\lambda_4\lambda_5\lambda_1 \\ + V\mu_3\mu_4 S\lambda_5\lambda_1\lambda_2 \\ + V\mu_4\mu_5 S\lambda_1\lambda_2\lambda_3 \\ + V\mu_5\mu_1 S\lambda_2\lambda_3\lambda_4 \\ - V\mu_1\mu_3 S\lambda_5\lambda_2\lambda_4 \\ - V\mu_3\mu_5 S\lambda_2\lambda_4\lambda_1 \\ - V\mu_5\mu_2 S\lambda_4\lambda_1\lambda_3 \\ - V\mu_2\mu_4 S\lambda_1\lambda_3\lambda_5 \\ - V\mu_4\mu_1 S\lambda_3\lambda_5\lambda_2 \end{array}\right\} \text{(vii.)}$$

The order of the suffices in the several terms of λ will be seen as follows:—



Writing the digits 1, 2, 3, 4, 5 round the circumference of a circle consecutively, we notice that in each of the five positive terms of λ the five digits succeed each other simply as written round the circle—*e.g.*, in the third the suffices are 3, 4, 5, 1, 2. Thus the positive terms can be written down at once.

The five terms with negative signs each have a row of digits, which are also obtained from the succession on the circle. In this case, however, we are to omit every alternate digit on the circumference—*e.g.*, commencing with 3 we omit 4, take 5, omit 1, take 2, omit 3, take 4, omit 5, take 1, and obtain 3, 5, 2, 4, 1—and this gives the sequence of suffices in the seventh term of (vii.)

We have thus found λ one of the two vectors (μ, λ) which are required for the determination of the screw reciprocal to five given screws, and it now only remains to find the other vector μ.

If in the equation (ii.) we had taken—

$$x_1 = S\mu_2\mu_3\mu_4\,;\quad x_2 = -S\mu_3\mu_4\mu_1\,;\quad x_3 = S\mu_4\mu_1\mu_2\,;\quad x_4 = -S\mu_1\mu_2\mu_3\,;$$

we see that μ must be at right angles to—

$$\lambda_1 S\mu_2\mu_3\mu_4 - \lambda_2 S\mu_3\mu_4\mu_1 + \lambda_3 S\mu_4\mu_1\mu_2 - \lambda_4\mu_1\mu_2\mu_3 = 0\,;$$

and, following the same reasoning as in the case of λ, we obtain for μ the value—

$$\mu = \left.\begin{aligned} &-V\lambda_1\lambda_2 S\mu_3\mu_4\mu_5 \\ &-V\lambda_2\lambda_3 S\mu_4\mu_5\mu_1 \\ &-V\lambda_3\lambda_4 S\mu_5\mu_1\mu_2 \\ &-V\lambda_4\lambda_5 S\mu_1\mu_2\mu_3 \\ &-V\lambda_5\lambda_1 S\mu_2\mu_3\mu_4 \\ &+V\lambda_1\lambda_3 S\mu_5\mu_2\mu_4 \\ &+V\lambda_3\lambda_5 S\mu_2\mu_4\mu_1 \\ &+V\lambda_5\lambda_2 S\mu_4\mu_1\mu_3 \\ &+V\lambda_2\lambda_4 S\mu_1\mu_3\mu_5 \\ &+V\lambda_4\lambda_1 S\mu_3\mu_5\mu_2 \end{aligned}\right\}\text{(viii.)}$$

It is easy to verify that these values of λ and μ denote a screw reciprocal to each of the five given screws. Obviously, $S\lambda\mu_k + S\lambda_k\mu = 0$ for all integral values of k 5. For example—

$$\begin{aligned} S\lambda\mu_4 = {} & S\mu_4\mu_1\mu_2 S\lambda_3\lambda_4\lambda_5 + S\mu_4\mu_2\mu_3 S\lambda\ \lambda_5\lambda_1 + S\mu_4\mu_5\mu_1 S\lambda_2\lambda_3\lambda_4 \\ & - S\mu_4\mu_1\mu_3 S\lambda_5\lambda_2\lambda_4 - S\mu_4\mu_3\mu_5 S\lambda_2\lambda_4\lambda_1 - S\mu_4\mu_5\mu_2 S\lambda_4\lambda_1\lambda_3 \\ S\lambda_4\mu = {} & - S\lambda_4\lambda_1\lambda_2 S\mu_3\mu_4\mu_5 - S\lambda_4\lambda_2\lambda_3 S\mu_4\mu_5\mu_1 - S\lambda_4\lambda_5\lambda_1 S\mu_2\mu_3\mu_4 \\ & + S\lambda_4\lambda_1\lambda_3 S\mu_5\mu_2\mu_4 + S\lambda_4\lambda_3\lambda_5 S\mu_2\mu_4\mu_1 + S\lambda_4\lambda_5\lambda_2 S\mu_4\mu_1\mu_3 \end{aligned}$$

whence

$$S\lambda\mu_4 + S\lambda_4\mu = 0.$$

We have thus obtained the complete quaternion solution of the fundamental problem of finding the vector co-ordinates of a screw reciprocal to five given screws.

Let $\omega_1, \omega_2, \omega_3, \omega_4, \omega_5$ be five vectors parallel to the axes of the cylindroids obtained by leaving out in succession each of the five screws and then forming the cylindroid reciprocal to the remaining four—

$$\left.\begin{aligned}
\omega_1 &= \mu_2 S\lambda_3\lambda_4\lambda_5 - \mu_3 S\lambda_4\lambda_5\lambda_2 + \mu_4 S\lambda_5\lambda_2\lambda_3 - \mu_5 S\lambda_2\lambda_3\lambda_4 \\
\omega_2 &= \mu_3 S\lambda_4\lambda_5\lambda_1 - \mu_4 S\lambda_5\lambda_1\lambda_3 + \mu_5 S\lambda_1\lambda_3\lambda_4 - \mu_1 S\lambda_3\lambda_4\lambda_5 \\
\omega_3 &= \mu_4 S\lambda_5\lambda_1\lambda_2 - \mu_5 S\lambda_1\lambda_2\lambda_4 + \mu_1 S\lambda_2\lambda_4\lambda_5 - \mu_2 S\lambda_4\lambda_5\lambda_1 \\
\omega_4 &= \mu_5 S\lambda_1\lambda_2\lambda_3 - \mu_1 S\lambda_2\lambda_3\lambda_5 + \mu_2 S\lambda_3\lambda_5\lambda_1 - \mu_3 S\lambda_5\lambda_1\lambda_2 \\
\omega_5 &= \mu_1 S\lambda_2\lambda_3\lambda_4 - \mu_2 S\lambda_3\lambda_4\lambda_1 + \mu_3 S\lambda_4\lambda_1\lambda_2 - \mu_4 S\lambda_1\lambda_2\lambda_3
\end{aligned}\right\} \text{(ix.)}$$

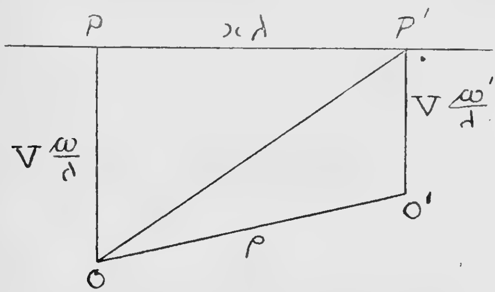
Substituting these quantities in the values for λ in (vii.), we obtain—

$$2\lambda = V(\mu_1\omega_1 + \mu_2\omega_2 + \mu_3\omega_3 + \mu_4\omega_4 + \mu_5\omega_5) \qquad \text{(x.)}$$

If we interchange λ and μ in all the terms of (ix.), and represent by $\eta_1, \ldots \eta_5$ what $\omega_1, \ldots \omega_5$ respectively would then become, we have—

$$2\mu = V(\lambda_1\eta_1 + \lambda_2\eta_2 + \lambda_3\eta_3 + \lambda_4\eta_4 + \lambda_5\eta_5).$$

A useful verification of these formulæ is provided by the following considerations. It has been arranged that with respect to a given origin O, the vector co-ordinates of a certain screw are μ, λ. Suppose that the origin be now transferred to another point O′, so that the vector $OO' = \rho$ we require to find the altered co-ordinates of the screw. It is plain that, as the direction of the screw is independent of the origin, there need be no change in λ. To find the change in μ, we



proceed as follows, Fig. 2:—Let PP′ be the screw and OP and O′P′ the perpendiculars on the screw from O and O′, then we have—

$$OP' = V\frac{\mu}{\lambda} + x\lambda = \rho + V\frac{\mu'}{\lambda};$$

and, as of course the expressions for the pitch of the screw must be the same in both cases,

$$S\frac{\mu}{\lambda} = S\frac{\mu'}{\lambda};$$

adding these two equations, we have—

$$\frac{\mu}{\lambda} + x\lambda = \rho + \frac{\mu'}{\lambda};$$

operating with both sides upon λ and equating the vectors—

$$\mu' = \mu - V\rho\lambda,$$

we thus learn that—

If (μ, λ) be the vector co-ordinates of a screw with respect to a certain origin O, then the vector co-ordinates of the same screw with respect to an origin O′ will be $\{(\mu - V\rho\lambda), \lambda\}$ where ρ is the vector OO′.

It is obvious that a change in the origin can make no difference in the direction of a screw reciprocal to five given screws; and consequently the expression (vii.) must remain unaltered if for μ_1, μ_2, &c., there be substituted $(\mu_1 - V\rho\lambda_1)$, $(\mu_2 - V\rho\lambda_2)$, &c, and this must be true whatever ρ may be. The verification is made by first noting that this change does not affect ω_1, ω_2, &c., ω_5, as was indeed to be expected, because these are the vectors of the axes of the reciprocal cylindroids. It is therefore only necessary to make the changes in μ_1 . . μ_5, &c., in (x.) leaving ω_1 . . ω_5 unaltered, and it is easy to verify by well-known quaternion formulæ that ρ disappears when the terms are summed.

As a further verification of the expressions of λ and μ we shall take the case of six canonical coreciprocal screws* lying two by two on three intersecting rectangular axes. If the axes be i, j, k, and the pitches be $\pm a$, $\pm b$, $\pm c$ respectively, we shall take the origin at the intersection and thus have $\lambda_1 = i$, $\mu_1 = ai$; $\lambda_2 = i$, $\mu_2 = -ai$; $\lambda_3 = j$, $\mu_3 = bj$: $\lambda_4 = j$, $\mu_4 = -bj$; $\lambda_5 = k$, $\mu_5 = ck$.

In each case $V\lambda_1/\mu_1 = o$; thus showing that all the screws pass through the origin; and for the pitch we have $S\lambda_1/\mu_1 = a$.

Substituting these values in the expressions (vii.) and (viii.), we obtain—

$$\lambda = 4\,abk \quad \mu = -\,4\,abck;$$

thus $V\lambda/\mu = o$ and $S\,\mu/\lambda = -c$; showing that the reciprocal screw is, as it ought to be, the sixth screw of the set of canonical coreciprocals.

A 4-system of the most general type may be defined by the four screws—

$$-ai,\ i\ ;\quad -bj,\ j\ ;\quad ck,\ k\ ;\quad -ck,\ k\ ;$$

and the general screw of the system will be represented by—

$$\mu^1 = axi + byj + zk$$
$$\lambda^1 = -xi - yj + z^1k\ ;$$

when x, y, z, z^1 are any scalars. This is verified by observing that μ, λ is reciprocal to both the screws ai, i and bj, j, as are also the four original screws.

If we substitute in formulæ (vii.) and (viii.) as follows:—

$$\begin{cases}\mu_1 = -ai, \\ \lambda_1 = i\end{cases} \begin{cases}\mu_2 = -bj \\ \lambda_2 = j\end{cases} \begin{cases}\mu_3 = ck \\ \lambda_3 = k\end{cases} \begin{cases}\mu_4 = -ck \\ \lambda_4 = k\end{cases} \begin{cases}\mu_5 = axi + byj + zk \\ \lambda_5 = -xi - yj + z'k,\end{cases}$$

it is easy to verify that all the terms in μ and all the terms in λ vanish identically. Thus we obtain the following theorem:—

If the five screws $(\mu_1 \lambda_1)$ . . . (μ_5, λ_5) belong to a 4-system (or a portion to any system of lower order), then the expressions for λ and μ given in formulæ (vii.) and (viii.) vanish identically.

* See Sir Robert Ball's Treatise on the Theory of Screws, Cambridge, 1900, p. 38.

2.—VARIABLE STARS OF LONG PERIOD.

By PROFESSOR E. C. PICKERING, Astronomical Observatory, Harvard University, U.S.A.

The astronomers of Australia have one great advantage over those in Europe and the United States. Few observations have been made in a large part of the sky within their reach, the region south of declination—30 deg. This is particularly the case with one of the most interesting and fruitful fields of work in astronomy, the study of the variable stars. The method described below has been used very extensively for the northern stars at the observatory of Harvard College. It has the great advantage that no instrument is required but a telescope, and little skill beyond that needed to identify with certainty a faint star. Without the latter ability, much useful work on the stars cannot be done. For the northern stars, the atlas of the Bonn Durchmusterung is almost indispensable. A similar atlas for the southern stars, including those of the ninth magnitude, and brighter, is still one of the greatest needs of astronomy.

The variable stars of long period are objects of special interest. At maximum, they are many times as bright as at minimum. Their changes are irregular, or at least unknown. It is, therefore, important that they should be observed at frequent intervals to enable astronomers, in the future, to determine the laws regulating their changes. The method adopted at the Harvard Observatory for observing these stars is as follows:—A list was first prepared of all the variables brighter than the ninth magnitude at maximum, and undergoing changes of more than three magnitudes. A sequence of comparison stars was next selected, each being about a third of a magnitude fainter than the next, the brightest being brighter than the variable at maximum, and the faintest being fainter than the variable at minimum. The magnitude of these stars is then determined photometrically, with great care. A photograph of the region, taken with the 24-in. Bruce telescope, and having an exposure of an hour, is then enlarged three times on an 8 by 10 plate. Prints from these enlargements gives maps of regions a degree square, on a scale of 20 seconds to a millimetre. The magnitudes of the stars are entered on these charts, omitting the decimal point, so that it shall not be mistaken for the image of a star. Thus, magnitude 11·2 is written 112. To observe the variable, it is only necessary to identify the region seen in the telescope with that of the chart. Thus, if the variable is fainter than a star marked 95, and brighter by an equal amount than a star marked 99, its magnitude will be 9·7. If more nearly equal to the first star, it will be 9·6, &c. Copies of several of these charts are enclosed, and may be kept by any astronomer here present who is ready to undertake the observations. The results may be plotted directly, using days for abscissas and magnitudes for ordinates. The observer should not know in advance the probable magnitude of the star, as his observations will have very little value unless they are independent. About 300 variables north of declination 30 deg. south are now being followed in this way at Harvard.

About 100 southern variables remain, which can be observed only occasionally at the Peruvian Station of this observatory. Organised and systematic observations of these stars by the astronomers of Australia would supply a great want, and furnish a valuable contribution to stellar astronomy.

3.—NOTE ON A GEOMETRICAL ILLUSTRATION OF THE CONVERGENCE OF THE GEOMETRICAL SERIES.

By PROFESSOR H. S. CARSLAW, Sc.D., University of Sydney, N.S.W.

4.—ON CERTAIN SURFACE AND VOLUME INTEGRALS OF AN ELLIPSOID.—PART II.

By EVELYN G. HOGG, M.A., Christ's College, Christchurch, N.Z.

The following paper is a continuation of one read by me before the A.A.A.S. at its Melbourne meeting (1900).* This earlier paper will be referred to as Part I., and for the sake of convenience the integrals in the present paper will be numbered so as to follow on consecutively with those given in Part I.

I have proved elsewhere† the following theorem connecting surface and volume integrals of any closed surface, viz.:—

$$\iiint \lesseqgtr F(r)\, d V$$

$$= \iint \lesseqgtr \frac{lx + my + nz}{r^{2k+3}} \left[\int r^{2k+2} F(r)\, dr \right] d S, \text{ ...... } (1)$$

where $\lesseqgtr$ is a homogeneous function of degree $2k$ in x, y, and z; l, m, n are the direction-cosines of the outward drawn normal to S at the point x, y, z: $r^2 = x^2 + y^2 + z^2$. The triple integral is taken through the volume enclosed by S and the double integral over the surface S, and $\lesseqgtr$ and $F(r)$ are subject to the condition that they do not become infinite at any point on or within the surface S.

Let the equation of the ellipsoid be—

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1,$$

then $lx + my + nz$ is the length of the central perpendicular on the tangent plane to the ellipsoid at $(x\ y\ z)$, and (*i*) may be written—

$$\iint \frac{p \lesseqgtr}{r^{2k+3}} \left[\int r^{2k+2} F(r)\, dr \right] d S = \iiint \lesseqgtr F(r)\, d V \text{ ...... } (22)$$

Let $F(r) = r^{2n}$ and $\lesseqgtr = \left(\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} \right)^k$

then $\int r^{2k+2} F(r)\, dr = \frac{r^{2k+2n+3}}{2k+2n+3}$ and $\lesseqgtr$ is unity at all points on the surface of the ellipsoid.

---

* Proc. A.A.A.S. (Melbourne), 1900, p. 191.

† "On a form of Green's Theorem," Proc. A.A.A.S. (Adelaide), 1907, p. 312.

Hence—

$$\iint pr^{2n}\,dS = (2k+2n+3)\iiint (x^2+y^2+z^2)^n \left(\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}\right)^k dV \quad\text{......(23)}$$

Putting k zero in the above equation,

$$\iint pr^{2n}\,dS = (2n+3)\iiint (x^2+y^2+z^2)^n\,dV \quad\text{......(24)}$$

Putting n zero in (23),

$$\iiint \left(\frac{x^2}{a^3}+\frac{y^2}{b^2}+\frac{z^2}{c^2}\right)^k dV = \frac{3}{2k+3}V \quad\text{...... (25)}$$

where V is the volume of the ellipsoid.

Let $\lessgtr = \left(\frac{x^2}{a^4}+\frac{y^2}{b^4}+\frac{z^2}{c^4}\right)^k$, while $F(r) = r^{2n}$.

Then $\lessgtr = \frac{1}{p^{2k}}$ for all points on the surface, and hence—

$$\iint \frac{r^{2n}\,dS}{p^{2k-1}} = (2k+2n+3)\iiint (x^2+y^2+z^2)^n \left(\frac{x^2}{a^4}+\frac{y^2}{b^4}+\frac{z^2}{c^4}\right)^k dV \quad\text{......(26)}$$

Putting n zero in (26),

$$\iint \frac{dS}{p^{2k-1}} = (2k+3)\iiint \left(\frac{x^2}{a^4}+\frac{y^2}{b^4}+\frac{z^2}{c^4}\right)^k dV. \quad\text{......(27)}$$

From integral (16) we have—

$$\iint pr^4\,dS = \left[\left\{\lessgtr (a^2)\right\}^2 + 2\lessgtr (a^4)\right]\frac{V}{5};$$

hence making $n=2$ in (24) we have—

$$\iiint (x^2+y^2+z^2)^2\,dV = \left[\left\{\lessgtr (a^2)\right\}^2 + 2\lessgtr (a^4)\right]\frac{V}{35} \;\cdots\; (28)$$

If in the fundamental equation of Part I.—viz.,

$$\iint (lu+mv+nw)\,dS = \iiint \left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right) dV \quad\text{...... } (A)$$

we make $u = \frac{a^2x}{p^4}$, $v = \frac{b^2y}{p^4}$, $w = \frac{c^2z}{p^4}$,

we obtain—

$$\iint \frac{r^2\,dS}{p^3} = \lessgtr (a^2) \iiint \left(\frac{x^2}{a^4}+\frac{y^2}{b^4}+\frac{z^2}{c^4}\right)^2 dV$$

$$+\,4\iiint \left(\frac{x^2}{a^4}+\frac{y^2}{b^4}+\frac{z^2}{c^4}\right)\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}\right) dV \quad\text{...... (29)}$$

Using integrals (7) and (11), it follows that—

$$\iint \frac{r^2\,dS}{p^3} = \lessgtr (a^2)\left[\left\{\lessgtr\left(\frac{1}{a^2}\right)\right\}^2 + 2\lessgtr\left(\frac{1}{a^4}\right)\right]\frac{V}{35} + \lessgtr\left(\frac{1}{a^2}\right)\frac{4V}{7} \quad\text{...... (30)}$$

Hence making $n = 1$, $k = 2$ in integral (23) we have—

$$\iiint (x^2 + y^2 + z^2)\left(\frac{x^2}{a^4} + \frac{y^2}{b^4} + \frac{z^2}{c^4}\right)^2 d\,V$$

$$= \Sigma (a^2) \left[\left\{ \Sigma \left(\frac{1}{a^2}\right) \right\}^2 + 2 \Sigma \left(\frac{1}{a^4}\right)\right] \frac{V}{315} + \Sigma\left(\frac{1}{a^2}\right) \frac{4\,V}{63} \quad \ldots\ (31)$$

If in equation (A) above, we put—

$$u = \frac{xr^{2n}}{a^2},\ v = \frac{yr^{2n}}{b^2},\ w = \frac{zr^{2n}}{c^2},\ \text{then—}$$

$$\iint \frac{r^{2n}\, d\,S}{p} = \Sigma\left(\frac{1}{a^2}\right) \iiint (x^2 + y^2 + z^2)^n\, d\,V$$

$$+ 2n \iiint (x^2 + y^2 + z^2)^{n-1} \left(\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2}\right)^d V \quad \ldots\ (32)$$

or, when $n = 2$,

$$\iint \frac{r^4\, aS}{p} = \Sigma \left(\frac{1}{a^2}\right) \iiint (x^2 + y^2 + z^2)^2\, d\,V$$

$$+ 4 \iint x^2 + y^2 + z^2) \left(\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2}\right) d\,V. \quad \ldots (33)$$

Using integrals 3 and 28, we obtain—

$$\iint \frac{r^4 dS}{p} = \Sigma \left(\frac{1}{a^2}\right) \left[\left\{ \Sigma\,(a^2) \right\}^2 + 2\,\Sigma\,(a^4)\right] \frac{V}{35}$$

$$+ \Sigma\,(a^2)\, \frac{4\,V}{7}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (34)$$

Hence making $n = 2$, $k = 1$ in (26), we obtain—

$$\iiint (x^2 + y^2 + z^2)^2 \left(\frac{x^2}{a^4} + \frac{y^2}{b^4} + \frac{z^2}{c^4}\right) d\,V$$

$$= \Sigma \left(\frac{1}{a^2}\right) \left[\left\{ \Sigma\,(a^2) \right\}^2 + \Sigma\,(a^4) \right] \frac{V}{315} + \Sigma\,(a^2)\, \frac{4\,V}{63}. \quad \ldots (35)$$

If in equation (A) we make—

$$u = a^4 x,\ v = b^4 y,\ w = c^4 z,$$

the —

$$\iint p\ (a^2x^2 + b^2y^2 + c^2z^2)\, d\,S = \Sigma\ (a^4)\ V. \quad \ldots\ldots\ldots (36)$$

From integral (1) $\iint pr^2\ d\,S = \Sigma\ (a^2)\ V$, we also have—

$$\iint pd\,S = \iint p \left(\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2}\right) d\,S = 3\,V.$$

Hence we have the series of equations—

$$a^2\iint px^2 dS + b^2\iint py^2 dS + c^2\iint pz^2 dS = \Sigma(a^4)\,V,$$

$$\iint px^2 dS + \iint py^2 dS + e\iint pz^2 dS = \Sigma(a^2)\,V,$$

$$\frac{1}{a^2}\iint px^2 dS + \frac{1}{b^2}\iint py^2 dS + \frac{1}{c^2}\iint pz^2 dS = 3V,$$

from which we obtain the following:—

$$\iint px^2 dS = a^2V,\ \iint py^2 dS = b^2V,\ \iint pz^2 dS = c^2V. \quad\ldots\ldots(37)$$

Similarly by solving for $\iint\frac{x^2dS}{p}$, $\iint\frac{y^2dS}{p}$, $\iint\frac{z^2dS}{p}$, from the equations—

$$\iint\frac{dS}{p} = \iint\frac{1}{p}\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}\right)dS = \Sigma\left(\frac{1}{a^2}\right)V,$$

$$\iint\frac{r^2dS}{p} = \iint\frac{x^2+y^2+z^2}{p}\,dS = \left[\Sigma(a^2)\,\Sigma\left(\frac{1}{a^2}\right)+6\right]\frac{V}{5}$$

$$\iint\frac{dS}{p^3} = \iint\frac{1}{p}\left(\frac{x^2}{a^4}+\frac{y^2}{b^4}+\frac{z^2}{c^4}\right)dS = \left[\left\{\Sigma\left(\frac{1}{a^2}\right)\right\}^2+2\,\Sigma\left(\frac{1}{a^4}\right)\right]\frac{V}{5},$$

we find—

$$\left.\begin{aligned}\iint\frac{x^2dS}{p} &= a^2\left(\frac{3}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}\right)\frac{V}{5}\\ \iint\frac{y^2dS}{p} &= b^2\left(\frac{1}{a^2}+\frac{3}{b^2}+\frac{1}{c^2}\right)\frac{V}{5}\\ \iint\frac{z^2dS}{p} &= c^2\left(\frac{1}{a^2}+\frac{1}{b^2}+\frac{3}{c^2}\right)\frac{V}{5}.\end{aligned}\right\}\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots(38)$$

5.—ON THE SYMMEDIAN POINT OF A TRIANGLE.

By EVELYN G. HOGG, M.A., Christ's College, Christchurch, N.Z.

1. The axis of homology of any point P $(\alpha'\beta'\gamma')$ with respect to the triangle of reference ABC has for equation—

$$\frac{\alpha}{\alpha'}+\frac{\beta}{\beta'}+\frac{\gamma}{\gamma'}=0.$$

If this line pass through the fixed point $(\alpha_0\beta_0\gamma_0)$, the locus of P is the conic

$$\frac{\alpha_0}{\alpha}+\frac{\beta_0}{\beta}+\frac{\gamma_0}{\gamma}=0.$$

In particular the circle ABC is the locus of points whose axes of homology with respect to the triangle ABC pass through the symmedian point S (abc) of that triangle.

If now three lines be taken, viz. :—

$$L' = l_1\alpha + m_1\beta + n_1\gamma = 0$$
$$L'' = l_2\alpha + m_2\beta + n_2\gamma = 0$$
$$L''' = l_3\alpha + m_3\beta + n_3\gamma = 0,$$

then the conic

$$\frac{L_0'}{L'} + \frac{L_0''}{L''} + \frac{L_0'''}{L'''} = 0, \quad \cdots\cdots\cdots\cdots\; C_1$$

where

$$L_0' = l_1\alpha_0 + m_1\beta_0 + n_1\gamma_0$$
$$L_0'' = l_2\alpha_0 + m_2\beta_0 + n_2\gamma_0$$
$$L_0''' = l_3\alpha_0 + m_3\beta_0 + n_3\gamma_0,$$

is the locus of points whose axes of homology with respect to the triangle formed by $L'L''L'''$ pass through the point $\alpha_0\beta_0\gamma_0$.

If we express that the conic C_1 is a circle, we obtain linear equations to determine the co-ordinates of the symmedian point of the triangle $L'L''L'''$.

If the equation of the circle circumscribing the triangle $L'L''L'''$ be known, the ratio $\alpha_0 : \beta_0 : \gamma_0$ may be at once found by comparing similar coefficients in the given equation and the equation C_1.

2. The equation of the circle passing through the three ex-centres I_1, I_2, I_3 of the triangle of reference is—

$$(\alpha+\beta+\gamma)(a\alpha+b\beta+c\gamma)+a\beta\gamma+b\gamma\alpha+c\alpha\beta=0.$$

If this circle be written—

$$\frac{\beta_0+\gamma_0}{\beta+\gamma} + \frac{\gamma_0+\alpha_0}{\gamma+\alpha} + \frac{\alpha_0+\beta_0}{\alpha+\beta} = 0,$$

where $\alpha_0\beta_0\gamma_0$ are the co-ordinates of the symmedian point of the triangle $I_1I_2I_3$, we have, on comparing coefficients—

$$\beta_0+\gamma_0=\kappa a,\ \gamma_0+\alpha_0=\kappa b,\ \alpha_0+\beta_0=\kappa c,$$

whence

$$\alpha_0:\beta_0:\gamma_0=b+c-a : c+a-b : a+b-c$$
$$= \cot\frac{A}{2} : \cot\frac{B}{2} : \cot\frac{C}{2}.$$

In a similar manner it may be shown that the trilinear ratios of the symmedian points of the triangles II_2I_3 ; II_3I_1 : II_1I_2 are, respectively, $s : s-c : s-b$; $s-c : s : s-a$; $s-b : s-a : s$, or $\cot\frac{A}{2} : \tan\frac{B}{2} : \tan\frac{C}{2}$; $\tan\frac{A}{2} : \cot\frac{B}{2} : \tan\frac{C}{2}$; $\tan\frac{A}{2} : \tan\frac{B}{2} : \cot\frac{C}{2}$.

The four points thus found, together with their isogonal conjugates with respect to the triangle ABC, lie on the cubic—

$$\frac{\alpha}{a}(\beta^2-\gamma^2) + \frac{\beta}{b}(\gamma^2-\alpha^2) + \frac{\gamma}{c}(\alpha^2-\beta^2) = 0.$$

3. If any point O be taken and the lines AO, BO, CO meet BC, CA, AB in D, E, F, respectively, then the equations of the lines EF, FD, DE are of the form

$$-l\alpha + m\beta + n\gamma = 0$$
$$l\alpha - m\beta + n\gamma = 0$$
$$l\alpha + m\beta - n\gamma = 0.$$

The equation of a conic circumscribing the triangle formed by these lines will be

$$\frac{\lambda}{-l\alpha + m\beta + n\gamma} + \frac{\mu}{l\alpha - m\beta + n\gamma} + \frac{\nu}{l\alpha + m\beta - n\gamma} = 0,$$

and this will be a circle if

$$\lambda : \mu : \nu = \frac{l}{a}\left(\frac{m}{b} + \frac{n}{c}\right)\theta_1 : \frac{m}{b}\left(\frac{n}{c} + \frac{l}{a}\right)\theta_2 : \frac{n}{c}\left(\frac{l}{a} + \frac{m}{b}\right)\theta_3$$

where

$$\theta_1 = l^2 + m^2 + n^2 - 2mn\cos A + 2nl\cos B + 2lm\cos C$$
$$\theta_2 = l^2 + m^2 + n^2 + 2mn\cos A - 2nl\cos B + 2lm\cos C$$
$$\theta_3 = l^2 + m^2 + n^2 + 2mn\cos A + 2nl\cos B - 2lm\cos C.$$

The co-ordinates of the symmedian point $(\alpha\,\beta\,\gamma)$ are given by

$$-l\alpha + m\beta + n\gamma = k\lambda$$
$$l\alpha - m\beta + n\gamma = k\mu$$
$$l\alpha + m\beta - n\gamma = k\nu,$$

that is to say,

$$\alpha : \beta : \gamma = \frac{\mu + \nu}{l} : \frac{\nu + \lambda}{m} : \frac{\nu + \mu}{n}.$$

If $l : m : n = \cos A : \cos B : \cos C$,
then $\theta_1 = \theta_2 = \theta_3 = 1$, and
$\lambda : \mu : \nu = a\cos A : b\cos B : c\cos C$:
hence the co-ordinates of S′, the symmedian point of the pedal triangle of the triangle of reference, are tan A cos (B − C) : tan B cos (C − A) : tan C cos (A − B).

The equation of the line joining S′ to S $(a\ b\ c)$ is $\cos^2 A \sin (B - C)\,\alpha + \cos^2 B \sin (C - A)\,\beta + \cos^2 C \sin (A - B)\,\gamma = 0$.

This equation is satisfied by (sec A, sec B, sec C) : hence we derive the theorem—

"The symmedian point of a triangle, its orthocentre, and the symmedian point of its pedal triangle are collinear."

If $l : m : n = a : b : c$
then $\theta_1 : \theta_2 : \theta_3 = a^2 : b^2 : c^2$
$= \lambda : \mu : \nu$,

hence the co-ordinates of S″, the symmedian point of the medial triangle of the triangle ABC, *i.e.*, the triangle formed by joining the middle points of the sides of that triangle, are—

$$\frac{b^2 + c^2}{a} : \frac{c^2 + a^2}{b} : \frac{a^2 + b^2}{c}$$

The equation of the line joining SS″ is—

$$a(b^2 - c^2)\alpha + b(c^2 - a^2)\beta + c(a^2 - b^2)\gamma = 0;$$

this being satisfied by $\left(\frac{1}{a}, \frac{1}{b}, \frac{1}{c}\right)$, we derive the theorem—

"The symmedian point and centroid of a triangle are collinear with the symmedian point of its medial triangle."

The equations of the nine-point circle of the triangle ABC corresponding to these two cases may be written—

$$\frac{a\cos A}{-\alpha\cos A + \beta\cos B + \gamma\cos C} + \frac{b\cos B}{\alpha\cos A - \beta\cos B + \gamma\cos C}$$
$$+ \frac{c\cos C}{\alpha\cos A + \beta\cos B - \gamma\cos C} = 0,$$

$$\frac{a^2}{-a\alpha + b\beta + c\gamma} + \frac{b^2}{a\alpha - b\beta + c\gamma} + \frac{c^2}{a\alpha + b\beta - c\gamma} = 0.$$

4. If three points $(\lambda a, \mu b, \nu c)$, $(\mu a, \nu b, \lambda c)$, $(\nu a, \lambda b, \mu c)$, where $\lambda + \mu + \nu = 0$, be taken on the line—

$$\frac{\alpha}{a} + \frac{\beta}{b} + \frac{\gamma}{c} = 0,$$

the axes of homology of these points form a triangle $A_1B_1C_1$ inscribed in the circle ABC and circumscribed to Brocard's ellipse,

$$\sqrt{\frac{\alpha}{a}} + \sqrt{\frac{\beta}{b}} + \sqrt{\frac{\gamma}{c}} = 0.$$

The axes of homology of the triangle ABC will intersect at the symmedian point of the triangle $A_1B_1C_1$.

Solving for the point of intersection of the axes of B and C, we obtain—

$$\frac{\alpha}{a} : \frac{\beta}{b} : \frac{\gamma}{c} = 9\lambda^2\mu^2\nu^2 - \theta_1\theta_2 : \theta_2^2 - 3\lambda\mu\nu\theta_1 : \theta_1^2 - 3\lambda\mu\nu\theta_2,$$

where
$$\theta_1 = \lambda\mu^2 + \mu\nu^2 + \nu\lambda^2$$
$$\theta_2 = \lambda^2\mu + \mu^2\nu + \nu^2\lambda.$$

Hence, observing that $\lambda^2 - \mu\nu = \mu^2 - \nu\lambda = \nu^2 - \lambda\mu = \theta$,

we find $$\frac{\alpha}{a} = \frac{\beta}{b} = \frac{\gamma}{c} = \theta.$$

Hence the theorem—

"All triangles inscribed in the circle ABC and circumscribed to the Brocard ellipse of the triangle ABC have a common symmedian point."

5. The envelope of the axes of homology with respect to the triangle $\angle'\angle''\angle'''$ (section i.) of points lying on the axis of homology of the point $(\alpha_0\beta_0\gamma_0)$ with respect to that triangle is the conic

$$\sqrt{\frac{\angle'}{\angle_0'}} + \sqrt{\frac{\angle''}{\angle_0''}} + \sqrt{\frac{\angle'''}{\angle_0'''}} = 0 \ldots\ldots\ldots\ldots\ldots C_2$$

Hence since the Brocard ellipse of any triangle is the envelope of the axes of homology with respect to that triangle of points lying on the axis of homology of the symmedian point of the triangle, the Brocard ellipse of a triangle may be at once found from the conic C_2 when the co-ordinates of the symmedian point are known. Thus the Brocard ellipses of the pedal and medial triangles of the triangle of reference are respectively—

$$\sqrt{\frac{-\alpha\cos A+\beta\cos B+\gamma\cos C}{\sin 2A}}+\sqrt{\frac{\alpha\cos A-\beta\cos B+\gamma\cos C}{\sin 2B}}$$
$$+\sqrt{\frac{\alpha\cos A+\beta\cos B-\gamma\cos C}{\sin 2C}}=0.$$

$$\frac{1}{a}\sqrt{-a\alpha+b\beta+c\gamma}+\frac{1}{b}\sqrt{a\alpha-b\beta+c\gamma}+\frac{1}{c}\sqrt{a\alpha+b\beta-c\gamma}=0.$$

The Brocard ellipse of the triangle $I_1I_2I_3$ is—

$$\sqrt{\frac{\beta+\gamma}{a}}+\sqrt{\frac{\gamma+\alpha}{b}}+\sqrt{\frac{\alpha+\beta}{c}}=0.$$

6. "If any two mutually perpendicular lines be drawn through the symmedian point of a triangle ABC, then the line joining the two points on the circle ABC, of which these lines are the axes, passes through a fixed point collinear with the centroid and orthocentre of the triangle ABC."

Let any two points, P' $(\alpha'\beta'\gamma')$ and P'' $(\alpha''\beta''\gamma'')$, be taken on the circle ABC. The axes of P' and P'' are—

$$\frac{\alpha}{\alpha'}+\frac{\beta}{\beta'}+\frac{\gamma}{\gamma'}=0$$

$$\frac{\alpha}{\alpha''}+\frac{\beta}{\beta''}+\frac{\gamma}{\gamma''}=0,$$

and these lines are at right angles to each other if—

$$\frac{1}{\alpha'\alpha''}+\frac{1}{\beta'\beta''}+\frac{1}{\gamma'\gamma''}-\cos A\left(\frac{1}{\beta'\gamma''}+\frac{1}{\beta''\gamma'}\right)$$
$$-\cos B\left(\frac{1}{\gamma'\alpha''}+\frac{1}{\gamma''\alpha'}\right)-\cos C\left(\frac{1}{\alpha'\beta'}+\frac{1}{\alpha''\beta'}\right)=0.$$

It may be easily shown that—

$$bc\left(\frac{1}{\beta'\gamma''}+\frac{1}{\beta''\gamma'}\right)=\frac{a^2}{\alpha'\alpha''}-\frac{b^2}{\beta'\beta''}-\frac{c^2}{\gamma'\gamma''}$$

with similar relations for the coefficients of cos B and cos C.

On substituting in the above condition of perpendicularity we obtain—

$$\frac{1}{\alpha'\alpha''}\left\{1+2\sin^2 A\cot B\cot C\right\}+\frac{1}{\beta'\beta''}\left\{1+2\sin^2 B\cot C\cot A\right\}$$
$$+\frac{1}{\gamma'\gamma''}\left\{1+2\sin^2 C\cot A\cot B\right\}=0,$$

E

showing that the chord P′P″ passes through the fixed point—

$$\left\{\frac{1+2\sin^2 A\cot B\cot C}{\sin A},\ \frac{1+2\sin^2 B\cot C\cot A}{\sin B},\ \frac{1+2\sin^2 C\cot A\cot B}{\sin C}\right\}$$

and it may be easily verified that this point lies on the line joining the centroid and orthocentre of the triangle ABC.

7. If the axis of homology of any point P with respect to the triangle ABC be parallel to that of its isogonal conjugate P′, then the line PP′ always passes through the symmedian point of the triangle ABC.

The locus of P is the cubic curve—

$$a\alpha(\beta^2-\gamma^2)+b\beta(\gamma^2-\alpha^2)+c\gamma(\alpha^2-\beta^2)=0:$$

the equation of PP′ is—

$$\alpha\alpha'(\beta'^2-\gamma'^2)+\beta\beta'(\gamma'^2-\alpha'^2)+\gamma\gamma'(\alpha'^2-\beta'^2)=0,$$

whence the above result at once follows.

This cubic curve passes through the vertices of the triangle ABC, the symmedian point, the centroid, the in- and ex- centres and the points in which the lines joining the vertices to the symmedian point meet the sides of the triangle. The tangents to the curve at the in- and ex- centres meet at the symmedian point.

8. If the extremities of the diameters of the circle ABC perpendicular to the sides BC, CA, AB are D_1, D_2 : E_1, E_2 : F_1, F_2, then—

the axes of D_1 and D_2, SB and SC,
the axes of E_1 and E_2, SC and SA,
the axes of F_1 and F_2, SA and SB,

form harmonic pencils.

The locus of the centres of conics which are the isogonal transformations of lines passing through the symmedian point of the triangle of reference is—

$$\sqrt{a\alpha}+\sqrt{b\beta}+\sqrt{c\gamma}=0.$$

6.—THEORY OF THE ALTERNATE CURRENT GENERATOR.

By THOMAS R. LYLE, M.A., Sc.D., Professor of Natural Philosophy in the University of Melbourne.

It has been usual hitherto to ascribe the distortion of the wave form of the current given by an alternate current generator to :—

1. "Lack of uniformity and pulsation of the magnetic field, causing a distortion of the induced e.m.f. at open circuit as well as under load."
2. "Pulsation of the reactance causing higher harmonics under load."
3. "Pulsation of the resistance causing higher harmonics under load also."*

and, as far as I have been able to find out, another cause has been overlooked—namely, the mutual reactions between armature and field, which when the generator is loaded is at least as important as any of the foregoing.

* Steinmetz. Alternating Current Phenomena.

If such is the case it can only be explained by the fact that the theory of the simple alternator has not hitherto been completely worked out.

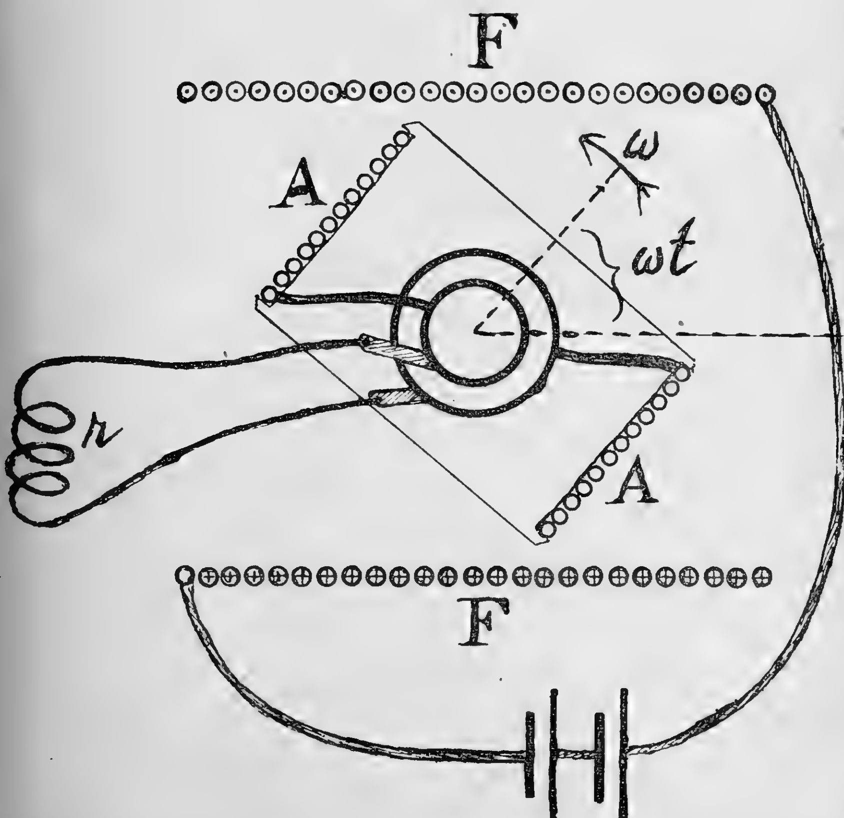
In the following paper this is done for an alternator with a uniform field, by means of a new application of the vector method in which all the harmonics of a periodic function are dealt with simultaneously.

In the same is shown how to take account of hysteresis and eddy currents, and the theory of the action of dampers in reducing the heating in the field is also given.

The theory of the alternate current synchronous motor is also dealt with.

1. Let two coils be arranged as indicated in Fig. I., one of them F, called the field coil, being fixed and having a battery of constant *e.m.f.* $= \eta$ in its circuit, the other A, called the armature coil, fitted in the usual way with slip rings for connection to an external circuit, and being rotated by power at a constant angular velocity ω round a fixed axis which is perpendicular to its own axis of figure and to the direction of the lines of force of F and which passes through its own centre. It is required to determine completely the currents that flow in both A and F.

FIG. I.



Let x and ξ be the currents at any instant in A and F respectively, and let the mutual inductance of A and F, when their axes are coincident, be m, and hence $m \cos \omega t$ at the time t. Also let r and l be the total resistance and self inductance of the A circuit, and ρ, λ, similar quantities for the F circuit.

Then when the armature is being driven at constant angular velocity ω, and x and ξ are flowing, the total number of lines linked on A is—

$$lx + m\xi \cos \omega t,$$

and the number linked on F is—

$$\lambda \xi + mx \cos \omega t.$$

Hence—

$$\left.\begin{aligned} rx + \frac{d}{dt}\left\{ lx + m\xi \cos \omega t \right\} &= 0 \\ \rho\xi + \frac{d}{dt}\left\{ \lambda\xi + mx \cos \omega t \right\} &= \eta \end{aligned}\right\} \qquad \text{(I.)}$$

where η is the applied steady *e.m.f.* in the F circuit.

2. If we assume as the solution of these equations—

$x = x_0/2 + x_1 \sin(\omega t + c_1) + x_2 \sin(2\,\omega t + c_2) + x_3 \sin(3\,\omega t + c_3) + \&c.$

$\xi = \xi_0/2 + \xi_1 \sin(\omega t + \gamma_1) + \xi_2 \sin(2\,\omega t + \gamma_2) + \xi_3 \sin(3\,\omega t + \gamma_3) + \&c.$

we can see at once on substitution that $\rho\xi_0 = 2\eta$, and that $x_0 = 0$, and it will be shown afterwards (section 15) that when $x_0 = 0$, then $\xi_1, x_2, \xi_3, x_4, \xi_5$, &c., vanish; or, in words, when $x_0 = 0$ only odd harmonics appear in x and only even ones in ξ. Let us therefore take—

$$\left.\begin{aligned} x &= x_1 \sin(\omega t + c_1) + x_3 \sin(3\,\omega t + c_3) + x_5 \sin(5\,\omega t + c_5) + \&c. \\ \xi &= \xi_0/2 + \xi_2 \sin(2\,\omega t + \gamma_2) + \xi_4 \sin(4\,\omega t + \gamma_4) + \&c. \end{aligned}\right\} \qquad \text{(II.)}$$

Now any harmonic in either x or ξ, for instance $x_q \sin(q\omega t + c_q)$, being completely specified by x_q, c_q, and q, can, when its order q is known, be represented by the vector drawn from the origin in any reference plane to the point in that plane whose polar co-ordinates are x_q, c_q, the constant term $\xi_0/2$ in ξ being represented in the same plane by the vector to the point ξ_0, $\pi/2$.

The form of solution (II.) assumed may now be written—

$$\left.\begin{aligned} x &= \mathrm{a}_1 + \mathrm{a}_3 + \mathrm{a}_5 + \mathrm{a}_7 + \&c. \\ \xi &= \alpha_0/2 + \alpha_2 + \alpha_4 + \alpha_6 + \&c. \end{aligned}\right\} \qquad \text{(III.)}$$

where a_1, a_3, &c., α_0, α_2, &c., are vectors whose orders are indicated by the subscribed numbers. Of these, one only, namely α_0, is known, as it is drawn to the point whose polar co-ordinates are ξ_0, $\pi/2$, where $\xi_0 = {}^2\eta/\rho$. The others have to be determined.

Note *a*.—In the sequel it will sometimes happen that a vector, say a_q, originally assumed of order q will be used to represent a harmonic of a different order, say $q + 1$. In such a case it will be written $(\mathrm{a}_q)_{q+1}$; thus $\mathrm{a}_q = x_q \sin(q\omega t + c_q)$ but $(\mathrm{a}_q)_{q+1} = x_q \sin\{(q+1)\,\omega t + c_q\}$.

Note *b*.—The length of a vector α will be written as $\bar{\alpha}$ (*i.e.*, with the bar), thus $\bar{\mathrm{a}}_3 = x_3$, unless in cases where no ambiguity can arise, when α simply will be written for the length of the vector α.

3. If we agree to indicate by ι^θ the operation of rotating any vector to which it is prefixed through an angle θ in the positive direction, then $\iota^\pi a = -a$ or $\iota^\pi = -1$, and $\iota^\theta a = (\cos\theta + \iota^{\frac{\pi}{2}}\sin\theta)a$ or $\iota^\theta = \cos\theta + \iota^{\frac{\pi}{2}}\sin\theta$.

Also, if $t = \mathrm{D}\iota^f$, ta is the vector obtained by increasing a D times in length and then rotating the increased vector through an angle f in the positive direction. Plane operators such as t are well known to be subject to the same rules as ordinary algebraical symbols. Again, the sum of two operators $a_1\iota^{\theta_1}$, $a_2\,\iota^{\theta_2}$ can be expressed as a single operator $\mathrm{A}\iota^\psi$ say, that is $\mathrm{A}\iota^\psi a = a_1\iota^{\theta_1}a + a_2\,\iota^{\theta_2}a$ where a is any vector. Using the expression for ι^θ given above—

$$\mathrm{A}\,(\cos\psi + \iota^{\frac{\pi}{2}}\sin\psi)\,a = a_1(\cos\theta_1 + \iota^{\frac{\pi}{2}}\sin\theta_1)\,a + a_2(\cos\theta_2 + \iota^{\frac{\pi}{2}}\sin\theta_2)\,a\,,$$

so that—

$$\mathrm{A}\cos\psi = a_1\cos\theta_1 + a_2\cos\theta_2\,;\ \ \mathrm{A}\sin\psi = a_1\sin\theta_1 + a_2\sin\theta_2.$$

Thence—

$$\mathrm{A}^2 = a_1^2 + a_2^2 + 2a_1a_2\cos(\theta_1 - \theta_2),$$

$$\text{and}\ \tan\psi = \frac{a_1\sin\theta_1 + a_2\sin\theta_2}{a_1\cos\theta_1 + a_2\cos\theta_2}.$$

Again, if $a_p = \xi\ \sin(p\omega t + \gamma_p)$, $\frac{d}{dt}(a_p) = p\omega\,\iota^{\frac{\pi}{2}}a_p$,

seeing that $\frac{d}{dt}(a_p) = p\omega\,\xi\ \sin\left(p\omega t + \gamma_p + \frac{\pi}{2}\right)$;

hence for x and ξ as expressed in section 2—

$$\frac{dx}{dt} = \omega\,\iota^{\frac{\pi}{2}}\Sigma q\mathrm{a}_q\,,\ \ \frac{d\xi}{dt} = \omega\,\iota^{\frac{\pi}{2}}\,\Sigma\,p\,a_p\,.$$

4. By means of the formula—

$$2\sin a\cos b = \sin(a + b) + \sin(a - b),$$

it is easy to show that $2x\cos\omega t$, where x is the a series of odd order vectors in section 2, is represented by the series of even order vectors of which the one of the pth order is the vector sum of a_{p-1} and a_{p+1}, or that—

$$2x\cos\omega t = (\mathrm{a}_1)_0 + (\mathrm{a}_1 + \mathrm{a}_3)_2 + (\mathrm{a}_3 + \mathrm{a}_5)_4 + (\mathrm{a}_5 + \mathrm{a}_7)_6 + \&\text{c.},$$

$(\mathrm{a}_1)_0$ being the resolved part of a_1 along the y axis, that is along the direction of vectors of zero order. (See note, section 2.)

Similarly—

$$2\xi\cos\ \omega t = (a_0 + a_2)_1 + (a_2 + a_4)_3 + (a_4 + a_6)_5 + \&\text{c.}$$

Again, by means of the formula—

$$2\sin a\sin b = \cos(a - b) - \cos(a + b),$$

it is easy to show that—

$$2\xi\ \sin\omega t = \iota^{-\frac{\pi}{2}}(a_0 - a_2)_1 + \iota^{-\frac{\pi}{2}}(a_2 + a_4)_3 + \&\text{c.}$$

$$= \iota^{-\frac{\pi}{2}}\Sigma\,(a_{q-1} - a_{q+1})_q\ \text{(where } q \text{ is odd).}$$

with a similar result for the product of x and sin ωt.

5. If we now substitute the vector expressions from sections 2, 3, 4, in equations I., and equate separately to zero each set of vectors terms of the same order, we obtain the two series of vector equations—

$$ra_q + q\omega\,\iota^{\frac{\pi}{2}}\left\{la'_q + \frac{m}{2}\,(a_{q-1} + a_{q+1})\right\} = 0, \qquad \text{(IV.)}$$

where q is any odd number—

$$\rho a_p + p\omega\,\iota^{\frac{\pi}{2}}\left\{\lambda a_p + \frac{m}{2}\,(a_{p-1} + a_{p+1})\right\} = 0, \qquad \text{(V.)}$$

where p is any even number except zero, together with $\xi_o = 2\eta/\rho$.

From IV. we get a series of equations of the type—

$$a_{q-1} + 2\,\frac{q\omega l - r\iota^{\frac{\pi}{2}}}{q\omega m}\,a_q + a_{q+1} = 0,$$

or—

$$a_{q-1} + t_q a_q + a_{q+1} = 0,$$

where t_q is the operator $D_q\iota^{-f_q}$, in which—

$$D_q \cos f_q = 2\frac{l}{m},\ D_q \sin f_q = \frac{2r}{q\omega m},$$

that is—

$$D_q = \frac{4}{m^2}\left(l^2 + \frac{r^2}{q^2\omega^2}\right),\quad \tan f_q = \frac{r}{q\omega l}.$$

Similarly from V. we get the series—

$$a_{p-1} + \tau_p a_p + a_{p+1} = 0,$$

where τ_p is the operator $\Delta_p\iota^{-\phi_p}$, in which—

$$\Delta_p \cos \phi_p = 2\frac{\lambda}{m},\quad \Delta_p \sin \phi_p = \frac{2\rho}{p\omega m}$$

$$\Delta_p^2 = \frac{4}{m^2}\left(\lambda^2 + \frac{\rho^2}{p^2\omega^2}\right),\quad \tan \phi_p = \frac{\rho}{p\omega\lambda}.$$

Note that the vector equations in this paragraph are equations connecting the different vectors, considered purely as vectors, without any reference whatever to the order of harmonic they originally represented.

6. We have thus obtained the following infinite series of equations connecting the vectors used to represent x and ξ:—

$$\begin{aligned}
t_1 a_1 + a_2 &= -a_0 \\
a_1 + \tau_2 a_2 + a_3 &= 0 \\
a_2 + t_3 a_3 + a_4 &= 0 \\
a_3 + \tau_4 a_4 + a_5 &= 0 \\
a_4 + t_5 a_5 + a &= 0 \\
&\&c.,\ \&c.\ ;
\end{aligned} \qquad \text{(VI.)}$$

and, as it is well known that algebraic methods are applicable to plane vector operators of the type here made use of, we obtain the following infinite determinant vector solution for a_1, namely,—

$$\begin{vmatrix} t_1 & 1 & 0 & 0 & 0 & 0 \ldots\ldots \\ 1 & \tau_2 & 1 & 0 & 0 & 0 \ldots\ldots \\ 0 & 1 & t_3 & 1 & 0 & 0 \ldots\ldots \\ 0 & 0 & 1 & \tau_4 & 1 & 0 \ldots\ldots \\ 0 & 0 & 0 & 1 & t_5 & 1 \ldots\ldots \\ 0 & 0 & 0 & 0 & 1 & \tau_6 \\ & & \&c., \&c. & & & \end{vmatrix} a_1 = - \begin{vmatrix} \tau_2 & 1 & 0 & 0 & 0 & 0 \ldots\ldots \\ 1 & t_3 & 1 & 0 & 0 & 0 \ldots\ldots \\ 0 & 1 & \tau_4 & 1 & 0 & 0 \ldots\ldots \\ 0 & 0 & 1 & t_5 & 1 & 0 \ldots\ldots \\ 0 & 0 & 0 & 1 & \tau_6 & 1 \ldots\ldots \\ & & \&c., \&c. & & & \end{vmatrix} \alpha_0$$

or—

$$P_1 a_1 = - \Pi_2 \alpha_0,$$

where P_1 is the infinite determinant operator whose leading term is t_1 and Π_2 that whose leading term is τ_2.

7. P_1, Π_2, P_3, Π_4, &c., being the determinants whose leading terms are t_1, τ_2, t_3, τ_4, &c., respectively, we find at once by expanding that—

$$P_1 = t_1 \Pi_2 - P_3$$
$$\Pi_2 = \tau_2 P_3 - \Pi_4, \quad \&c.;$$

hence—

$$\frac{P_1}{\Pi_2} = t_1 - \frac{P_3}{\Pi_2} = t_1 - \frac{1}{\Pi_2/P_3}$$

$$= t_1 - \cfrac{1}{\tau_2 - \cfrac{1}{t_3 - \cfrac{1}{\tau_4 - \&c.}}}$$

$$= S_1 \text{ say,}$$

so that—

$$a_1 = - \frac{1}{S_1} \alpha_0,$$

where S_1 is the infinite continued fraction operator whose leading term is t_1.

Again if—

$$\Sigma_2 = \tau_2 - \cfrac{1}{t_3 - \cfrac{1}{\tau_4 - \cfrac{1}{t_5 - \&c.}}}$$

$$S_3 = t_3 - \cfrac{1}{\tau_4 - \cfrac{1}{t_5 - \cfrac{1}{\tau_6 - \&c.}}}$$

&c., &c.,

we find in a similar way, or by making use of equations VI., that—

$$\alpha_2 = - \frac{1}{\Sigma_2} a_1$$

$$a_3 = - \frac{1}{S_3} \alpha_2, \qquad \&c., \&c.;$$

hence for the complete solution we have—

$$\alpha_0 = -S_1 a_1 = S_1 \Sigma_2 \alpha_2 = -S_1 \Sigma_2 S_3 a_3 = \&c.,$$

which gives a_1, a_3, a_5, &c., $\alpha_2, \alpha_4, \alpha_6$, &c., in terms of the known vector α_0, provided the continued fraction operators S_1, Σ_2, S_3, &c., are determinate.

It is easily seen that they are determinate, for when q becomes a large number—

$$t_q = 2 \frac{l}{m} = t_{q+2}$$

$$\tau_{q+1} = 2 \frac{\lambda}{m} = \tau_{q+3}; \qquad \text{(\textit{See} section 5.)}$$

that is $S_1, \Sigma_2, S_3, \Sigma_4$, &c., are recurring continued fraction operators, and the recurring elements when reached are simple numbers.

8. The form of solution obtained is one very easy of practical application. In computing the continued fraction operators just so many of their known t, τ, elements (see section 5) need be taken account of as are necessary to give the required degree of approximation. Moreover, in the case of a practical alternator, as the resistance of the field coils is negligible relative to their reactance, all the τ elements are practically simple numbers independent of the field resistance, while for the t elements q is never a large odd number when t_{q+2} differs little from t_q. So that we could obtain S_q with considerable accuracy by assuming the recurring stage to be reached, and, therefore—

$$S_q = t_q - \cfrac{1}{\tau_{q+1} - \cfrac{1}{S_q}}$$

which gives the quadratic in S_q

$$S_q - t_q S_q + \frac{t_q}{\tau_{q+1}} = 0$$

from which S_q can be obtained by ordinary algebra.

[In solving this quadratic the two operators that come under the square root symbol will have to be reduced by the addition theorem in section 3 to a single operator $a\iota^b$ say, and the root of this is $\sqrt{a}\ \iota^{b/2}$.]

If S_q obtained in either of these ways be $s_q \iota^{-b_q}$, then as—

$$\Sigma_{q-1} = \tau_{q-1} - \frac{1}{S_q} = \tau_{q-1} - \frac{1}{s_q}\iota^{b_q}$$

Σ_{q-1} can be obtained by the addition theorem, and so on for S_{q-2}, Σ_{q-3}, &c. up to S_1.

Let the results be written—

$$S_1 = s_1 \iota^{-b_1}, \Sigma_2 = \sigma_2 \iota^{-\beta_2}, S_3 = s_3 \iota^{-b_3}, \&c.,$$

and in general $S_q = s\ \iota^{-b_q}$, $\Sigma_p = \sigma_p \iota^{-\beta_p}$.

9. As α_0 is the vector of length $2\eta/\rho$ lying along the axis of y $\left(\text{phase} = \frac{\pi}{2}\right)$, and as—

$$a_1 = -\frac{1}{S_1}(\alpha_0)_1 = -\frac{1}{s_1}\iota^{b_1}(\alpha_0)_1$$

$$a_1 = -\frac{2\eta}{s_1\rho}\sin\left(\omega t + \frac{\pi}{2} + b_1\right) = \frac{2\eta}{s_1\rho}\sin\left(\omega t - \frac{\pi}{2} + b_1\right)$$

Again—

$$\alpha_2 = -\frac{1}{\Sigma_2}(a_1)_2 = -\frac{1}{\sigma_2}\iota^{\beta_2}(a_1)_2,$$

that is—

$$\alpha_2 = \frac{2\eta}{s_1\sigma_2\rho}\sin\left(2\omega t + \frac{\pi}{2} + b_1 + \beta_2\right).$$

Similarly—

$$a_3 = \frac{2\eta}{s_1\sigma_2 s_3\rho}\sin\left(3\omega t - \frac{\pi}{2} + b_1 + \beta_2 + b_3\right).$$

$$\alpha_4 = \frac{2\eta}{s_1\sigma_2 s_3\sigma_4\rho}\sin\left(4\omega t + \frac{\pi}{2} + b_1 + \beta_2 + b_3 + \beta_4\right).$$

$$a_5 = \frac{2\eta}{s_1\sigma_2 s_3\sigma_4 s_5\rho}\sin\left(5\omega t - \frac{\pi}{2} + b_1 + \beta_2 + b_3 + \beta_4 + b_5\right),$$

&c. &c.;

and substituting these values in—

$$x = a_1 + a_3 + a_5 + \text{ \&c.}$$
$$\xi = \eta/\rho + \alpha_2 + \alpha_4 + \text{ \&c.}$$

we obtain the armature and field currents in the usual trigonometrical form of expression.

It is worth while drawing attention to the fact that the period of the alternating current induced in the field circuit is half that of the armature current, and that it contains all harmonics, both odd and even, relative to its own fundamental, and so its wave form will in general be unsymmetrical with respect to the time axis.

10. The total *e.m.f.* E generated in the armature circuit being equal to $-\frac{d}{dt}(m\,\xi\cos\omega t)$

$$E = -\frac{m}{2}\frac{d}{dt}\Sigma(\alpha_{q-1} + \alpha_{q+1})_q. \qquad \textit{(See section 4.)}$$

$$= -\frac{\omega m}{2}\iota^{\frac{\pi}{2}}\Sigma q(\alpha_{q-1} + \alpha_{q+1})_q.$$

also as $\alpha_{q-1} + t_q a_q + \alpha_{q+1} = 0$

$$E = \frac{\omega m}{2}\iota^{\frac{\pi}{2}}\Sigma q t_q a_q.$$

and in either of these formulæ the trigonometrical expressions in Section 9 for the vectors can be substituted. In the first, however, it must be noted that both a_{q-1} and a_{q+1} are to be taken of order q (odd). Thus the fundamental harmonic of E is—

$$= \frac{\omega m \eta}{\rho} \left\{ \sin \omega t + \frac{1}{s_1 \sigma_2} \sin (\omega t + b_1 + \beta_2) \right\}$$

from the first expression, or—

$$= \frac{\omega m \eta}{\rho} \frac{D_1}{s_1} \sin (\omega t + b_1 - f_1)$$

from the second, t_1 being equal to $D_1 \iota^{-f_1}$.

Similarly the total alternating *e.m.f.* H generated in the field circuit is given by either—

$$H = - \frac{\omega m}{2} \iota^{\frac{\pi}{2}} \Sigma p (a_{p-1} + a_{p+1})_p \quad .$$

or—

$$H = \frac{\omega m}{2} \iota^{\frac{\pi}{2}} \Sigma p \, \tau_p \, a_p \quad .$$

so that the fundamental harmonic of H is equal to either—

$$\frac{2 \omega m \eta}{\rho} \left[\frac{1}{s_1} \sin (2 \omega t + b_1 + \pi) + \frac{1}{s_1 \sigma_2 s_3} \sin (2 \omega t + b_1 + \beta_2 + b_3 + \pi) \right]$$

$$\text{or} \quad \frac{2 \omega m \eta}{\rho} \frac{\Delta_2}{s_1 \sigma_2} \sin (2 \omega t + b_1 + \beta_2 - \phi_2 + \pi).$$

11. The mean value of the product $\sin (a \omega t + \theta) \sin (b \omega t + \phi)$ being zero when a and b are unequal, and $\frac{1}{2} \cos (\theta - \phi)$ when a and b are equal, we find that the mean value of x^2 where $x = \Sigma \, a_q$ is—

$$= \frac{1}{2} \Sigma \, \bar{a}_q^2,$$

and the mean value of ξ^2, where $\xi = \frac{a_0}{2} + \Sigma \, a_p$ is—

$$= \frac{\bar{a}_0}{4} + \frac{1}{2} \Sigma \, \bar{a}_p^2.$$

Again, for the same reason, if a and β be any two vectors *representing harmonics of the same order*, and if $V \, a \beta$ be the product of the lengths of a and β into the sine of the angle from a to β *measured in the positive direction*, then the mean value of the product—

$$\iota^{\frac{\pi}{2}} a. \text{ into } \beta$$
$$= \tfrac{1}{2} V \, a \beta = - \tfrac{1}{2} V \, \beta a.$$

Applying these principles to determine the mean value $\overline{Ex}$ of the product of E and x, that is, of the electrical power developed in the armature circuit, we find from the first expression for E, section 10, that—

$$\overline{\mathrm{E}x} = -\frac{\omega m}{4} \Sigma\, q\, \mathrm{V}\, (a_{q-1} + a_{q+1})\, \mathrm{a}_q \,;\ \text{or}$$

$$\overline{\mathrm{E}x} = -\frac{\omega m}{4} \left\{ \begin{matrix} \mathrm{V}\alpha_0 \mathrm{a}_1 - \mathrm{V}\mathrm{a}_1\alpha_2 + 3\,\mathrm{V}\alpha_2\mathrm{a}_3 - 3\,\mathrm{V}\mathrm{a}_3\alpha_4 + 5\,\mathrm{V}\alpha_4\mathrm{a}_5 - 5\,\mathrm{V}\mathrm{a}_5\alpha_6 \\ + \&c. \end{matrix} \right\}.$$

And from the second expression for E that—

$$\overline{\mathrm{E}x} = \frac{\omega m}{4} \Sigma\, q.\, \mathrm{V}\, (t_q\, \mathrm{a}_q.\, \mathrm{a}_q\,) = \frac{\omega m}{4} \Sigma\, q\, \mathrm{D}_q \mathrm{V}\iota^{-f_q}\, \mathrm{a}_q.\mathrm{a}_q.$$

$$= \frac{\omega m}{4} \Sigma\, \bar{\mathrm{a}}_q^{\,2}\, q\, \mathrm{D}_q \sin f_q = \frac{1}{2} r\, \Sigma\, \bar{\mathrm{a}}_q^2$$

$$\text{as } \mathrm{D}_q \sin f_q = \frac{2r}{qm\omega}. \quad (\textit{See}\ \text{section 5}).$$

= the heat developed in the armature circuit.

Similarly the total electrical power $\overline{(\mathrm{H} + \eta)\, \xi}$ developed in the field circuit is given by—

$$\overline{(\mathrm{H} + \eta)\, \xi} = \frac{\eta a_0}{2} - \frac{\omega m}{4}\ \Sigma p\, \mathrm{V}\, (\mathrm{a}_{p-1} + \mathrm{a}_{p+1})\, a_p$$

$$= \rho \frac{\bar{a}_0^2}{4} - \frac{\omega m}{4} \left\{ 2\, \mathrm{V}\, \mathrm{a}_1\, \alpha_2 - 2\, \mathrm{V}\, \alpha_2\, \mathrm{a}_3 + 4\, \mathrm{V}\, \mathrm{a}_3\, \alpha_4 - 4\, \mathrm{V}\, \alpha_4\, \mathrm{a}_5 + \&c. \right\}$$

or by—

$$\overline{(\mathrm{H} + \eta)\, \xi} = \rho \frac{a_0^2}{4} + \frac{\rho}{2} \left(\bar{a}_2^2 + \bar{a}_4^2 + \bar{a}_6^2 + \&c. \right).$$

= total heat developed in the field circuit and made up of two parts, the first $= \rho \frac{\bar{a}_0^2}{4}$ due to the direct exciting current, and the second $\frac{\rho}{2} \left(\bar{a}_2^2 + \bar{a}_4^2 + \&c. \right)$ due to the induced alternating field current.

Adding the first expressions for $\overline{\mathrm{E}x}$ and $\overline{(\mathrm{H} + \eta)\, \xi}$, and cancelling $\overline{\eta\xi}$ against $\rho \frac{\bar{\mathrm{a}}_0^2}{4}$ we find that—

$$\overline{\mathrm{E}x} + \overline{\mathrm{H}\,\xi} = -\frac{\omega m}{4} \left\{ \mathrm{V}\, \alpha_0\, \mathrm{a}_1 + \mathrm{V}\, \mathrm{a}_1\, \alpha_2 + \mathrm{V}\, \alpha_2\, \mathrm{a}_3 + \mathrm{V}\, \mathrm{a}_3\, \alpha_4 + \&c. \right\}$$

12. The torque exerted at any instant in driving the alterna or is—

$$= -x\,\xi \frac{d}{d\,(\omega t)}\ (m \cos \omega t) = mx\,\xi \sin \omega t$$

$$= \frac{m}{2} \Sigma\, \mathrm{a}_q \times \iota^{-\frac{\pi}{2}} \Sigma\, (a_{q-1} - a_{q+1})_q. \qquad (\textit{See}\ \text{section 4.})$$

$$= -\frac{m}{2} \Sigma\, \mathrm{a}_q \times \iota^{\frac{\pi}{2}} \Sigma\, (a_{q-1} - a_{q+1})\, q\,.$$

Taking the mean value of this product, we find that the mean driving torque T is given by—

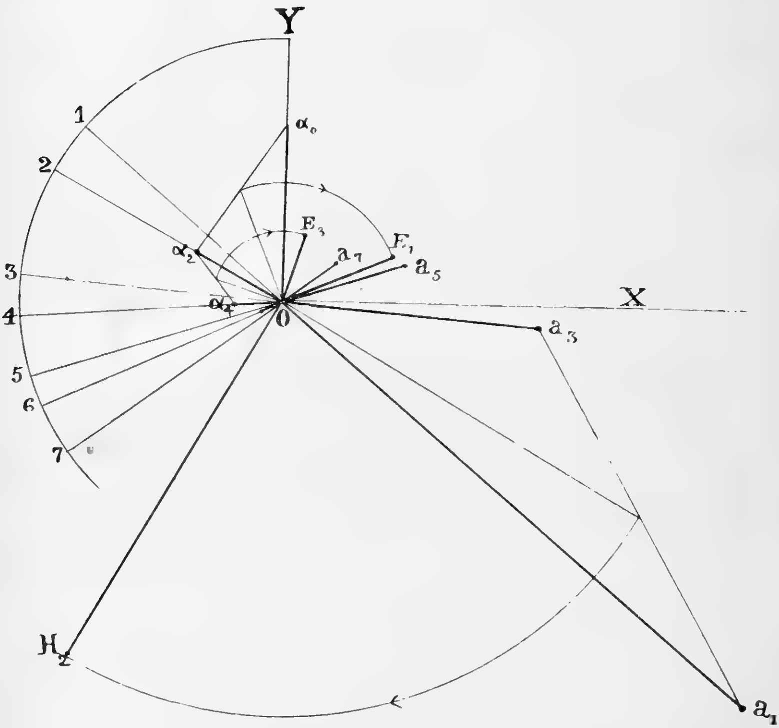
$$T = -\frac{m}{4}\left\{ V\alpha_0 a_1 + Va_1\alpha_2 + V\alpha_2 a_3 + Va_3\alpha_4 + \&c. \right\},$$

which result, combined with the last obtained in section 11, gives the power equation—

$$wT = \overline{Ex} + \overline{H\xi}$$

as it ought.

Fig. II.



13. The solution obtained can be represented geometrically in an interesting way as follows :—

Take two lines OX, OY (Fig. II.) at right angles. Measure off from OY in the positive direction the angles $YO1 = b_1$, $1O2 = \beta_2$, $2O3 = b_3$, $3O4 = \beta_4$, &c., where b_1, β_2, b_3, β_4, &c., are the angles determined in section 8.

In OY take $O\alpha_0 = 2\eta/\rho = 2 \times$ exciting current. Produce 1O through O to a_1 so that $Oa_1 = \frac{O\alpha_0}{s_1}$. In O2 take $O\alpha_2 = \frac{Oa_1}{\sigma_2}$. Produce 3O through O to a_3 so that $Oa_3 = \frac{O\alpha_2}{s_3}$, and so on where s_1, σ_2, s_3, σ_4, &c., are the quantities determined in section 8.

Then the vectors to a_1, a_3, a_5, &c., represent completely in amplitude and phase the different harmonics of the armature current, the subscribed numbers indicating the orders of the harmonics; and those to α_2, α_4, α_6, &c., represent completely, in the same way, the different harmonics of the induced alternating field current.

Again (*see* section 10) if we rotate the vector drawn to the middle point of $\alpha_0\,\alpha_2$ backwards through a right angle we obtain the vector OE_1 that represents $1/m\omega$ into the first harmonic of the total e.m.f. E generated in the armature; and if we rotate backwards through $\pi/2$ the vector to the middle point of $\alpha_2\,\alpha_4$ we obtain the vector OE_3 that represents $1/3m\omega$ into the third harmonic of E; and similarly for the other harmonics of E.

In the same way, by rotating backwards through $\pi/2$ the vector to the middle point of $a_1\ a_3$, we obtain the vector OH_2 that represents $1/2\,m\omega$ into the fundamental harmonic of the e.m.f. H induced in the field circuit, and so on for the other harmonics of H.

Again, the mean torque exerted on the generator is equal to $m/2$ into the sum of the areas of the triangles $\alpha_0 O a_1$, $a_1 O \alpha_2$, $\alpha_2 O a_3$, $a_3 O \alpha_4$, &c., these triangles, in the case of any generator, being all taken as positive.

14. When, for any generator, the t, τ, operators have been calculated for a particular load (*see* section 5) a geometrical solution can easily be obtained to a high degree of accuracy by aid of a ruler, scale, slide rule, and protractor.

Thus, if we neglect the harmonics α_8 a_9, &c., then, drawing any vector from the origin to represent a_7, we can construct for α_6, as $\alpha_6 = -\,t_7 a_7$ (*see* section 6). From α_6 we can construct for $\tau_6\alpha_6$, and as $a_5 + \tau_6\alpha_6 + a_7 = 0$, the triangle of vectors gives us a_5. Proceeding in this way, we obtain in succession α_4, a_3, α_2, a_1, α_0, which represent the harmonics of x and ξ correct as regards relative phase and relative amplitude. But, as α_0 is equal to twice the exciting current, we have a scale for our diagram, and hence obtain a complete solution. The fact that for a practical alternator the τ operators are very approximately pure numbers (*see* sections 8, 22) renders this method of solution both easy and expeditious.

15. If a source of constant e.m.f. be included in the armature circuit as well as in the field circuit of the simple alternator indicated in Fig. 1, equations 1, section 1 become—

$$rx + \frac{d}{dt}\left(lx + m\xi \cos \omega t\right) = e$$

$$\rho\xi + \frac{d}{dt}\left(\lambda\xi + mx \cos \omega t\right) = \eta$$

and both the armature and field currents will now contain harmonics of all orders, odd and even.

Assume—

$$x = \frac{a_0}{2} + a_1 + a_2 + a_3 + \&c.$$

$$\xi = \frac{\alpha_0}{2} + \alpha_1 + \alpha_2 + \alpha_3 + \&c.$$

where a_0 is the vector to the point whose polar co-ordinates are $^{2e}/r$, $^{\pi}/2$, and α_0 is, as before, the vector to the point $^{2\eta}/\rho$, $^{\pi}/2$. The other vectors a_1, a_2, a_3, a_4, &c., α_1, α_2, α_3, &c., have to be determined.

On substituting for x and ξ in the above equations it will be found that the odd order vectors in x and the even order ones in ξ, are determined by the same equations VI., section 6, as when $e = 0$, and are completely independent of the even order vectors in x and the odd order ones in ξ, these latter depending only on e and vanishing with e.

This being so, a_1, α_2, a_3, α_4, &c., are given by the solution already obtained, and α_1, a_2, α_3, a_4, &c., will be given by a similar set of equations written down from symmetry. Thus the complete solution is given by—

$$\alpha_0 = -S_1 a_1 = S_1 \Sigma_2 \alpha_2 = -S_1 \Sigma_2 S_3 a_3 = \&c.$$
$$a_0 = -\Sigma_1 \alpha_1 = \Sigma_1 S_2 a_2 = -\Sigma_1 S_2 \Sigma_3 \alpha_3 = \&c.$$

where α_0 is the vector to $2\eta/\rho$, $\pi/2$, as before and

a_0 the vector to $2e/r$, $\frac{\pi}{2}$.

Note.—In the former case ($e = o$) the t operators were all of odd and the τ ones of even order. In this case the operators of either class are of both orders.

The translation from the above vector solution to the ordinary sine form follows as in section 10.

16. In the preceding solutions the magnetic fluxes have been assumed to be in phase with the magnetizing current-turns, and so iron loss due to hysteresis and eddy currents has been neglected. To take account of the latter the interpretation of the well-known relation $B = \mu H$ connecting steady magnetizing force and induction produced has to be modified. The induction produced by $H = H_1 \sin(wt + c_1)$ is known to be of the form,

$B = m_1 H_1 \sin(wt + c_1 - \delta_1)$ + higher harmonics, and attending only to the fundamental harmonic in B, if H be represented as explained in section 2 by the vector h_1, and B by the vector b_1, then the above trigonometrical relation may be written $b_1 = \mu_1 h_1$ where μ_1 is the operator $m_1 \iota^{-d_1}$.

In a former paper* by me was shown how these *permeability operators*, as they may be called, can be determined. They depend on the character of the iron and the thickness of the laminæ, on the amplitude and period of the fundamental harmonic of the induction oscillation they refer to, and to some extent on the wave form of the latter.

* Variation of Magnetic Hysteresis with Frequency. Phil. Mag., Jan., 1905.

For the purposes of the following discussion we will assume that when the magnetizing force—

$$H = h_1 + h_3 + h_5 + \&c.,$$

prod ces the induction—

$$B = b_1 + b_3 + b_5 + \&c.,$$

then $b_1 = \mu_1 h_1$, $b_3 = \mu_3 h_3$, &c., where the μ_qs are operators of the type given by $\mu_q = m_q \iota^{-\delta_q}$.

[This assumption as regards all the harmonics of B but the fundamental is not strictly in accordance with what is known concerning the behaviour of laminated iron under periodic magnetizing forces, for b_3, b_5, &c., depend, at any rate for large values of b_1 more on b_1 than on h_3, h_5, &c. At the same time it is hoped that the following discussion may be of some value.]

In general if $H = \Sigma h_q$ produce $B = \Sigma b_q$, as the total iron loss per c.c. per cycle due to both hysteresis and eddy currents is—

$$\frac{1}{4\pi} \int H\,dB = \frac{1}{4\pi} \int_0^T H \frac{dB}{dt}\,dt$$

Where T is the period, the total iron loss per c.c. per second is—

$$= \frac{1}{4\pi} \cdot \text{ Average value of product } H \frac{dB}{dt},$$

$$= \frac{1}{4\pi} \text{ av. product } \Sigma h_q \text{ into } \omega \iota^{\frac{\pi}{2}} \Sigma q\, b_q$$

$$= \frac{\omega}{8\pi} \left\{ V b_1 h_1 + 3\, V b_3 h_3 + 5\, V b_5 h_5 + \&c. \right\} \qquad \text{(\textit{See} section 11.)}$$

$$= \frac{\omega}{8\pi} \Sigma q\, \bar{b}_q \bar{h}_q \sin \delta_q.$$

Again, it is well known that if the steady magnetizing current-turns nx act on a magnetic circuit composed of different materials, the flux F produced is given by—

$$F = \frac{4\pi n x}{\Sigma \dfrac{L}{A\mu}}$$

where the L,As are the lengths and sectional areas respectively of the different portions of the circuit, and the μs are the permeabilities of these portions for the particular flux densities in them.

If now the magnetizing current be an alternating one, that is, if $x = x_1 \sin(\omega t + c_1) = a_1$ (a vector), the same equation will give the corresponding harmonic of the flux produced, but the μs are now the permeability operators for the different portions of the circuit for the amplitudes and period of the flux densities in them.

$\Sigma \dfrac{L}{A\mu}$ can, by the addition theorem in section 3, be reduced to a single operator, so that if the flux f_1 (vector) be produced by the current-turns na_1 in any magnetic circuit, we have always a relation of the form—

$$f_1 = G_1 \, na_1$$

where G_1 is an operator of the form $g_1 \iota^{-\delta}$, which can be determined.

Hence, following the assumption already made, if the magnetizing current-turns—

$$nx = n \, (a_1 + a_3 + a_5 + \&c.)$$

produce in a magnetic circuit a flux $F = f_1 + f_3 + f_5 + \&c.$, then $f_1 = nG_1a_1, f_3 = nG_3a_3, f_5 = nG_5a_5$, &c., where the G's are operators of the type given by $G_q = g_q \iota^{-\delta_q}$.

In the above the back e.m.*f.*, *e* say, in the magnetizing coils due to change of flux is—

$$e = n \frac{dF}{dt} = n \omega \iota^{\frac{\pi}{2}} \Sigma q f_q$$

and the power absorbed, that is the total iron loss in the magnetic circuit, is the mean value of ex, that is of—

$$nx \frac{dF}{dt}, \text{ that is of } n\omega\Sigma a_q \text{ into } \iota^{\frac{\pi}{2}} \Sigma q f_q$$

which is $= \frac{1}{2} n\omega\Sigma q \, Vf_q \, a_q$ (*See* Section 11.)

$$= \frac{1}{2} \omega\Sigma q \frac{f_q^2}{g^q} \sin \delta_q \; .$$

17. As an example, let us determine the G operator for a magnetic circuit of uniform cross section = 100 cm² made up of 40 cm length of laminated iron and two air gaps each 1 m.m. when B maximum= 5000 and the frequency 30.

In the paper already quoted we find for a sample of No. 26 iron, with good insulation between the laminæ, when B max. = 5000 and frequency = 30 *q.p.* that

$$\mu = 2500 \, \iota^{-50^\circ} \qquad (q.p.)$$

Now—

$$G = \frac{4\pi}{\Sigma \frac{L}{A\mu}}$$

and—

$$\Sigma \frac{L}{A\mu} = \frac{1}{100} \left\{ \frac{40}{2500} \iota^{50^\circ} + \cdot 2 \right\}$$

$$= \frac{1}{10^5} \left\{ 16 \, \iota^{50} + 200 \right\}$$

$$= \frac{1}{10^5} \; 210{\cdot}6 \, \iota^{3^\circ 18'} .$$

Hence—

$$G = 5968 \, \iota^{-3\ 18'} .$$

18. Returning to the alternator, if n be the number of armature turns, ν the number of field turns, and $x = a_1 + a_3 + a_5 + \&c.$, $\xi = \alpha_0/2 + \alpha_2 + \alpha_4 + \&c.$, the armature and field currents respectively, the magnetizing current-turns M_x producing flux across the air gap and through the armature in a direction axial to its windings are given by—

$$M_x = nx + \nu\xi \cos \omega t$$

and the current-turns M_y producing flux across the air gap and through the armature in a direction parallel to the planes of the windings and *behind* that of M_x by 90° are given by—

$$M_y = \nu\xi \sin \omega t,$$

or in vector notation (*see* section 4)—

$$M_x = \Sigma \left[n a_q + \frac{\nu}{2} (\alpha_{q-1} + \alpha_{q+1})_q \right]$$

$$M_y = \frac{\nu}{2} \iota^{-\frac{\pi}{2}} \Sigma (\alpha_{q-1} - \alpha_{q+1})_q$$

which produce the armature fluxes A_x and A_y given by—

$$A_x = \Sigma G_q \left[n a_q + \frac{\nu}{2} (\alpha_{q-1} + \alpha_{q+1})_q \right]$$

$$A_y = \frac{\nu}{2} \iota^{-\frac{\pi}{2}} \Sigma G_q (\alpha_{q-1} - \alpha_{q+1})_q$$

where $G_q = g_q \iota^{-\delta_q}$ and q any odd number.

[Note that the directions of A_x and A_y are fixed in the armature.]

Now, if magnetic leakage be otherwise taken account of, the flux in the stator must be continuous with that in the rotor, so that the flux F looped on the field windings at any instant is given by—

$$F = A_x \cos \omega t + A_y \sin \omega t$$

which by means of the relations in section 4 can be reduced to—

$$F = \Sigma \left[\nu G_p \alpha_p + \frac{n}{2} (G_{p-1} a_{p-1} + G_{p+1} a_{p+1})_p \right]$$

where p is even and $2G_p = G_{p-1} + G_{p+1}$.

19. If l^1 be the self inductance in the armature circuit either external to the armature or due to magnetic leakage in it, and if λ^1 be a similar quantity for the field circuit, the equations for the two circuits are—

$$rx + l^1 \frac{dx}{dt} + n \frac{d}{dt} A_x = 0$$

$$\rho\xi + \lambda^1 \frac{d\xi}{dt} + \nu \frac{d}{dt} F = \eta$$

where r, ρ, η, x and ξ have the same significations as in section 1.

Substituting in these equations from section 18, and then equating separately to zero each set of vector terms of the same order, we obtain the two series of vector equations—

$$r\mathrm{a}_q + q\omega l^{\mathrm{I}}\,\iota^{\frac{\pi}{2}}\mathrm{a}_q + nq\omega\,\iota^{\frac{\pi}{2}}\mathrm{G}_q\left\{n\mathrm{a}_q + \frac{\nu}{2}(\alpha_{q-1} + \alpha_{q+1})\right\} = 0$$

$$\rho\alpha_p + p\omega\lambda^{\mathrm{I}}\,\iota^{\frac{\pi}{2}}\alpha_p + \nu p\omega\,\iota^{\frac{\pi}{2}}\left\{\nu\,\mathrm{G}_p\,\alpha_p + \frac{n}{2}(\mathrm{G}_{p-1}\,\mathrm{a}_{p-1} + \mathrm{G}_{p+1}\,\mathrm{a}_{p+1})\right\} = 0$$

with $\alpha_0 = 2\eta/\rho$.
where q is odd and p even.

These reduce at once to the two series—

$$\alpha_{q-1} + t_q\,\mathrm{G}_q\,\mathrm{a}_q + \alpha_{q+1} = 0$$

$$\mathrm{G}_{p-1}\,\mathrm{a}_{p-1} + \tau_p\,\alpha_p + \mathrm{G}_{p+1}\,\mathrm{a}_{p+1} = 0$$

or, after putting $\mathrm{a}^{\mathrm{I}}_q$ for $\mathrm{G}_q\,\mathrm{a}_q$, to—

$$\alpha_{q-1} + t_q\,\mathrm{a}^{\mathrm{I}}_q + \alpha_{q+1} = 0$$

$$\mathrm{a}^{\mathrm{I}}_{p-1} + \tau_p\,\alpha_p + \mathrm{a}^{\mathrm{I}}_{p+1} = 0$$

equations of exactly the same form as those for the simple case, but in which the values of the t and τ operators are now given by—

$$t_q = \frac{2}{n\nu\mathrm{G}^2_q}\left\{n^2\,\mathrm{G}_q + l^{\mathrm{I}} - \frac{r}{q\omega}\,\iota^{\frac{\pi}{2}}\right\}$$

$$\tau_p = \frac{2}{n\nu}\left\{\nu^2\,\mathrm{G}_p + \lambda^{\mathrm{I}} - \frac{\rho}{p\omega}\,\iota^{\frac{\pi}{2}}\right\}.$$

These operators having been calculated from known data, the solution for a'_1, a'_3, a'_5, &c., α_2, α_4, &c., proceeds exactly as in the simple case, and as $\mathrm{a}'_1 = \mathrm{G}_1\mathrm{a}_1$, $\mathrm{a}'_3 = \mathrm{G}_3\mathrm{a}_3$, &c., a_1, a_3, a_5, &c., can then be obtained.

20. In section 16 it was shown that the iron loss (*i.e.*, energy dissipated per sec. in the iron) in a magnetic circuit is—

$$\frac{1}{2}\,\omega\Sigma q\,\frac{\overline{f_q}^2}{g_q}\,\sin\,\delta_q$$

hence the loss due to the flux A_x, section 18, is—

$$\frac{1}{2}\,\omega\Sigma q g_q\,\sin\,\delta_q\,\overline{n\mathrm{a}_q + \frac{\nu}{2}(\alpha_{q-1} + \alpha_{q+1})}^2$$

and that due to the flux A_y is—

$$\frac{1}{2}\,\omega\Sigma q g_q\,\sin\,\delta_q\,\frac{\nu^2}{4}\,\overline{(\alpha_{q-1} - \alpha_{q+1})}^2$$

Adding these, we find that the total iron loss in the generator is—

$$\frac{1}{2}\,\omega\Sigma q g_q\,\sin\,\delta_q\left\{\overline{n\mathrm{a}_q + \frac{\nu}{2}(\alpha_{q-1} + \alpha_{q+1})}^2 + \frac{\nu^2}{4}\,\overline{(\alpha_{q-1} - \alpha_{q+1})}^2\right\}.$$

Expanding and remembering that—

$$\overline{\alpha + \beta}^2 = \bar{\alpha}^2 + \bar{\beta}^2 + 2\bar{\alpha}\bar{\beta} \cos \widehat{\alpha\beta},$$

and that—

$$\alpha_{q-1} + \alpha_{q+1} = - t_q \, G_q \, a_q \qquad (\textit{see} \text{ section 19}),$$

we find that the total iron loss is equal o—

$$\Sigma \left[\frac{1}{2} q \omega g_q \sin \delta_q \left\{ \frac{\nu^2}{2} (\bar{\alpha}_{q-1}^2 + \bar{\alpha}_{q+1}^2) - n^2 \bar{a}_q^2 \right\} - \left\{ r \sin^2 \delta_q + q \omega l^{\text{I}} \sin \delta_q \cos \delta_q \right\} \bar{a}_q^2 \right]$$

where q is any odd number.

21. An approximate determination of the effect of iron loss on the performance of an alternator can be obtained by taking all the G operators for its magnetic circuit as equal to G_1; that is, to the one for the fundamental harmonic of the armature flux.

Making this simplification in the equations of section 19, we find that a_1, a_3, &c., α_0, α_2, &c., are connected by the two series of equations—

$$\alpha_{q-1} + t_q \, a_q + \alpha_{q+1} = 0$$
$$a_{p-1} + \tau_p \, \alpha_p + a_{p+1} = 0$$

with $\alpha_0 = 2\eta/\rho$ in which—

$$t_q = \frac{2}{n\nu G} \left\{ n^2 G + l^{\text{I}} - \frac{r}{q\omega} \iota^{\frac{\pi}{2}} \right\} = \frac{2}{n\nu} \left\{ n^2 + \frac{l^{\text{I}}}{g} \iota^{\delta} - \frac{r}{qg\omega} \iota^{\frac{\pi}{2} + \delta} \right\}$$

$$\tau_p = \frac{2}{n\nu G} \left\{ \nu^2 G + \lambda^{\text{I}} - \frac{\rho}{p\omega} \iota^{\frac{\pi}{2}} \right\} = \frac{2}{n\nu} \left\{ \nu^2 + \frac{\lambda^{\text{I}}}{g} \iota^{\delta} - \frac{\rho}{pg\omega} \iota^{\frac{\pi}{2} + \delta} \right\}$$

as $G = g\bar{\iota}^{\,-\delta}$

Putting l for qn^2, λ for $g\nu^2$, and m for $gn\nu$, and, remembering that δ is a small angle (*see* section 17), unity for cos δ, we find that—

$$t_q = D_q \, \bar{\iota}^{f_q}, \; \tau_p = \Delta_p \, \bar{\iota}^{\phi_p},$$

where

$$D_q^2 = \frac{4}{m^2} \left\{ (l + l^{\text{I}})^2 + \frac{r^2}{q^2\omega^2} + 2 \frac{lr}{q\omega} \sin \delta \right\}$$

$$D_q \sin f_q = \frac{2r}{qm\omega} - \frac{2l^{\text{I}}}{m} \sin \delta$$

$$\Delta_p^2 = \frac{4}{m^2} \left\{ (\lambda + \lambda^{\text{I}})^2 + \frac{\rho^2}{p^2\omega^2} + 2 \frac{\lambda\rho}{p\omega} \sin \delta \right\}$$

$$\Delta_p \sin \phi_p = \frac{2\rho}{pm\omega} - \frac{2\lambda^{\text{I}}}{m} \sin \delta.$$

The t and τ operators having been calculated from these formulæ, the rest of the solution for this case follows in every particular the course for the simple case fully explained in sections 8 and 9.

22. In order to illustrate the practical application of the foregoing theory, I will determine the performance of a small two-pole alternator when carrying a rather heavy non-inductive load.

The details of the alternator are as follows:—

Armature { diameter 12 cm.
length 8 cm.
turns $n = 100$
resistance ·25 ohms.

Air gap = 1 m.m.

Field { turns $\nu = 400$.
resistance $\rho = 3$ ohms.
exciter three storage cells; $\eta = 6{\cdot}6$ volts.

Frequency $= {}^{100}/\pi$; *i.e.* $\omega = 200$.

Magnetic leakage = 5 per cent.

Flux operator $G = g\iota^{-\delta}$ where $g = 5000$, $\delta = 3°$.

Let the external resistance in the armature circuit in the case in hand be 4·75 ohms so that $r = 5$ ohms.

Hence (*see* section 21)—

$l = 5.10^7$, $l^1 = {\cdot}05 l = {\cdot}25.10^7$

$\lambda = 8.10^8$, $\lambda^1 = {\cdot}05\lambda = 4.10^7$

$m = 2.10^8$, $r = 5.10^9$, $\rho = 3.10^9$, $\omega = 200$, $\delta = 3°$, and $a_0 = 2\eta/\rho = {\cdot}44$ (abs.)

Using these values for the constants and the formulæ in section 21, we obtain the t, τ, operators which are given in the following table:—

$t_q = D_q\,\iota^{-f_q}$			$\tau_p = \Delta_p\,\iota^{-\phi_p}$		
q	D_q	f_q	p	Δ_p	ϕ_p
		° ′			° ′
1	·592	24 51	2	8·4	0 22
3	·535	8 48	4	8·4	8
5	·530	5 18	6	8·4	1
7	·528	3 45	8	8·4	− 1
9	·527	2 54	10	8·4	− 2
11	·526	2 21	12	8·4	− 3
13	·526	1 57	14	8·4	− 4
15	·526	1 40	16	8·4	− 5
17	·526	1 28	18	8·4	− 5

[Note that the τ operators are all practically equal and simple numerical multipliers. (*See* section 8.)]

And from these, by the method explained in section 8, we obtain the S, Σ, continued fraction operators which are given in the following table:—

$S_q = s_q \iota^{-b_q}$			$\Sigma_p = \sigma_p \iota^{-\beta_p}$		
q	s_q	b_q	p	σ_p	β_p
		° ′			° ′
1	·457	36 32	2	5·82	7 46
3	·366	15 32	4	5·63	5 8
5	·353	9 50	6	5·57	3 40
7	·350	7 9	8	5·55	2 54
9	·348	5 34	10	5·53	2 18
11	·346	4 30	12	5·51	1 51
13	·346	3 42	14	5·50	1 21

and from these, as explained in section 9, we obtain the different harmonics of both the armature current and the induced field current. These also are given in tabular form below:—

$x = \Sigma x_q \sin(q\omega t - \frac{\pi}{2} + c_q)$			$\xi = \cdot 22 + \Sigma \xi_p \sin(p\omega t + \frac{\pi}{2} + \gamma_p)$		
q	x_q	c_q	p	ξ_p	γ_p
		° ′			° ′
1	·963	36 32	2	·166	44 18
3	·453	59 50	4	·080	64 58
5	·228	74 48	6	·041	78 28
7	·117	85 37	8	·021	88 31
9	·061	94 5	10	·011	96 23
11	·032	100 53	12	·006	102 44
13	·017	106 26	14	·003	107 47

The virtual armature current in amperes being equal to $10\sqrt{\frac{1}{2}\Sigma x^2}$ is 7·75 amps., and the terminal virtual voltage, being 4·75 times this, is 36·8 volts. The no-load voltage for the same exciting current is 62·2.

The virtual value of the alternating current induced in the field circuit in amperes being—

$$10\sqrt{\tfrac{1}{2}\Sigma\,\xi_p^2} \text{ is } 1{\cdot}34.$$

The copper losses are—

In the armature, 15 watts.

In the field, due to exciting current, 12 watts.

In the field, due to induced current, 5·4 watts.

The total iron loss calculated by means of the formula in section 20 is 20 watts.

The total losses are, therefore, 52·4 watts, and, as the output is 285 watts, the efficiency is 84 per cent.

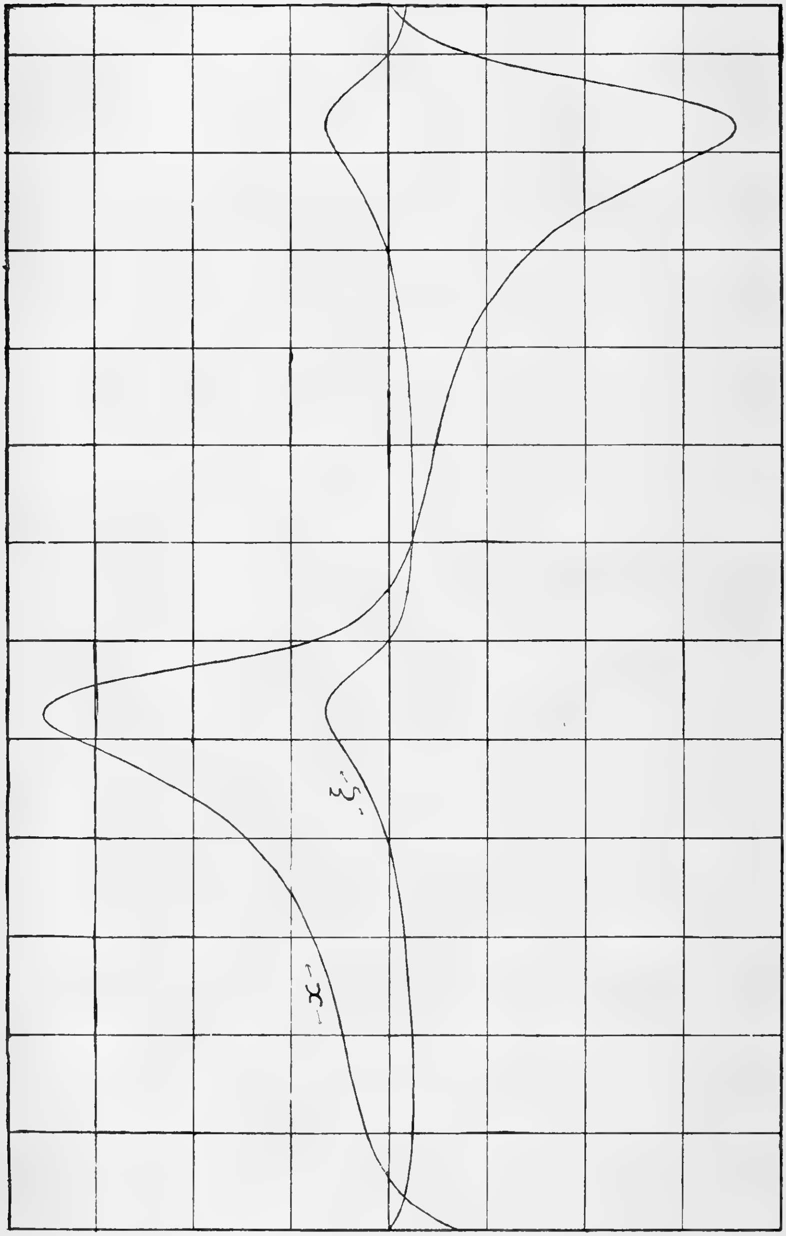


Fig. III.—Theoretical Armature Current (x) and Induced Field Current (ξ) in a Fully-loaded Alternator.

In Fig. III. are plotted the wave forms of both the armature and induced field currents determined above, correctly as regards both their relative amplitudes and phases.

23. In designing the field of an alternator, attention should be given to the fact that the conductors have to carry not only the exciting current but also the induced field current, which, as we have seen, may at full load attain a relatively large value. In addition, it should not be forgotten that in the field magnet cores there is the associated alternating flux which causes some additional heat.

It is well known that in a case of excessive heating in the field reduction of the heating is effected by the employment of heavy closed copper conductors, called dampers, embracing the field magnet poles.

To explain this action let us consider a two-pole machine on each field pole of which is a damper.

Neglecting magnetic leakage and iron loss, if ζ be the current in each damper, the magnetic flux through the armature windings is—

$$g\{nx + (\nu\xi + 2\zeta)\cos\omega t\}$$

and that through the field windings and the dampers is—

$$g\{\nu\xi + 2\zeta + nx\cos\omega t\}$$

so that the equations connecting x, ξ, and ζ are—

$$\text{(I.)}\quad \begin{aligned} rx + gn\frac{d}{dt}\left\{nx + (\nu\xi + 2\zeta)\cos\omega t\right\} &= 0 \\ \rho\xi + g\nu\frac{d}{dt}\left\{\nu\xi + 2\zeta + nx\cos\omega t\right\} &= \eta \\ z\zeta + g\frac{d}{dt}\left\{\nu\xi + 2\zeta + nx\cos\omega t\right\} &= 0 \end{aligned}$$

where z is the resistance of each damper and the other symbols have the same significations as in the previous sections of this paper.

There is no constant term in ζ, and considering only the variable terms (harmonics) in ξ we see at once that—

$$\nu z\zeta = \rho\xi$$

from which it follows that—

$$\nu\xi + 2\zeta = \nu\xi(1+\kappa) = \nu\xi^{\text{I}} \text{ say}$$

where— $\kappa = \dfrac{2\rho}{\nu^2 z}$

and that—

$$2z\zeta^2 = \kappa\rho\xi^2.$$

The first two of equations I. may now be written—

$$rx + gn\frac{d}{dt}\left\{nx + \nu\xi^{\text{I}}\cos\omega t\right\} = 0.$$

$$\frac{\rho}{1+\kappa}\xi^{\text{I}} + g\nu\frac{d}{dt}\left\{\nu\xi^{\text{I}} + nx\cos\omega t\right\} = \frac{\eta}{1+\kappa}$$

η being divided by $1+\kappa$ as the constant term in ξ^{I}, is equal to the constant term in ξ, that is to η/ρ (ζ having no constant term).

Now, x and ξ^{I} determined from these equations will be very approximately the same as x and ξ determined from the equations in section 1 for the alternator without dampers, for α_0 the given vector is the same for both, as are all the t operators. The τ operators differ in $\rho/1+\kappa$ being substituted for ρ, but in section 8, and in notes, section 22, it is shown that the value of ρ the field resistance has practically no effect on the τ operators for alternators as ordinarily constructed.

Hence we see that ξ^1 is the alternating field current if the dampers are absent, ξ its value when the dampers are attached, and these currents are connected by the relation—

$$\xi^1 = (1 + \kappa)\, \xi.$$

In addition as $2z\zeta^2 = \kappa\rho\xi^2$

$$\rho\xi^2 = \frac{2}{\kappa} z\zeta^2 = \frac{1}{(1+\kappa)^2}\, \rho\xi^{1^2}.$$

Hence, if H^1 be the copper loss in the field coils due to induced alternating currents when the generator is without the dampers, H the same when the dampers are attached, and h the loss in the dampers themselves—

$$H = \frac{H^1}{(1+\kappa)^2},\ h = \frac{\kappa H^1}{(1+\kappa)^2},\ H + h = \frac{H^1}{1+\kappa}.$$

If we assume that the mean length of a field turn is equal to the length of a damper turn, it is easy to show that κ is the ratio of the volume of copper in the dampers to the volume of copper in the field windings when there is no resistance external to the windings in the field circuit, and greater than this ratio if there is external resistance; so the action of the dampers in reducing the heating in the field windings, due to induced current in them, has been determined.

The magnetic flux in the field cores being $g\,\{\nu\,\xi^1 + nx \cos \omega t\}$ is practically unaffected by the presence of the dampers, so that the iron losses in the field magnets remain the same.

24. If a source of alternating e.m.f. E where—

$$E = E_1 \sin(\omega t + h_1) + E_3 \sin(3\,\omega t + h_3) + E_5 \sin(5\omega t + h_5) + \text{\&c.}$$
$$= e_1 + e_3 + e_5 + \text{\&c.} \quad \text{(vectors)}$$

be included in the armature circuit, and, if the armature rotate in synchronism with this e.m.f., we have the case of the synchronous motor.

The armature and field currents x and ξ are now connected by the equations (*see* section 1)—

$$rx + \frac{d}{dt}\left\{ lx + m\xi \cos \omega t \right\} = \Sigma\, E_q \sin(q\omega t + h_q)$$
$$\rho\xi + \frac{d}{dt}\left\{ \lambda\xi + mx \cos \omega t \right\} = \eta\,.$$

Assuming, as in section 2, that—

$$x = a_1 + a_3 + a_5 + \text{\&c.}$$
$$\xi = \frac{\alpha_0}{2} + \alpha_2 + \alpha_4 + \text{\&c.}$$

and proceeding exactly as in section 5 we obtain the infinite series of equations—

$$\begin{aligned}
t_1 a_1 + \alpha_2 &= -\alpha_0 - k_1 \\
a_1 + \tau_2\alpha_2 + a_3 &= 0 \\
\alpha_2 + t_3 a_3 + \alpha_4 &= -k_3 \\
a_3 + \tau_4\alpha_4 + a_5 &= 0 \\
\alpha_4 + t_5 a_5 + \alpha_6 &= -k_5 \\
\&c., \&c.
\end{aligned}$$

in which $\alpha_0 = \frac{2\eta}{\rho}$ the vector to the point $\frac{2\eta}{\rho}, \frac{\pi}{2}$, as before—

$$k_q = \frac{2}{q\omega m} \iota^{\frac{\pi}{2}} e_q$$

where Σe_q is the applied *e.m.f.*, and the t and τ operators have the same values as in section 5.

Solving for a_1 we find that—

$$P_1 a_1 = -\Pi_2(\alpha_0 + k_1) - \Pi_4 k_3 - \Pi_6 k_5 - \&c.$$

where P_1, Π_2, Π_4, &c., are the infinite determinant operators whose leading terms are t_1, τ_2, τ_4, &c., respectively as in section 6.

Reducing to the continued fraction operators of section 7, we obtain—

$$a_1 = -\frac{1}{S_1}(\alpha_0 + k_1)_1 - \frac{1}{S_1\Sigma_2 S_3}(k_3)_1 - \frac{1}{S_1\Sigma_2 S_3\Sigma_4 S_5}(k_5)_1 - \&c.,$$

and using the equations—

$$\begin{aligned}
\alpha_2 &= -t_1 a_1 - \alpha_0 - k_1, \\
a_3 &= -\tau_2\alpha_2 - a_1, \\
\alpha_4 &= -t_3 a_3 - \alpha_2 - k_3, \ \&c.,
\end{aligned}$$

the successive harmonics of the armature and field currents can be obtained.

25. If, in the last example, the e.m.f. inserted in the armature circuit be sinusoidal and equal to E sin $(\omega t + h) = e$ (a vector), the solution will obviously be identical with that for the simple generator given in sections 5 *et seq.*, when in the latter $\alpha_0 + \kappa$ is substituted for α_0 where—

$$\kappa = \frac{2}{\omega m} \iota^{\frac{\pi}{2}} e,$$

and in this case it is important to know the condition which determines whether the machine will run as a motor and develop mechanical power.

In section 12 the *driving* torque T was shown to be given by—

$$T = -\frac{m}{4}\left\{ V\alpha_0 a_1 + Va_1\alpha_2 + V\alpha_2 a_3 + Va_3\alpha_4 + \&c. \right\}$$

and T must be negative for a motor.

Now as—

$$\mathrm{a}_1 = -\frac{1}{S_1}(\alpha_0 + \kappa) = -\frac{\iota^{b_1}}{s_1}(\alpha_0 + \kappa), \text{ (\textit{see} section 8)},$$

$$\mathbf{V}\alpha_0\mathrm{a}_1 = -\frac{1}{s_1}\left\{ \mathrm{V}\alpha_0\iota^{b_1}\alpha_0 + \frac{2}{\omega m}\mathrm{V}\alpha_0\iota^{\frac{\pi}{2}+b_1}e \right\}$$

$$= -\frac{1}{s_1}\left\{ \bar{a}_0^2 \sin b_1 + \frac{2}{\omega m}\bar{a}_0\bar{e}\sin(b_1 + h)\right\}.$$

Again as—

$$\alpha_2 = -\frac{1}{\Sigma_2}\mathrm{a}_1 = -\frac{\iota^{\beta_2}}{\sigma_2}\mathrm{a}_1$$

$$\mathrm{V}\mathrm{a}_1\alpha_2 = -\frac{\sin\beta_2}{\sigma_2}\bar{\mathrm{a}}_1^2 = -\frac{\sin\beta_2}{s_1^2\sigma_2}\overline{(\alpha_0 + \kappa)}^2$$

similarly—

$$\mathrm{V}\alpha_2\mathrm{a}_3 = -\frac{\sin b_3}{s_1^2\sigma_2^2 s_3}\overline{(\alpha_0 + \kappa)}^2 \quad \&c., \&c.$$

and as—

$$\overline{(\alpha_0 + \kappa)}^2 = \bar{\alpha}_0^2 + \bar{\kappa}^2 + 2\bar{\alpha}_0\bar{\kappa}\cos\widehat{\alpha_0\kappa},$$

$$= \bar{a}_0^2 + \frac{4}{\omega^2 m^2}\bar{e}^2 + \frac{4}{\omega m}\bar{a}_0\bar{e}\cos h.$$

We find, if—

$$\mathrm{B} = \frac{\sin\beta_2}{s_1^2\sigma_2} + \frac{\sin b_3}{s_1^2\sigma_2^2 s_3} + \frac{\sin\beta_4}{s_1^2\sigma_2^2 s_3^2\sigma_4} + \&c.,$$

that—

$$\frac{4\mathrm{T}}{m} = \left\{\frac{\sin b_1}{s_1} + \mathrm{B}\right\}\bar{a}_0^2 + \frac{2}{\omega m}\left\{\frac{\sin(b_1 + h)}{s_1} + 2\mathrm{B}\cos h\right\}\bar{a}_0\bar{e}$$
$$+ \frac{4}{\omega^2 m^2}\mathrm{B}\bar{e}^2,$$

which must be negative if the machine runs as a motor.

Now s_1, σ_2, s_3, σ_4, &c., $\sin b_1$, $\sin\beta_2$, $\sin b_3$, &c., are all essentially positive, and, therefore, B is so.

Also $\bar{a}_0$ and $\bar{e}$ are essentially positive. So, in order that the machine may work as a motor h, the phase angle of the applied e.m.f. must have such a value as to make the above expression for T negative.

The power supplied by the source e being the mean value of the product of e and x, that is of e and a_1, or of e and $-\frac{1}{s_1}\iota^{b_1}(\alpha_0 + \kappa)$

is $= -\frac{1}{2s_1}\bar{a}_0\bar{e}\sin(h - b_1) + \frac{1}{2s_1}\bar{e}\bar{\kappa}\sin b_1$. (*See* section 11.)

$$= -\frac{\bar{e}}{2s_1}\left\{\bar{a}_0\sin(h - b_1) - \frac{2\bar{e}}{\omega m}\sin b_1\right\}.$$

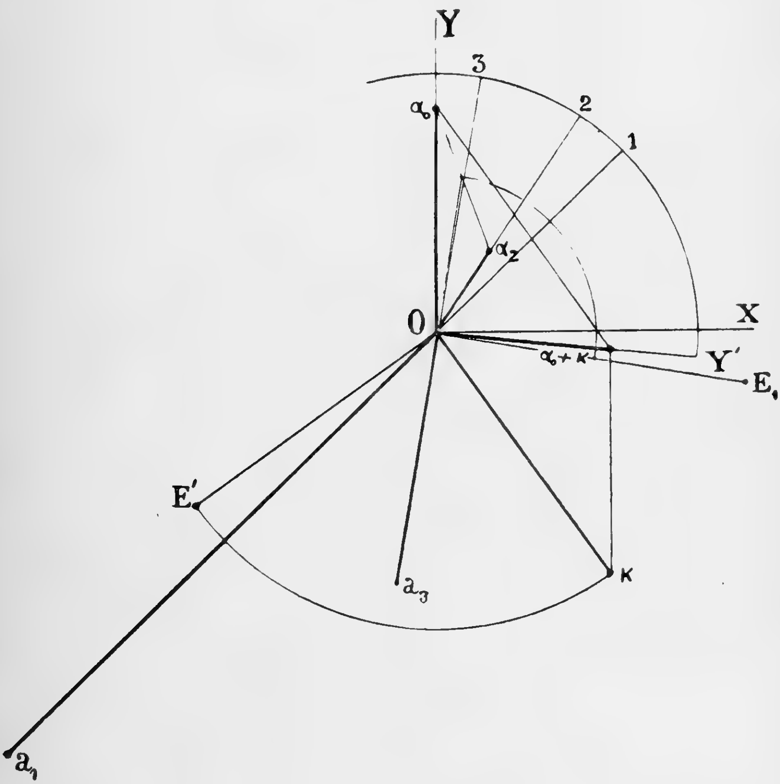
It is interesting to note that the armature and alternating field currents which flow when an e.m.f. $= E \sin(\omega t + h)$ is acting in the armature circuit, the angular velocity of the armature is ω, and the exciting current C would be unchanged if the e.m.f. $E \sin(\omega t + h)$ be removed, the speed maintained, and the exciting field-current changed from C to—

$$\sqrt{C^2 + \frac{2}{\omega m} CE \cos h + \frac{1}{\omega^2 m^2} E^2}.$$

This follows immediately from the vector equations in section 24 connecting a_1, a_2, a_3, &c., with $a_0 + \kappa$ when κ_3, κ_5, &c., are zero.

26. The case of the synchronous motor with sinusoidal applied e.m.f., discussed in the last paragraph, can easily be represented geometrically.

Fig. IV.



In Fig. IV. let $O\alpha_0$ taken in the axis of Y be equal, as in section 13, to twice the steady exciting current of the machine. Draw the vector OE' to represent in amplitude and phase $2/\omega m$ times the applied e.m.f.; that is if the latter $= e' \sin(\omega t + h)$ $OE' = 2e'/\omega m$, and the angle from OX to OE' measured positively is $= h$.

Rotating OE^{I} forward through 90° gives us κ of section 25, and completing the parallelogram $\alpha_0 O \kappa$, its diagonal is $\alpha_0 + \kappa$ in the line OY^{I}. Knowing the motor circuits we can determine s_1, b_1, σ_2, β_2, s_3, b_3, &c., and then construct for a_1, α_2, a_3, α_4, &c., exactly as in section 13, unless that in this construction the vector $\alpha_0 + \kappa$ takes the place of α_0 in section 13.

Now the mechanical torque *developed by the machine* is (*see* section 12)—

$$\frac{m}{4}\left\{ V\alpha_0 a_1 + Va_1\alpha_2 + V\alpha_2 a_3 + Va_3\alpha_4 + \&c. \right\}$$

$= \frac{m}{2}$ into the sum of the areas, attending to signs, of the triangles $\alpha_0 O a_1$, $a_1 O \alpha_2$, $\alpha_2 O a_3$, &c.

But the triangles $a_1 O \alpha_2$, $\alpha_2 O a_3$, &c., are all essentially negative [their sum is equal to $-\frac{1}{2} B \overline{\alpha_0 + \kappa}^2$, *see* section 25], so that if the machine is to develop mechanical power and run as a motor the phase of OE^{I} must be such that the area of the triangle $\alpha_0 O a_1$ is positive (as it is in Fig. IV.), and numerically greater than the sum of $a_1 O \alpha_2$, $\alpha_2 O a_3$, &c.

The power supplied by the source is—

$$= \frac{1}{2} \cdot \bar{a}_1 \frac{\omega m}{2} \cdot \overline{OE^{I}} \cos a_1 OE^{I}$$

$$= \frac{\omega m}{4} \bar{a}_1 \bar{\kappa} \sin a_1 O \kappa$$

$$= \frac{\omega m}{2} \times \text{area of triangle } a_1 O \kappa$$

And the power developed by the motor—

$= \omega T = \frac{\omega m}{2} \times$ sum of triangles $\alpha_0 O a_1$, $a_1 O \alpha_2$, $\alpha_2 O a_3$, &c., attending to signs. Hence the efficiency is equal to—

$$\frac{\alpha_0 O a_1 + a_1 O \alpha_2 + \alpha_2 O a_3 + \&c.}{a_1 O \kappa}$$

By rotating the vector from O to the middle point of $\alpha_0 \alpha_2$ backwards through 90°, and doubling, we obtain OE_1, which represents in amplitude and phase $2/\omega m$ times the first harmonic of the total e.m.f. of the motor. (*Ses* section 13.) This vector can now be compared with OE^{I} which represents $2/\omega m$ times the applied e.m.f.

Fig. IV. easily explains how by increasing the exciting current of an A.C. motor the phase of the armature current is advanced relative to that of the applied e.m.f.

7.—EXPERIMENTS ON THE BEHAVIOUR OF IRON UNDER PERIODIC MAGNETIZING FORCES.

By PROFESSOR T. R. LYLE, M.A., Sc.D., and J. A. GRAY, B.Sc.

1. This research was undertaken for the purpose, principally, of finding out whether any simple relation as regards relative amplitude or phase holds either between the upper harmonics of an induction oscillation in laminated iron and its fundamental—or (as we call it) its first harmonic—or between its successive upper harmonics, when the magnetizing force is approximately sinusoidal; it was hoped that some hint might thus be obtained concerning the link by which these harmonics, all of odd order, are bound together, and, hence, some conception rendered possible as to the nature of the oscillating system in an ultimate magnetic particle when excited by periodic magnetizing forces.

Thus, if the sinusoidal magnetizing force—

$$H = H_1 \sin \omega t$$

—be applied to a laminated iron ring in the usual way, it is known that the induction B produced contains the full series of odd harmonics and may be written—

$$B = B_1 \sin (\omega t - \theta_1) + B_3 \sin 3 (\omega t - \theta_3) + B_5 \sin 5 (\omega t - \theta_5) + \&c.$$

We wished to find out whether any simple relation connected B , B_5, &c., θ_1, θ_3, θ_5, &c., either to B_1 or to one another or to the period of the oscillations.

In this we were not successful, but we think that the results we obtained will be of value, especially to those interested in magnetic research.

In addition to the above purpose we wished to test, in a more accurate manner than has hitherto been done, the correctness of some conclusions given in a former paper* by one of us, relating to—(*a*) what was called kinetic hysteresis; (*b*) the formula proposed in the same paper for the total iron loss I as a function of the frequency *n*, and what was called the effective induction $\mathfrak{B}$, namely—

$$I = (\lambda + \mu n) \mathfrak{B}^x$$

where *x* is a number about 1·5—1·6; (*c*) the modifications produced on the characteristics of a B wave by change of wave form of the magnetizing force H.

2. In the paper already quoted, it was found that when H was approximately sinusoidal B_3/B_1, B_5/B_1 were, after B_1 had attained a certain value, practically linear in B_1; but it was pointed out that the values of B_3, B_5, &c., obtained, were probably much modified by a peculiar action in the iron ring by which some of the energy transmitted to it by the magnetizing force H sin ωt was reflected back to the magnetizing circuit in the form of currents, whose frequencies were 3, 5, 7 times respectively that of the exciting current.

* Variations of Magnetic Hysteresis with Frequency. Phil. Mag., Jan., 1905.

Thus when the induction—

$$B = B_1 \sin (\omega t - \theta_1) + B_3 \sin 3 (\omega t - \theta_3) + B_5 \sin 5 (\omega t - \theta_5) + \&c.,$$

is produced by—

$$H = H_1 \sin \omega t.$$

B_3, B_5, &c., cannot in any direct way be due to H_1 but must be due to B_1, arising from the latter by means of some property of the oscillating system within the ultimate magnetic particle. We may, therefore, assume that with a fundamental harmonic B_1 of the induction there are necessarily associated magneto-motive forces m_3, m_5, &c., of periods T/3, T/5, &c., which would produce inductions B_3, B_5, &c., provided no reactions due to induced currents in the circuits round the iron ring tend to modify these inductions. But as there must be at least one circuit there will always be modifying reactions. Thus, considering only the third harmonic, if αB_3 be the resultant flux of this order (α being the sectional area of the ring) variation of this will induce a current C_3 in the magnetizing circuit, and from C_3 we have the magneto-motive force (M.M.F.) $4\pi n\ C_3$ acting round the ring. The resultant magneto-motive force is, therefore, the vector sum of m_3 and $4\pi n\ C_3$, and B_3 is the induction produced by this resultant M.M.F.

In the simple case in which the copper circuit is non-inductive, and, when magnetic lag is neglected, the relations between m_3, C_3, and $\alpha\ B_3$, can easily be expressed by a vector diagram, as follows:—

Draw a line OF (Fig. I.), to represent in amplitude and phase the resultant flux $F = \alpha B_3$ multiplied by the reluctance of the ring.

Fig. I.

Variation of F generates an *e.m.f.* whose amplitude is $3\omega n F$ and whose phase position is 90° behind OF.

[$2\pi/\omega = T$=period of fundamental, and n=number of magnetizing turns on ring.]

This *e.m.f.* produces a current equal to $3\omega n$F over r, where r is the resistance of the circuit, and hence the reacting M.M.F. is—

$$= \frac{12\pi\omega n^2 F}{r} = \frac{12\pi\omega n^2 a}{r} B_3 = X \text{ say,}$$

and whose phase position is 90° behind B_3.

Hence, from F, draw FM perpendicular to OF and equal to X. The vector MF completely represents X. Join OM. OM will represent the M.M.F. m_3 arising from B_1 in the iron, for the resultant of m_3 and X is OF, which is the final M.M.F. producing the resultant flux F or aB_3.

From the above we see that B_3 is always reduced in amplitude and shifted in phase by this reflecting action of the iron, and more so as the resistance (and, therefore, in general, the impedance) of the magnetizing circuit is less.

It is easy to show that the amount of reflected energy is proportional to the area of the triangle OMF.

3. In the above we saw that the M.M.F. due to reactions is—

$$\frac{12\pi\omega n^2 a}{r} B_3$$

and dividing by l, the length of the magnetic circuit, we get the magnetizing force due to reactions—

$$= \frac{12\pi\omega n^2 a}{r\,l} B_3 = \frac{12\pi\omega}{r} \frac{n^2}{l^2} l a\, B_3 = \frac{12\pi\omega}{r} N^2 V B_3$$

where N is the number of magnetising turns per unit length, and V is the volume of the iron.

Hence these disturbing reactions are, all other things being equal, directly proportional to the volume of the iron used, and inversely as the impedance of the magnetizing or other circuits that may embrace the ring.

The fact that the effect is proportional to the volume of iron used follows at once from general principles, if we admit that the effect is due to some peculiar action in each ultimate magnetic particle.

[The above discussion will, with slight modifications, apply to the action of eddy currents in modifying the induction produced in iron by periodic magnetizing forces.]

4. In order to keep this disturbing action small, the experiments described in this paper were performed on a small single annular

lamina of annealed transformer iron of which the details are as follows:—

Internal diameter	7·56 cm.
External diameter	10·16 cm.
Mass	9·13 grams
Density	7·76
Length of magnetic circuit	27·86 cm.
Section of magnetic circuit	·04225 cm².
Thickness	·03275 cm.
No. of primary turns	125
No. of secondary turns	10 or 20
Specific resistance of the iron at 15°C	13600.

Its magnetic properties, statically determined by Ewing and Classen's method, are given below. U representing the hysteresis loss per c.c. per cycle—

$B_{max.}$ ...	3989	6431	9076	13200
$H_{max.}$ ...	1·456	2·451	4·321	11·65
μ	2740	2624	2100	1133
U	930	2020	3830	7750

The values of U, which were required for values of $B_{max.}$ intermediate to and beyond the above four values of $B_{max.}$, were obtained as follows:—On a large sheet of squared paper we plotted from the above the log U against log B_{max}. The four points lay on a line nearly straight with slight but regular curvature. From this line, when extended, all the values of U, made use of in the tables that are to follow, were calculated.

5. The arrangement of the apparatus by means of which the first three series of results given below were obtained was practically identical with that already described by one of us.*

The magnetizing current was obtained from a four-pole rotary converter supplied with direct current from storage cells. The speed was regulated by means of a rheostat in its field circuit, and by varying the number of cells used while it was continuously determined by means of a chronograph. The magnetizing current was adjusted to any required value by means of a Kelvin Balance and an adjustable inductance. The reducing factor of the galvanometer used with the wave tracer was determined by means of a Clark cell and a megohm.

The second three series of results were obtained by means of a new wave tracer, the commutator of which was attached to the spindle of a 12-pole alternate current generator, whose armature is surface wound, and which was driven by a direct current shunt motor. The A.C. generator supplied the magnetizing current. The other details of the arrangement were exactly as for the first three series.

From both these sources we obtained a magnetizing current of approximately sine wave form, but the variation from the sine form in the two was essentially different.

Thus if the magnetizing force was—

$$H = H_1\{\sin \omega t + h_3 \sin 3\,(\omega t - \phi_3) + h_5 \sin 5\,(\omega t - \phi_5) + \&c.\}$$

in the case of the rotary converter h_3 was negative while in that of the generator h_3 was positive.

* Lyle. Variation of Magnetic Hysteresis with Frequency. Phil. Mag., Jan., 1905.

In addition it was possible to insert a much larger inductance in the magnetizing circuit when the generator was used and so keep down the reactions explained in section 2.

The procedure in any one experiment has also been described.* In every case a full wave was taken, the ordinates being 12° in phase apart. The wave forms having been analysed, the results were reduced to absolute measure by applying to them the proper factors† to reduce them to magnetic intensity and induction respectively, in the form—

$$H = H_1 \{\sin \omega t + h_3 \sin 3 (\omega t - \phi_1) + h_5 \sin 5 (\omega t - \phi_5) + \&c.,\}.$$

$$B = B_1 \{\sin (\omega t - \theta) + b_3 \sin 3 (\omega t - \theta_3) + b_5 \sin 5 (\omega t - \theta_5) + \&c.\}.$$

From these the value of I, the total iron loss per c.c. per cycle, was calculated by the formula—

$$I = \frac{H_1 B_1}{4} \left\{ \sin \theta_1 + 3h_3 b_3 \sin 3 (\theta_3 - \phi_3) + 5h_5 b_5 \sin 5 (\theta_5 - \phi_5 + \&c. \right\}$$

which can be shown to be—

$$= \frac{1}{4\pi} \int H\, dB.$$

The eddy current loss E, which is part of I, was calculated, as in the paper already quoted from the formula—

$$E = \frac{\pi^2 x^2}{6\rho T} \mathfrak{B}^2$$

where x = thickness, ρ = specific resistance, T = period, and $\mathfrak{B}$, which has been called the effective induction, is given by—

$$\mathfrak{B}^2 = B_1^2 \{ 1 + 9b_3^2 + 25b_5^2 + 49b_7^2 + \&c.,\}.$$

U the statical hysteresis having been determined for each experiment as explained in section 4, the difference I — (E + U), which Fleming has called the kinetic hysteresis, was also obtained for each experiment, and is given in the tables that are to follow.

6. Tables I., II., III., which follow, embody the results, completely reduced, which were obtained when the magnetizing current was taken from the rotary converter, while tables IV., V., VI., those when the alternator was used.

Frequencies up to 200 per sec. could be obtained with the generator, while about 60 per sec. was the highest frequency at which the rotary would work satisfactorily.

The meanings of the different symbols in the tables are given by—

T = period

$$H = H_1 \{\sin \omega t + h_3 \sin 3 (\omega t - \phi_3) + h_5 \sin 5 (\omega t - \phi_5) + \&c.\}$$

$$B = B_1\{\sin (\omega t - \theta) + b_3 \sin 3 (\omega t - \theta - \psi_3) + b_5 \sin 5 (\omega t - \theta - \psi_5) + \&c.\}$$

$$\mu_0 = \frac{B_1}{H_1},\ \mu = \frac{B\ \max.}{H\ \max.},\ \omega \mathfrak{B} = \sqrt{2}.\ \text{R.M.S.} \left(\frac{dB}{dt}\right).$$

I = total iron loss per c.c. per cycle.
E = calculated eddy current loss per c.c. per cycle.
U = statical hysteresis for B max. of experiment.

* *Loc. cit.*
† T. R. Lyle. Phil. Mag. [6] vol. VI., p. 549 (1903).

Table I.

T	H_1	$-h_3$	ϕ_3	$-h_5$	ϕ_5	$H_{max.}$	B_1	θ	b_3	ψ_3	b_5	ψ_5	b_7	ψ_7	b_9	ψ_9	$B_{max.}$	μ_0	μ	I	U	E	K	𝔅
			°		°			°		°		°		°		°								
·0836	·868	·0581	2·65	·0151	−2·7	·943	1924	38·27	·1337	16·52	·0370	22·78	·0173	28·77	·0049	30·60	1816	2217	1926	255	—	6·9	—	2116
·0836	1·380	·0441	2·25	·0050	4·40	1·445	4292	39·30	·1842	10·52	·0621	12·22	·0122	16·92	·0155	15·20	3856	3110	2670	916	880	39	—3	5056
·0834	1·931	·0463	3·07	·0083	12·80	2·014	6225	35·63	·1995	7·69	·0771	9·12	·0337	9·77	·0192	10·37	5466	3224	2714	1670	1549	96	25	7874
·0832	2·410	·0501	4·08	·0044	15·72	2·534	7640	31·97	·2016	6·27	·0803	7·85	·0383	7·08	·0269	8·02	6508	3170	2568	2309	2080	160	69	10170
·0842	4·520	·0529	2·40	·0093	−8·7	4·804	11300	22·73	·2146	3·00	·0964	3·20	·0613	3·33	·0297	3·62	9635	2500	2046	4530	4140	369	21	15520
·0826	8·710	·0497	3·13	·0133	12·45	9·270	14630	14·92	·2193	1·90	·0975	1·85	·0651	2·42	·0319	2·60	12410	1680	1338	7450	6607	676	167	20800

Table II.

T	H_1	$-h_3$	ϕ_3	$-h_5$	ϕ_5	$H_{max.}$	B_1	θ	b_3	ψ_3	b_5	ψ_5	b_7	ψ_7	b_9	ψ_9	$B_{max.}$	μ_0	μ	I	U	E	K	𝔅
			°		°			°		°		°		°		°								
·0328	·665	·0328	5·52	·0011	9·33	·684	550	24·52	·0525	24·47	·0297	30·00	·0076	38·18	·0027	—	534	827	781	37·6	—	1·2	—	565
·0319	1·033	·0405	4·30	·0057	12·87	1·076	1781	40·00	·1080	18·05	·0210	22·82	·0063	34·95	·0052	—	1719	1725	1597	294	257	14·5	23	1897
·0320	1·197	·0424	5·67	·0085	12·00	1·251	2996	46·00	·1358	14·77	·0316	21·38	·0101	26·65	·0028	—	2863	2504	2288	641	560	43	38	3277
·0322	1·733	·0321	6·20	·0023	7·40	1·788	5280	44·05	·1642	10·37	·0508	14·83	·0149	18·43	·0050	19·0	4770	3047	2668	1590	1230	147	213	6060
·0322	2·401	·0302	4·82	·0019	9·38	2·442	7176	38·18	·1888	7·48	·0655	10·90	·0258	12·92	·0101	13·0	6278	2989	2571	2558	1928	304	326	8704
·0322	5·659	·0308	7·38	·0080	12·37	5·779	12150	24·63	·2164	3·75	·0903	5·42	·0468	5·95	·0246	6·62	10320	2147	1786	6800	4790	1073	937	16370
·0320	11·80	·0320	4·00	·0079	0·30	12·06	15700	15·53	·2284	1·57	·1035	2·78	·0579	3·43	·0371	4·35	13190	1330	1094	11570	7740	2100	1730	22820
·0328	24·62	·0269	2·05	·0121	2·45	25·11	18520	8·97	·2563	1·00	·1250	1·50	·0791	2·02	·0567	2·57	15240	752	607	16730	10300	3740	2690	30840

Table III.

T	H_1	$-h_3$	ϕ_3	$-h_5$	ϕ_5	$H_{max.}$	B_1	θ	b_3	ψ_3	b_5	ψ_5	b_7	ψ_7	b_9	ψ_9	$B_{max.}$	μ_o	μ	I	U	E	K	𝔅
			°		°					°		°		°		°								
·0203	·584	·0417	3·27	·0012	−7·63	·616	319	21·67	·0407	23·97	·0125	37·85	·0061	44·52	·0052	42 42	316	546	513	17	—	—	—	323
·0202	·879	·0343	4·95	$\overline{\cdot0044}$	$\overline{13\cdot53}$	·914	996	33·75	·0736	21·93	0131	31·82	·0108	45·82	·0021	42·62	974	1133	1066	120	—	6·7	—	1024
·0202	1·170	·0379	3 50	$\overline{\cdot0031}$	$\overline{4\cdot42}$	1·222	2584	48 30	·1062	17·77	0174	26·05	·0067	38·07	·0011	—	2508	2210	2052	566	450	48	68	2725
·0201	1·711	·0375	5·53	$\overline{\cdot0030}$	$\overline{10\cdot62}$	1·793	4958	50·20	1398	13 08	·0344	19 05	0064	23·08	·0028	25·33	1570	2898	2549	1625	1150	190	285	5450
·0200	2·738	0378	3 65	0032	15 55	2·842	7912	42·80	·1789	8·45	·0546	12·70	·0184	15·53	·0069	16·70	7038	2889	2476	3613	2370	555	688	9275
·0200	3·862	·0364	4·68	·0066	17·33	4·035	9954	36·35	·2006	6·85	·0633	8·62	·0280	11·17	·0128	11·25	8622	2577	2137	5464	3460	967	1037	12250
·0202	6·684	·0361	1·92	·0090	10 73	6·95	12970	25·97	·2167	4·28	·0800	6·12	·0481	6·73	·0259	7·68	11060	1941	1592	8920	5530	1878	1512	17150
·0202	10·89	·0411	0·13	·0075	10·50	11·38	15380	19·88	·2240	2·08	·0962	4·10	·0549	4·37	·0377	4·52	12810	1412	1126	13050	7260	2938	2852	21450

Table IV.

T	H_1	h_3	ϕ_3	h_5	ϕ_5	$H_{max.}$	B_1	θ	b_3	ψ_3	b_5	ψ_5	$B_{max.}$	μ_o	μ	I	U	E	K	𝔅
			°		°			°		°		°								
·0197	·821	·0234	11·82	·0042	11·25	·797	768	23·48	·0794	17·17	·0083	33·45	719	935	902	63	...	...	...	...
·0199	1 000	·0286	9·15	·0065	12·48	·960	1755	36·43	·0804	13·53	·0078	34·87	1666	1755	1736	263	245	21	—3	1805
·0197	1·793	·0313	15·60	·0035	5·30	1·721	5000	46·38	·1443	8 78	·0301	9·00	4522	2789	2626	1622	1135	200	287	5533
·0198	2·843	·0272	7·77	·0056	7·47	2 780	7948	37·83	·1847	6 07	·0552	10·25	6895	2796	2480	3545	2270	583	692	9436
·0198	4·429	·0269	11·27	·0047	21·27	4·292	10600	30·00	·2178	5·05	·0879	6·65	9079	2393	2115	6065	3590	1280	1195	13980
·0196	5·125	·0281	14·70	·0034	14·50	5·014	11350	27·88	·2251	3·53	·0841	5 90	9518	2214	1898	6460	3830	1480	1150	15030
·0198	8·70	·0297	27·30	·0017	12·60	8·69	14190	20·72	·2436	2·57	·1017	4·83	11860	1631	1365	10790	5284	2725	2781	20400
·0198	9·96	·0316	27·18	·0030	13·27	9·89	14890	19·75	·2420	2·42	·1066	3·90	12360	1495	1250	12270	5636	3000	3634	21400

Table V.

T	H_r	h_3	ϕ_3	h_5	ϕ_5	$H_{max.}$	B_r	θ	b_3	ψ_3	b_5	ψ_5	$B_{max.}$	μ_o	μ	I	U	E	K	$\mathfrak{B}$
			°		°			°		°		°								
·0106	·931	·0287	3·33	·0031	3·70	·905	1159	37·42	·0525	11·77	·0077	28·0	1110	1245	1226	163	133	17	13	1175
·0106	1·545	·0274	8·47	·0028	4·28	1·503	3247	51·42	·0633	13·47	·0070	31·10	3097	2102	2061	983	631	133	219	3309
·0106	2·327	·0277	7·78	·0044	12·12	2·268	5948	51·53	·1086	9·85	·0136	19·55	5477	2556	2415	2719	1549	480	690	6283
·0106	3·601	·0251	8·22	·0037	9·28	3·513	9122	44·18	·1542	7·22	·0338	13·72	8090	2533	2304	5813	3055	1239	1519	10090
·0105	6·302	·0273	9·53	·0037	3·07	6·188	12510	32·65	·2063	4·38	·0715	7·18	10650	1981	1721	10980	5176	2965	2839	15610
·0106	12·47	·0255	15·42	·0045	17·97	12 28	15950	20·50	·2371	2·47	·0982	4·08	13270	1279	1081	17820	7760	6020	4040	22240

Table VI.

T	H_r	h_3	ϕ_3	h_5	ϕ_5	$H_{max.}$	B_r	θ	b_3	ψ_3	b_5	ψ_5	$B_{max.}$	μ_o	μ	I	U	E	K	$\mathfrak{B}$
			°		°			°		°		°								
·00572	·924	·0331	0·62	·0060	0·58	·896	834	33·02	·0315	8·95	·0061	9·6	810	902	904	105	...	15·8	...	838
·00571	1·320	·0330	1·00	·0045	1·27	1·275	1777	46·27	·0219	16·70	·0045	—	1751	1346	1373	424	236	72	86	1782
·00564	1·826	·0288	3·77	·0053	5·63	1·781	3261	56·03	·0328	16·93	·0030	—	3201	1786	1797	1215	660	245	310	3277
·00565	3·044	·0293	5·77	·0038	6·72	2·969	6662	56 60	·0703	11·97	0044	23·3	6328	2189	2131	4227	1968	1059	1200	6809
·00549	5·622	·0287	3·37	·0058	3·32	5·488	11380	43 60	·1393	6·93	·0245	13·6	10180	2024	1855	11190	4720	3618	2852	12410
·00549	11·91	·0259	7·93	·0039	8·08	11·66	15640	27·15	·2046	3·33	·0630	6·43	13270	1313	1138	21970	7800	8640	5530	19180

Attention will now be directed to a few of the more important results contained in the foregoing tables.

7. The influence of the wave form of H on the induction produced can be clearly seen by comparing Tables III. and IV. In these two series the periods of the oscillations were practically the same, but for the series in Table III., which was obtained by using the rotary converter, the average wave form of H is given by—

$$L = \sin \omega t - \cdot 038 \sin 3 (\omega t - 3 \cdot 5^\circ) - \&c.,$$

while for the series in Table IV., obtained from the generator, the average wave form of H is given by—

$$M = \sin \omega t + \cdot 028 \sin 3 (\omega t - 15^\circ) + \&c.$$

[L is of the peaked, while M is of the flat type of wave form.]

It must be remembered, however, that in every case H is due to the magnetizing current which is produced by the resultant *e.m.f.* in the magnetizing circuit, and the components of this resultant are the *e.m.f.* of the source (converter or generator as the case may be), and the *e.m.f.* due to the reaction of the iron ring.

In these experiments the latter was kept relatively small by using a small sample of iron (as explained in sections 3 and 4), and by using a high *e.m.f* of the source, the required magnetizing current being obtained by inserting ironless inductances in the circuit.

L and M are practically the wave forms of the *e.m.fs.* on open circuit of the two sources used.

On Fig II. are plotted from Tables III. and IV. the characteristics μ_0, θ, b_3, and the iron loss I, against different values of B_1, the amplitude of the first harmonic of the induction, as abscissæ, when these two wave forms of magnetizing current were used, the period being practically the same for both series.

It will be noticed that though the iron loss points for both series fall practically on the same curve, yet there are considerable differences between corresponding values of the other characteristics.

On referring to the formula for I in section 5, and to the values for h_3, h_5, &c., b_3, b_5, &c., in Tables III. IV., it will be found that in the series with wave form L, I_3, I_5, &c., the energies dissipated in the iron through the 3rd, 5th, &c., harmonics are negative, while in the series with the wave form M, I_3, I_5, &c., are positive. Thus, with wave form L, electric energy which had been received from the magnetizing circuit through the fundamental harmonic was reflected back to the circuit by means of the higher harmonics, while with the wave form M electric energy was received from the circuit through all the harmonics and dissipated as heat in the iron.

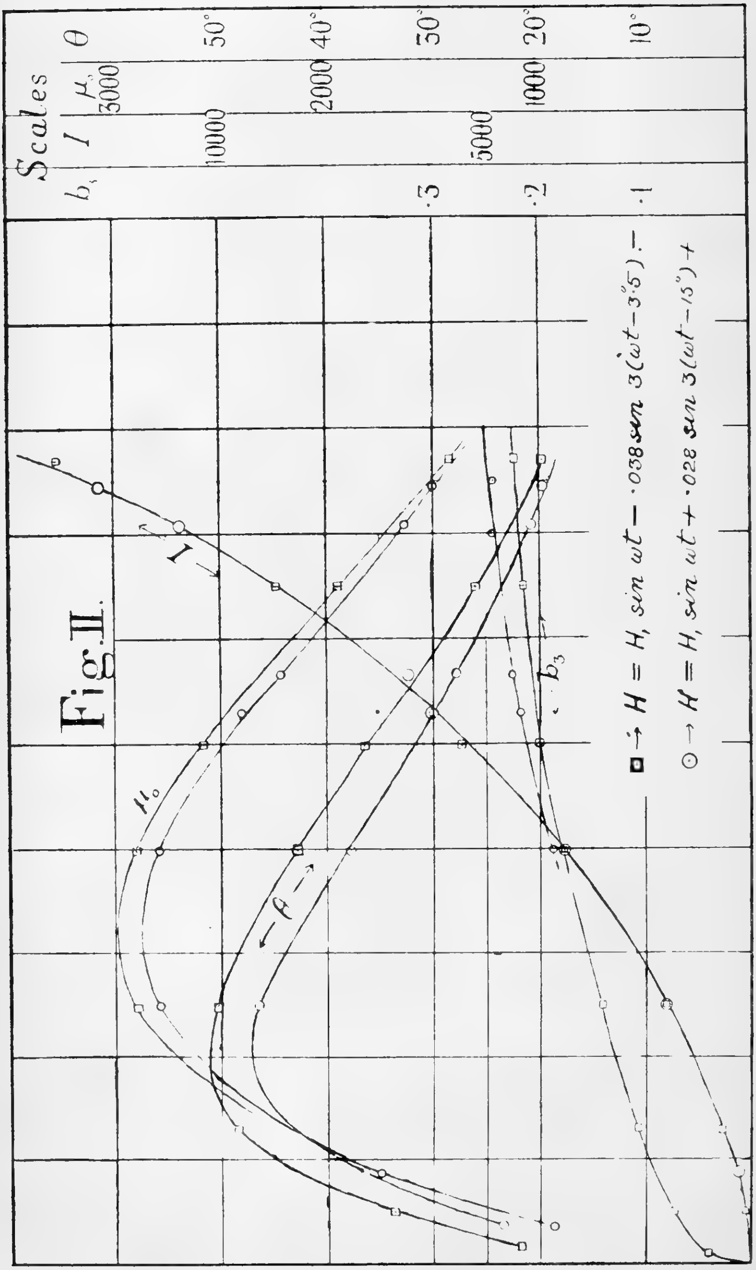
As the total loss I is the same (*q.p.*) for both, I_1 (*i.e.* energy received by the first harmonic), in the case of L must be greater than I_1 in the case of M, but (see section 5)—

$$I_1 = \frac{H_1 B_1 \sin \theta}{4} = \frac{1}{4} B_1^2 \frac{\sin \theta}{\mu_0}$$

and as we find that θ and μ_0 are both greater for L than for M_1 a small difference in I_1, that is in $\sin \theta / \mu_0$ for the same value of B_1 will cause, as we find, a large change in the corresponding values of θ and μ_0 for the two series.

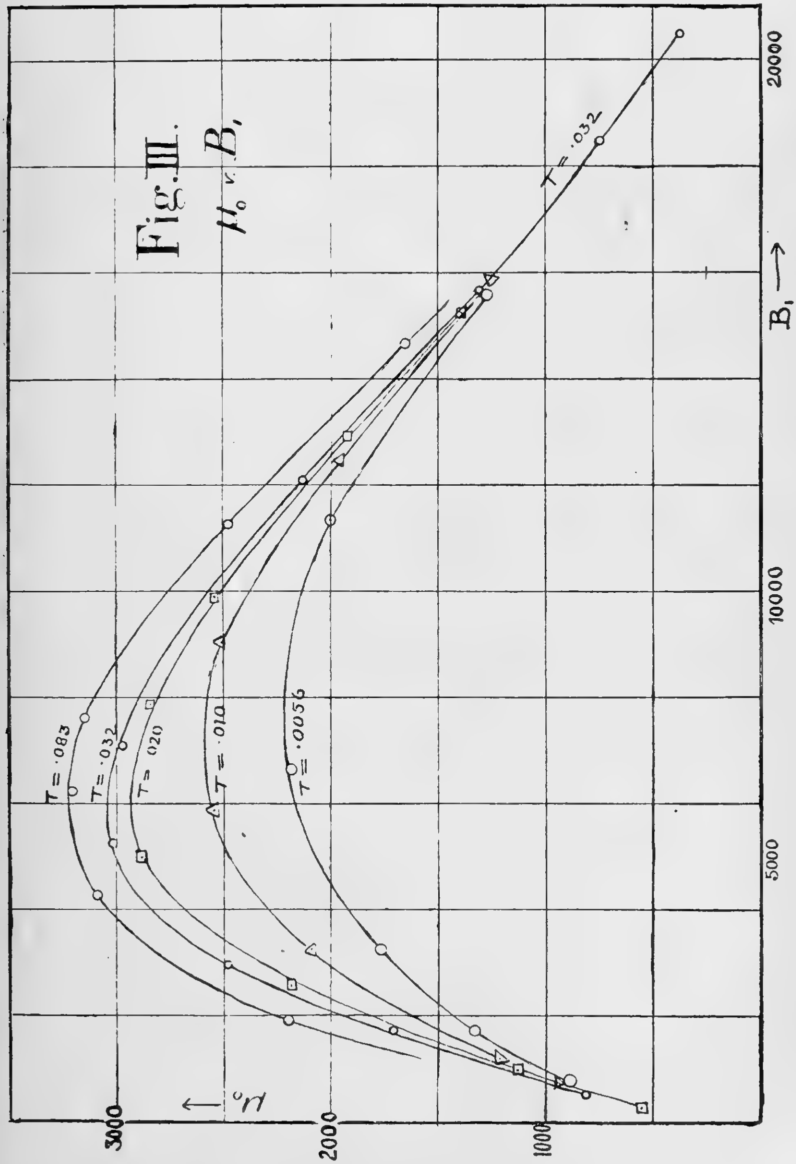
It will also be seen in Fig. II. that the values of b_3 for the L wave form are less than corresponding ones for the M wave form.

This result is as would be expected from general considerations. In the case of M energy is received which becomes magnetic before



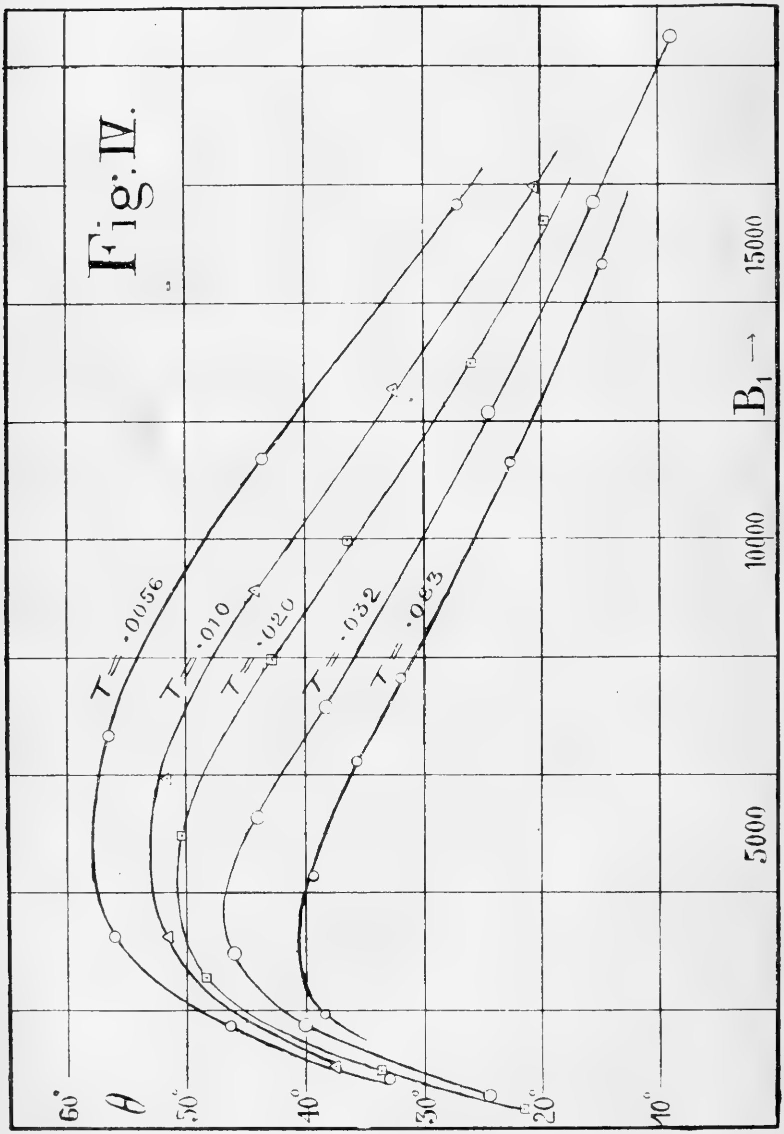
being dissipated as heat. To effect this b_3 the amplitude of the magnetic oscillation is made greater than its value due to B_1 alone—that is, than its value if H were of pure sine form $= H_1 \sin \omega t$ without upper harmonics.

In the case of L some of the energy received from B_1 is sent out, and so less magnetic energy is dissipated in the iron, and this is effected by the amplitude of b_3 being reduced.



The b_3 curve for pure sine excitation must therefore lie between the two curves for $\bar{b}_3$ in Fig. II.

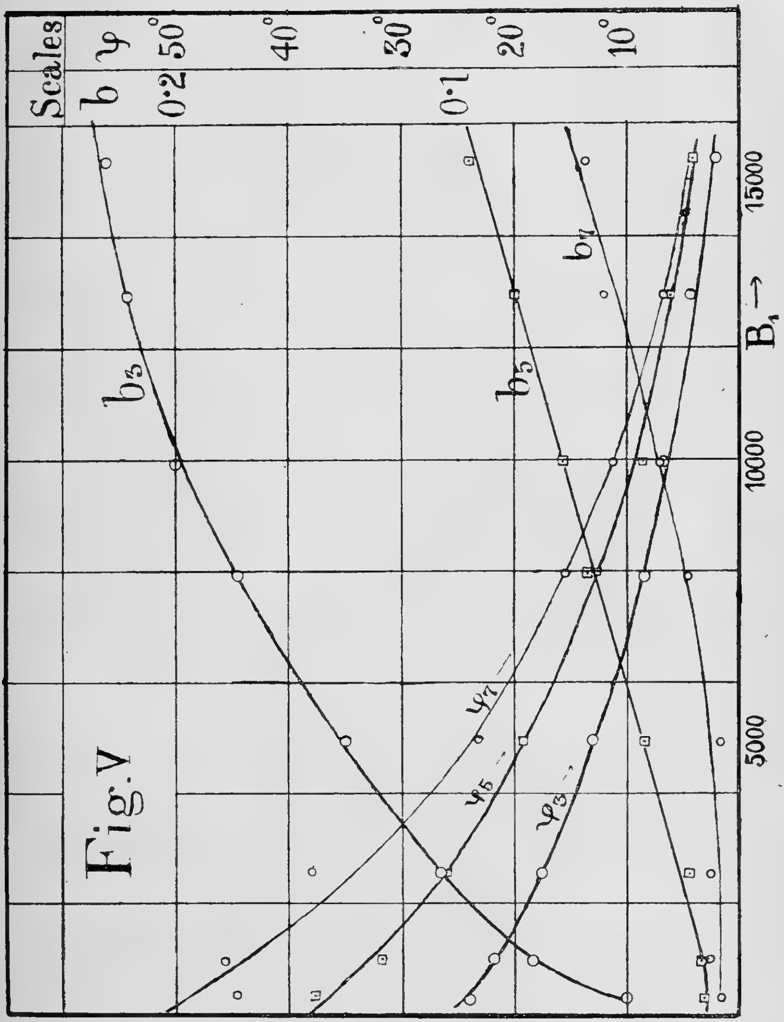
8. The most important of the magnetic characteristics of iron are μ_0 and θ, as from these its behaviour is to the first order determined.



The curves in Fig. III. show how μ_0 varies under different conditions of induction density and frequency, while the curves in Fig. IV. show the variations of θ.

As the induction B_I approaches zero both μ_o and θ seem to tend to definite small values which are independent of the frequency, while as B_I gets very large μ_o again seems to tend to low values that are independent of the frequency.

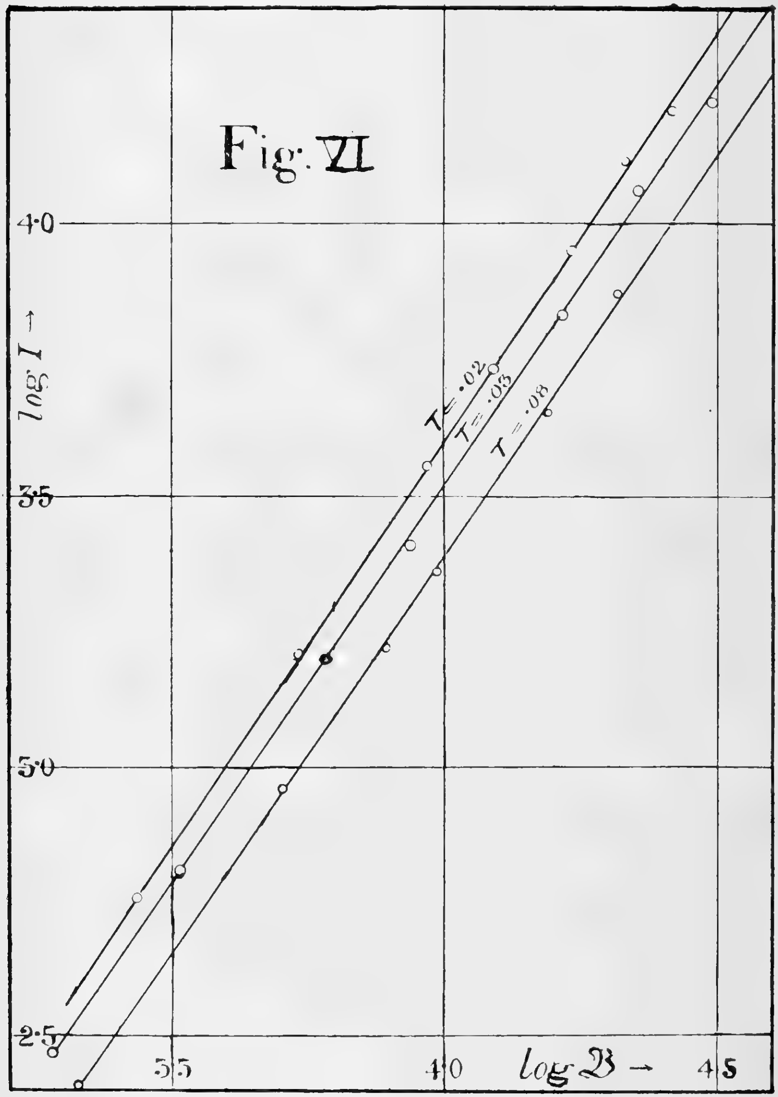
We have been unable to find any simple formula by which the relations of either μ_o or θ to B_I and T can be expressed.



9. The characteristics of the upper harmonics of the induction are plotted against B_I (from Table III.) in Fig. V. It will be seen that b_3 is not linear in B_I as was suggested by one of us in a former paper. The present results were obtained in any one series with practically constant wave form for all inductions, while the former

were obtained with wave forms of H which steadily departed more and more from the sine form as the induction increased.

It is worth noting, however, that in the series represented in Fig. V., b_3 is concave to the B_1 axis, b_5 is a straight line, and is therefore linear in B_1, while b_7 is convex to the B_1 axis.



On the same diagram the corresponding phase angles ψ_3, ψ_5, ψ_7 of b_3, b_5, b_7 are plotted, and the curves show the gradual slipping backwards along the time axis of the rising points of the b_3, b_5, b_7 sine curves towards the rising point of the B_1 sine curve as the induction increases, until, at saturation, the rising points of all higher harmonics become coincident with that of the first harmonic of the induction.

For purposes of more critical investigation, a series of b, ψ, curves such as those in Fig. V., together with corresponding ones such as are given in Figs. III., IV., for μ_0 and θ for the same speed, would enable one to construct a series of induction waves for that speed from which the experimental errors and slips in reduction (which we can hardly hope are entirely absent from this work) would be partly eliminated.

10. With regard to the formula—

$$I = (a + bn)\,\mathfrak{B}^x$$

proposed by one of us, we find that it is only an approximate representation of the facts x the index of $\mathfrak{B}$ is not independent of the frequency, and, probably, not of the wave form of H. That it is a fairly close approximation, however, when one type of exciting current is used and the range of frequency not very large, is shown by Fig VI., in which log I is plotted against log $\mathfrak{B}$ from Tables I., II., and III. The points for each frequency are seen to fit closely to a straight line, and the three lines for the three frequencies are very nearly parallel, the slope showing a slight tendency to increase as the frequency increases.

The formula—

$$I = (\cdot 00257 + \cdot 00006\,n)\,\mathfrak{B}^{1\cdot 467}$$

gives the values of I in these three series with considerable accuracy.

For frequencies higher than 50 per sec. the above formula does not apply. For any one frequency, however, I is given by an expression of the form $\sigma\mathfrak{B}^x$. Thus for series IV. in which—

$$n = 50\ (q.p.)\ I = \cdot 00371\,\mathfrak{B}^{1\cdot 5},$$

for series V. in which—

$$n = 100,\ I = \cdot 00424\,\mathfrak{B}^{1\cdot 528},$$

and for series VI. in which—

$$n = 179,\ I = \cdot 00214\,\mathfrak{B}^{1\cdot 64}.$$

Obviously further investigation on this subject is needed.

11. The former conclusions as regards the actuality of such a quantity as Kinetic hysteresis, and the general way in which it varies with induction density and frequency, are fully verified by the present investigation, as a glance down the columns under K in the tables will show.

8.—PHOTOGRAPHS OF ARC SPECTRA OF METALS UNDER HIGH PRESSURE.

By W. GEOFFREY DUFFIELD, D.Sc.

In 1896 it was discovered by Humphreys and Mohler* that when a source of light was subjected to pressure, the spectral lines were in general broadened and displaced towards the red end of the spectrum; that is to say, the rapidity of the vibration was diminished by pressure.

The present research was undertaken in the physical laboratories of the Manchester University in 1904, at the suggestion of Dr.

* Astrophysical Journal, vi., 161, 1896.

Schuster, with the object of repeating and extending the work of Humphreys and Mohler, which then only concerned pressures as high as 14½ atmospheres. In 1906 the writer showed to the British Association† photographs of the iron arc under pressures of +3, +4, +5, +10, +15, +20, +25, +30, +40, +50, +60, +80, and +100 atms., and presented in 1907 a detailed account of the work.‡ At the same time (1907) Humphreys§ published the displacements of lines of iron and various metals under pressures of 42, 69, and 101 atmospheres. Photographs have now been obtained by the writer of the spectrum of the copper,|| silver, iron, gold, and metal arcs up to 200 atmospheres, and alloys have also been investigated up to the same pressure. The apparatus consists of a drawn steel cylinder (designed by Dr. J. E. Petavel, F.R.S.), 2 ft. long, 3 in. internal, 5 in. external diameter. Heavy covers are bolted to the top and bottom, and these are furnished with insulated stuffing-boxes through which pass steel rods, to whose ends can be clamped the electrodes whose spectrum is required. These were connected with the terminals of the corporation mains at 100 volts, and an arc formed between them opposite a glass window in the side of the cylinder. The light was examined by means of a large Rowland grating spectograph (21½ ft. radius), which, in the second order, gave a dispersion of 1 mm. = 1·3 A. Us.

Iron presents a spectrum whose lines exhibit most of the phenomena associated with pressure changes. The effects first noticeable as the pressure is increased are the broadening of the lines and their tendency to reverse, but careful examination also shows that they are displaced from their original positions by an amount which is greater as the pressure is increased. To compare the original and displaced lines it is usual to employ a comparison shutter, which allows the central strip of the plate to be exposed to the normal arc, and then covers that part of the plate and exposes the rest of it to the spectrum given by the arc under pressure. The two are then in close juxtaposition, and the displacements are easily seen, and are measureable.

Careful measurements of the displacements of the iron lines show that three groups exist with displacements in the ratio of 4 : 2 : 1. The unsymmetrically reversed lines are anomalously displaced, the reversal being displaced half as much as the non-reversed part. From this we learn that the outer envelope of an arc does not necessarily absorb the most intense vibration emitted by the central core. Forty thousand measurements of the displacement of sixty lines were necessary for the determination of the relationship of the displacement to the pressure up to 100 atmospheres. The plates taken between 100 and 250 atmospheres are now being measured by an assistant at the Manchester University, and, as far as has at present been ascertained, there is no discontinuity throughout the whole range of pressure. The relation between the pressure and the displacement is in general a linear one, though some anomalous readings

† Brit. Assocn. Report, York, p. 481, 1906.

‡ Roy. Soc. Proc., 1907; Phil. Trans. Roy. Soc., *208*, iii., 1908.

§ Astrophysical Journal, *26*, 18, 1907.

|| Roy. Soc. Proc., A., *81*, 378, 1908.

were obtained in the neighbourhood of 25 atmospheres, where some plates gave values for the displacement twice those found on other plates. This result has been discussed more fully elsewhere.* The evidence favours the probability of there being two values for the displacement of a given line at any one pressure. This point, however, requires further examination before it is finally established.

Between 100 and 215 atmospheres there is a marked increase in the number of reversals in the ultra violet part of the spectrum, which assists in the resolution of the spectrum into series of lines, and also into well-marked triplets.

Copper.—Very few of the copper lines reverse under pressure besides the strong members of the principal series, 3247, 3274, but the broadening and displacement are pronounced; at 200 atmospheres the displacement being nearly 2 Angström units. The most striking feature is the disappearance of the lines belonging to the first and second subordinate series within the region λλ 4000-4600. The systems responsible for these vibrations do not appear to exist at high pressures.

Gold.—Two rods of gold, $1\frac{1}{2}$ in. long, $\frac{5}{8}$ in. diameter, were obtained from Messrs. Johnson and Matthey, of Hatton Gardens, London, and these were screwed to the ends of the electrodes. The gold arc burnt well under pressure, but not so brightly as other metallic arcs. The lower poles burnt away rapidly, the molten metal running down the sides much as does the wax from a candle. Slides are presented showing the behaviour of this spectrum at 200 atmospheres.

Nickel.—Photographs have also been taken with the poles of this metal at pressures up to 200 atmospheres.

Silver.—Under pressure the spectrum of this metal undergoes most remarkable changes. At atmospheric pressure silver gives a line spectrum closely resembling that of copper, save that the doublets are more widely separated; but, as the pressure of the surrounding air is increased, this gradually vanishes, and gives place to a banded spectrum which is not unlike that obtained when silver is heated in a carbon-tube furnace, but actual identification of the bands is difficult since the latter spectrum was obtained at atmospheric pressure.†

Increase of pressure up to 80 atmospheres effects the gradual change of the banded spectrum into a continuous spectrum, which may be regarded as being due to the broadening of each individual band. Another peculiarity is the structural appearance of the broadened lines of the first subordinate series (which, in the region, λλ 4000 to 4600 seem responsible for the banded spectrum).

A remarkable feature is the appearance on plates taken between 5 and 20 atmospheres of pronounced bands (of doubtful origin) in the neighbourhood of 3914. They present a unique phenomenon in that one of the two heads is displaced towards the violet. This is the first

* Phil. Trans. Roy. Soc., 208, iii., 1908.

† Duffield and Rossi, Astrophysical Journal, 1908.

record of—(1) The displacement of a band spectrum under pressure; (2) a displacement being directed towards the violet. This latter phenomenon is shared by some lines in the ultra-violet region.

It is at present uncertain whether the banded spectrum is due to an oxide or to some molecular grouping of the atoms of silver alone. Hartley, in considering his fluted flame spectrum, inclines to the latter view; whichever be the case, the spectrum at high pressures is that characteristic of a molecular or compound substance, and it is interesting to note that at the high temperature of the silver arc such a spectrum can be produced. The existence of banded spectra in sun spots has generally been accepted as evidence that they are regions of low temperature, but it is not out of the question that they are areas of high temperature, and of great pressure, since the latter agency seems capable of counterbalancing the tendency to dissociation occasioned by the former. Whittaker pointed out, before he was aware of these results, that, from theoretical considerations based on Willard Gibbs' work, this effect was to be expected.

9.—INTERNATIONAL SOLAR RESEARCH.

(Abstract of Paper presented to Section A of the Australasian Association for the Advancement of Science, Brisbane Meeting, 1909.)

By W. GEOFFREY DUFFIELD, D.Sc., F.R.A.S.

An account is given of the work carried on at the Mount Wilson and South Kensington Solar Physics Observatories, and slides, kindly supplied by Professor Hale, illustrate a portion of the equipment of the Mount Wilson Observatory, and show the nature of the sun's surface when photographed in the light emitted by hydrogen, calcium, and iron vapours. The investigations into solar radiation, solar rotation, and the spectrum and nature of sun spots are discussed, and the work of the International Union for Solar Research is detailed, and an account given of the steps that have been taken to secure Australian co-operation in the international scheme, which is especially desirable, for the following reasons:—

(1) Australia's position in longitude is such that an Australian station would fill a gap at present existing in the chain of observatories round the earth, and enable the sun to be kept under continual observation throughout the whole of the 24 hours.

(2) Australia's position in latitude makes her co-operation especially valuable, because no station devoted to solar physics exists south of the equator, where one is necessary to examine the question of solar radiation, and to determine if the fluctuations recorded by the American Observatories are due to local or solar changes.

(3) Australia's climatic conditions are uniquely favourable, both because her skies are clear and the sunshine is almost unfailing, and also because observations would be possible at a time when the rainy season in India, America, and Western Europe prevents observations from being satisfactorily made.

Besides the theoretical importance of solar study in its relation to the problem of stellar and inorganic evolution, there is the reasonable hope that a knowledge of the relationship between solar and terrestrial phenomena may prove of practical service to mankind. It is interesting to note that India has erected a solar observatory, in the belief that it will ultimately prove of value in famine prediction.

10.—POLAR LINES IN ARC SPECTRA.

By W. GEOFFREY DUFFIELD, D.Sc.

Several writers have chronicled the occurrence of "spark" lines in arc spectra. Fowler* has described the appearance in the spectrum of an iron arc of lines which are strongest at the poles, and diminish in intensity as they approach the centre, being, however, stronger on the positive than on the negative pole. He investigated the region F to C, and pointed out the identity of these lines with the enhanced lines of iron and with those lines that are weakened in sun spots. The ultra-violet region of the spectrum of the iron arc has been investigated by the writer,† a vertical image being focussed upon the vertical slit of the 21½-ft. Rowland grating spectograph in the Manchester University, the length of the arc being so adjusted that the tip of each pole was just included upon the slit. The astigmatism of the grating was not sufficient to mask the phenomenon. Many lines appear only on the tips of the poles in these photographs, but they differ from Fowler's in that they are of nearly the same intensity on the two poles. The arc was supplied with current from the corporation mains at 110 volts; this was continuous, but, to ensure that a superinduced alternating current was not disturbing the continuous current and producing a weak spark discharge, several photographs were taken when the arc was run from the storage batteries, and the same phenomena were again observed. It should be added that the exposure was not begun until the arc had been struck, and that it burned steadily until the shutter was closed.

In view of the fact that these lines occur in a normal iron arc, it is the writer's conviction that the term "spark" line is misleading. The term "polar" lines is suggested to distinguish those occurring most strongly at the poles of the arc or spark from those occurring most strongly at the centre, for which the term "median" lines seems suitable.

The phenomenon does not seem capable of being referred to a "temperature" effect, a conclusion which has been strengthened by Dr. G. A. Heinsalech's notable research upon spectra emitted by flames at different temperatures—he finds, for instance, that the low-temperature Bunsen flame gives a spectrum consisting almost entirely of the enhanced polar lines of iron, and that, as flames of higher temperature are employed, these lines diminish in intensity relatively to the median lines, at the highest temperature many having completely disappeared.

A list of 202 polar lines in the iron spectrum between λλ 2350 and 3,500 has been compiled, the polar lines becoming rarer

---

* Fowler.—Monthly Notices, Royal Astronomical Society, *67*, 154, 1907.
† Duffield. Astrophysical Journal, xxvii., 260, 1908.

as the wave-length increases. Direct comparison with the spectrum from a spark discharge shows that below $\lambda = 2350$ and $\lambda = 2630$ all lines have their counterparts in the polar lines in the arc, but with increasing wave length the arc becomes richer in median lines, some of which now correspond to lines from the spark discharge, and the polar lines decrease, as already stated, in number and intensity.

The origin of the polar lines and the bearing of pressure, density, temperature, and potential gradient upon the phenomenon are discussed. The distinctive character of the polar lines should assist in the resolution into series of the iron arc spectrum. In the copper arc spectrum there are differences between the lines, which admit of classification into polar arc lines (those strongest at the poles of an arc) and polar spark lines (those strongest at the poles of a spark discharge). These behave differently under different external conditions.*

In the iron arc in the extreme ultra-violet the median lines are diffuse and nebulous, the polar lines sharp. Instances are given of median lines losing in intensity in the arc when polar lines appear near them.

11.—ELASTIC SOLID ETHER, WITH TWO MODULI, SATISFYING MacCULLAGH'S CRYSTALLINE OPTICAL CONDITIONS.

By PROFESSOR A. MCAULAY, M.A., University of Tasmania.

12.—ON THE RADIUM CONTENT OF CERTAIN IGNEOUS ROCKS FROM THE SUB-ANTARCTIC ISLANDS OF NEW ZEALAND.

By C. COLERIDGE FARR, D.Sc., and D. C. H. FLORANCE, M.A.

13.—RECENT EXPERIMENTS ON THE VISCOSITY OF WATER.

By RICHARD HOSKING, B.A. (Camb.), B.Sc. (Sydney).

14.—THE SPECTRUM OF SILVER GIVEN BY A CARBON-TUBE FURNACE.

By W. G. DUFFIELD, D.Sc., F.R.A.S.

15.—THE LAWS OF MOBILITY AND DIFFUSION OF THE IONS FORMED IN GASEOUS MEDIA.

By E. M. WELLISCH, M.A., Emmanuel College, Cambridge, Eng.

ABSTRACT.

Expressions have been deduced from the kinetic theory of gases for the mobility and coefficient of diffusion of an ion, allowance being made for the increase in collision frequency due to the polarisation of the neutral molecules by the charge associated with the ion. This charge is shown to be replaceable, as far as collisions are concerned,

* Duffield. "Effect of Pressure on Arc Spectra, No. 2 Copper."—Phil. Trans. Roy. Society.

by an extension of the sphere of force of the ionic nucleus. The expressions given involve only known physical constants of the gas, and are, therefore, directly comparable with the values as determined experimentally. It is found that the observed values of the mobilities and diffusion coefficients, as well as certain deviations from the mobility-pressure law, can be approximately explained on the supposition that the ion consists of a single molecule of the gas, with which is associated a charge equal to that carried by the monovalent ion in electrolysis.

16.—THE THEORY OF THE SMALL ION IN AIR.

By WILLIAM SUTHERLAND, M.A., B.Sc.

17.—THE BLEECK-LOVE ELECTRIC BATTERY.

By W. A. BLEECK, Brisbane.

18.—ON SOME OBSERVATIONS WITH SELENIUM CELLS.

By O. U. VONWILLER, B.Sc., Sydney University, N.S.W.

19.—THE ELECTRODELESS DISCHARGE IN MERCURY VAPOUR.

By S. G. LUSBY, M.A.

20.—A NOTE ON THE ELECTRON THEORY OF THE CARBON ARC.

By PROFESSOR J. A. POLLOCK, D.Sc.

21.—THE SCATTERING OF BETA RAYS.

By J. P. V. MADSEN, B.Sc., B.E.

22.—THE SCATTERING OF X RAYS.

By PROFESSOR W. H. BRAGG, M.A., F.R.S.

23.—SHORT NOTES ON—I. TAYLOR'S THEOREM, AND II. ENVELOPES.

By PROFESSOR E. J. NANSON.

24.—UNIVERSAL RADIO-ACTIVITY. NEW EXPERIMENTS WITHOUT RADIUM.

By J. W. H. HULLETT.

25.—THE TEACHING OF MATHEMATICS.

By R. H. ROE, M.A.

26.—THE PROOF BY PROJECTION OF CERTAIN TYPES OF GEOMETRICAL THEOREMS.

By H. TOMKYS.

Section B.

CHEMISTRY.

ADDRESS BY THE PRESIDENT,

PROFESSOR T. H. EASTERFIELD, M.A., PH. D.

Victoria University College, Wellington, N.Z.

THE POSITION OF CHEMICAL RESEARCH IN AUSTRALASIA.

In the drawing up of an ideal course of study the inclusion or rejection of any subject must be eventually decided by the question of usefulness. Not that subjects which have no direct monetary value must be discarded, but rather that only those may be retained which are likely to develop the intellect and intelligence of our citizens.

Amongst the studies which will obtain greater and greater recognition from our educational authorities, I believe that chemistry stands pre-eminent, for there is none which touches human interests at so many points, has a greater power of exciting enthusiasm or of developing clear methods of thought. Like all other subjects of sterling value, such as literature, history, or mathematics, chemistry may be so badly taught as to lose its value, a fact which has had much to do with the tardy recognition given to the educational worth of the science. Too often the teaching of chemistry has been restricted to the imparting of so-called useful facts dealing with metallurgy or chemical manufactures. Such teaching, without a good foundation of philosophical chemistry, can be of little use even to the student of technology, and to the seeker after general culture it is practically valueless. Useful facts are rapidly forgotten, but the student who learns to "think in a chemical way" acquires a habit of thought which will be of value in any calling which he may follow. More than two centuries ago Robert Boyle pleaded for the study of chemistry as an independent science, and not as the handmaid to any art or profession; with all humility I would recall to Australasian chemists the soundness of the attitude which Boyle took up.

That the skilled technological chemist is of great value to the community is well recognised by our State authorities. In Australia and New Zealand together there are about 100 men holding State appointments as analysts, assayers, and Government chemists. These men are doing a most important work in protecting the public from fraud, and in helping on the development of the natural resources of the States in which they are employed. There is, moreover, in Australia and New Zealand a large number of men engaged in the teaching of chemistry. Each State has its own arrangements, and in some States the work is more effectively carried out than in others. I will make no comparisons, but merely state that all the secondary boys' schools in New Zealand which have come under my notice possess laboratories, and that personal observation has convinced me that in these schools a good foundation of chemical knowledge is being laid.

From the above statements, which it would not be without interest to amplify, it would appear as though the position of Chemical Science in Australasia is a satisfactory one. Careful examination of the facts has, however, led me to the conclusion that in one most important particular our chemical affairs are by no means as they should be. I allude to the attitude of our chemists towards research, the spring from which our science takes its source, and without which the province of chemistry must become a barren and thirsty land.

If we examine the transactions of the various Australasian learned societies, we find that the number of chemical investigations recorded is small compared with the papers dealing with other sciences. This cannot be explained by the assumption that much of the work carried out in Australasia is published in European rather than local journals. From each of our universities and university colleges there appears from time to time in the journal of the Chemical Society the record of some investigation or research, but the length of time which elapses between the appearance of these papers seems to show that chemical research has not yet got a serious hold of our laboratories, and that the importance of original investigation is not realised by our educational authorities, our teaching staffs, or our students.

Now, no branch of study can be considered to be in a healthy state if the exponents of the subject are contented to watch with interest the work which is done by outsiders, and to reap the benefits accruing from their labours without themselves contributing to the advancement of the science by active research work. It is, therefore, surprising that public opinion has not long ago recognised the importance of a research atmosphere in educational institutions, and in technical and State laboratories. Few will deny the economic importance of an exact knowledge of still unexplored chemical phenomena, for the history of the nineteenth century is largely a record of the discovery of apparently unimportant scientific principles, followed by the application of these principles as the foundation of important industries. The freezing industry, the coal-tar colour trade, and the modern development of the manufacture of sulphuric acid are typical instances, and the recognition of the importance of the exact study of the physical chemistry of our metallurgical processes is being attended with equally surprising developments.

In a teaching institution the value of research work is largely psychological, and lies in its influence upon the teaching staff and upon the students. It has been my privilege to work in many laboratories, some magnificent, some extremely humble in their equipment; only in those laboratories, however, in which the research spirit was dominant did I find that scientific enthusiasm was an important characteristic of the place, and I have known beautiful laboratories in which the scientific ideal was sadly lacking. My own enthusiasm for chemistry dates from the commencement of my first research, begun when I was a very elementary student and a most indifferent manipulator. The work made me realise my own incompetence, and caused me to approach the study of chemistry from a totally changed point of view.

An objection which is often raised to modern research work is that so much of it is apparently incapable of technical application. Two important points must, however, be borne in mind—(1) that scientific discoveries which have no monetary value to-day may eventually be of the greatest service to mankind; (2) that to the student the development of the habit of investigation is of far greater importance than the value of the discoveries which he makes. To a young man who proposes to take up technological work, a year spent at close application to research work under the guiding hand of a skilful and sympathetic investigator is of priceless value; it will deeply influence his mode of thought, and leave its mark upon all his future work.

Were I requiring an assistant professor in my own laboratory I would not accept a degree of any kind from any university as a guarantee of fitness for the post. If, however, I had read with approval the candidate's original papers, and convinced myself that he possessed tact, personality, and enthusiasm, I should have no hesitation in recommending his appointment, even though his examination record was poor. It may not be out of place to mention here that the two most brilliant professors of chemistry in Germany have placed on record that they did very badly in their degree examinations.

It would be of interest if we could ascertain the causes of the lack of enthusiasm for chemical research in Australasia.

(1.) Is the Australian climate to blame?

Undoubtedly there is a great call to an open-air life, to the cricket ground and the ocean beach, but as these attractions do not sensibly divert business men from the pursuit of wealth it can hardly be maintained that they would seriously hinder an enthusiastic investigator in his search after exact knowledge.

(2.) Is the young Australasian unfitted by nature to take up research work? Certainly he is not!

The success of Australasians who have gone to work in Europe has demonstrated that our best students are unsurpassed in research ability by the men with whom they come in contact in English and German laboratories. Rutherford, of Christchurch, is, of course, unique. Mellor, of Dunedin, and Steele, of Melbourne, have both done excellent work in physical chemistry. Of the younger men, the names of Wilsmore (Melbourne), Denham and Prideaux (Christchurch), Allen and Worley (Auckland) arise in my mind as recent contributors of papers to the journal of the Chemical Society. Youngest of all is the case of P. W. Robertson, of Wellington, whom I find credited with investigations on physical, organic, analytical, and technological chemistry. Of the work done by chemists holding official positions in Australia several have interested themselves with the chemistry of the native flora. Of these the work of Mr. Henry G. Smith upon the eucalypts is particularly worthy of mention. In the agricultural laboratories I find that Mr. Brünnich (Queensland) and Mr. Aston (New Zealand) have carried out interesting work on plants which are poisonous to stock; these researches are the more welcome as coming from laboratories in which the amount of routine work is so great as to compel all research work to be carried out under conditions of the greatest difficulty. The names which I have mentioned by no means conclude the list of our chemical investigators. They suffice, however, to show that our people are not lacking in the power to do good research work.

(3.) Are our educational systems to blame for the comparatively small amount of attention which has been paid to research?

To a large extent I believe that they are to blame. The trail of the examination has ruined many courses of study. The Australasian is a great lover of examinations, and to many parents it seems more important that their children should receive certificates of competency without being proficient rather than that they should possess the proficiency without the certificate. It is, to my mind, absurd that the degree of B.Sc. should be conferred upon any student until he has shown that he has the ability to carry out a simple investigation in some experimental science. I am not an extreme advocate of the heuristic method, but I do believe that very early in a student's career he should learn that he has the power of finding out things for himself, that these things are worth finding out, and that he commits an immoral act if he does not make it his business to find them out. To those who raise objections I would remark that the knack of investigation, like dancing, can only be learnt by doing it.

(4.) Are our professors and teachers responsible for the present state of affairs?

Some portion of the blame undoubtedly rests at our door, for, with the exception of Orme Masson, none of us has succeeded in forming a recognised research school. Unquestionably, the most important function of a university professor is to set the ideal towards which his students must strain. In too many cases, however, teachers of chemistry have taken the path of least resistance, and accepted as inevitable the lack of ideals on the part of their less privileged fellowmen. I have even heard professors maintain that no student should be allowed to think about research work until after graduation; an attitude of mind calculated to destroy all youthful enthusiasm. The student whose attention is not directed to the importance of research work learns to look upon the text book and the examination as the two most important factors in a university education, and I fear that many of us have been satisfied that this should be the case. After all, research students cause some inconvenience to a professor; they stick so tenaciously to the laboratory, and they are for ever asking questions. If we can postpone their research work until the time when they can have no opportunity for doing it we shall be saved much worry and inconvenience.

If a professor does not himself engage in research work it is unlikely that his students will wish to do so. In his early researches a student needs much sympathy and encouragement. Apparent failures do much to discourage the youthful investigator, but a little sympathetic advice readily impresses the lesson that the failures teach as important lessons as the successes.

Having now cast a share of blame upon the teaching profession, let me say something in defence of our teachers. As a rule too much of a professor's time is taken up in the organisation of his department and in the teaching of elementary students. In at least three cases which have come under my notice in Australasia the professor of chemistry held also the chair of physics, and was allowed only one demonstrator. Under such circumstances it is evident that the concentration of mind necessary for successful research work is seldom possible; the mental overstrain deadens the intellectual ideal, and the professor may surely be pardoned, if, when the vacation comes, he shuns his laboratory as he would a plague-infested area.

May I here be allowed to digress in order to make a few remarks upon the appointment of professors and university lecturers? It is unfortunate that the members of the governing bodies of many universities have not yet been led to an appreciation of the value of research work, and, therefore, are apt to appoint men with a brilliant examination record or with a great reputation for getting students through examinations rather than those who are known to surround themselves with an atmosphere of scientific enthusiasm. It is, I know, a matter of difficulty to find candidates with all the characteristics which we hope for in a university professor. When, however, we consider that nearly all great investigators gather around them a research school, the members of which introduce the scientific habit into all work which they undertake, it becomes obvious that no man should be appointed to a professorship of chemistry unless he can show a good research record, together with evidence that he has the power of stimulating others to the undertaking of similar work. Such a professor will leave a profound impression upon the students who have been fortunate enough to come under his influence, and will benefit his generation to a far greater extent than the commonplace hack who succeeds in preparing crowds of students to dodge the traps laid by the university examiners.

When it is remembered that a university professor, unless absolutely lacking in backbone, leaves a pronounced stamp upon the intellectual ideals of a whole generation of students, it must be admitted that every appointment to a professorial chair is an affair of national importance. It, therefore, behoves Australasians to work as one man to see that in the making of such appointments all personal and parochial considerations are eliminated, and that only men of the highest type are chosen as professors and university lecturers. Choose men with some Australasian experience, if possible, that they may understand our local conditions; let them be men who have worked also in Europe, that their outlook may be a broad one; insist that they be men of affairs with high intellectual ideals, and our universities will become, as indeed they should, centres of the most leavening influence upon the life and aspirations of our citizens.

In concluding an address which is already too long, and which has, I fear, wandered only too freely from the subject chosen, let me enter a plea on behalf of those who, having shown scientific ability and power of conducting investigations, find themselves unable from lack of funds to carry out their researches. The tendency in the past has been to grant scholarships in order that schoolboys might get a university education, and to stop those scholarships as soon as the student has graduated, *i.e.*, just at the time when with no more examinations before him he could, in the absence of financial worry, give his mind completely to the pursuit of higher work. The New Zealand Government has recently recognised this need, and has established in each of the four university colleges of the Dominion a research scholarship of £100 per annum, tenable for two years. The University of Melbourne has also decided to spend £1000 per annum on research scholarships, and it is to be hoped that all the other universities will follow this good example. Such a policy would do much to develop the research ideal amongst our students, and would go far to stamp out the common error that university education ends when the degree examinations are passed.

PAPERS READ IN SECTION B.

1.—THE ALKALOIDS OF THE PUKATEA *(LAURELIA NOVAE-ZEALANDIÆ)*.

By BERNARD CRACROFT ASTON, Chief Chemist, Department of Agriculture, N.Z.

The pukatea is one of the most characteristic trees in swampy forests of the North Island of New Zealand, but is rare and local in the South Island. Mature trees are easily distinguished by the radiating buttresses at the foot of the trunk, which are of considerable size, sometimes doubling what would be the circumferance of the tree without them. The pale, almost white, bark, and the aromatic odour from the bruised leaves or branchlets, constitute additional means of recognition.

The tree, endemic to New Zealand, originally described by Allen Cunningham as Laurelia, was subsequently referred by Hooker to Atherosperma, but has now been replaced by Cheeseman in its original genus belonging to the family Monimiaceæ, the nearest ally being a species of Laurelia, in Chili. According to Colenso and T. Kirk, the wood is soft, of great strength, extremely tough, does not split, allowing nails to be driven in any direction, is difficult to burn, and is not durable in contact with the ground. The pukatea is among the largest of New Zealand trees, sometimes reaching a height of 150 feet, and a clear diameter of 5 to 7 feet, exclusive of the immensely wide buttresses at the base. The roots extend along the surface for a considerable distance, those of a tree measured at Day's Bay being visible for fully 50 feet. It is related that upon one occasion a man, being chased in the bush by a bull, tripped over some pukatea roots and lay perfectly still, parallel and between two of them. The bull stood poking, pawing, and snorting, for some time, and at length, finding he could not come at his *vis-a-vis*, withdrew. In the Marlborough Sounds these trees attain enormous dimensions. In one instance observed, a camp for fifteen men was made between two buttresses of a pukatea. Colenso (p. 33, Essay, Vol.. I., Trans. N.Z. Inst., 1868) states that the Maoris generally used the wood of the pukatea for the carved figureheads of their canoes and for boat-building, it being highly serviceable for the bottom boards of boats, as in case of striking a rock only the spot so struck is staved.

In the annual report of the New Zealand Department of Agriculture for 1901 (p. 284), attention was first drawn by the author to the occurrence of alkaloids in the bark of the pukatea; and the peculiar property possessed by the bark when chewed of causing a tingling of the tongue—probably well known to bushmen and others ere this—was traced to a crystalline alkaloid of definite melting point.

The presence of alkaloids makes it extremely probable that the tree contains medical properties of some value. The possibility of this was recognised so long ago as 1868 by Colenso (Trans. N.Z. Inst., 1868, Essay, p. 51), who says that from the aromatic leaves and bark of the pukatea a valuable essential oil might be extracted, seeing that from a closely allied plant of Tasmania—*Atherosperma moschata*—an essential oil called "sassafras oil" has been obtained, and Dr. F. Mueller has recently strongly recommended the bark of that tree as "deserving extensive adoption in medicine."

R. Stockman (Pharm. Journal, (3), xxiii., p. 512), however, in 1892, concluded that neither the volatile oil nor any of the constituents of the bark of *Atherosperma moschata* is particularly active or poisonous, and, further, that the volatile oil has a close resemblance in physiological action to other volatile oils.

Finally, Goldie, in a paper on "Maori Medical Lore" (Trans. N.Z. Inst., 1904, p. 118), states that the inner layer of the bark of the pukatea is boiled in water and the decoction thus prepared is applied externally to tuberculous and chronic ulcers and various cutaneous diseases by the Maoris. A strong decoction held in the mouth relieves odontalgia, and is also taken internally, and applied locally, in syphilis. Its nearest ally in New Zealand, *Hedycarya dentata*, is used in the medicated bath.

Alkaloids occur throughout the vegetable kingdom in almost all the different plant families. Some families are noted for the number of alkaloids which they contain, among which are the Rubiaceæ (yielding caffeine and quinine), the Apocynaceæ (alkaloids of alstonia and nerium), the Solanaceæ (solanine and atropine), the Papaveraceæ (the opium alkaloids), and the Leguminosæ (cytisine, sparteine, and the lupine alkaloids).

In other families equally important, such as Labiatæ, Rosaceæ, and Orchidaceæ, no alkaloids have as yet been found (Pictet).

Why some plants are able to produce alkaloids in abundance* while whole families of others produce none is one of those unsolved mysteries of plant chemistry which it may be the good fortune of future research workers to solve. At present one can merely recount facts and suggest hypotheses.

If the function of alkaloids and poisons of plants were known, some light might be thrown on their eccentric occurrence in nature. Pfeffer states that the poisonous substances which plants produce, including alkaloids, ptomaines, toxalbumins, certain glucosides, hydrocyanic acid, &c., have, for the most part, a biological importance, forming a protection against herbiverous animals and against the penetration of parasites. They may also enable certain plants, especially bacteria, either to compete successfully with other organisms, or by killing the latter, to provide for their own growth. Peirce has shown that the penetration of cuscuta (dodder, the parasite of clover) into a host plant is hindered by the presence of poison in the latter, and the same is the case with fungi. On the other hand, M. Treub (Ann. Jard. Bot. Buitenzorg, 1907, p. 107) denies that prussic acid has in general a protective effect—while some enemies may be warded off by its presence others seem to be attracted by it, and the toxicity of the hydrocyanic acid plays no *rôle* in the economy of the plant.

---

* The P.B. standard for cinchona bark is 5–6 per cent. total alkaloids, and by artificial selection the plant may be made to produce a bark containing 10 per cent. of quinine. (Howard, J.S.C.I., 1906, p. 99.)

In the case of the Laurelia the theory of the protective function of alkaloids certainly has some evidence to support it. The leaves of the New Zealand species have not been observed to be attacked by leaf eaters, and Mueller (Select Extra-tropical plants, 1895) states that a Chilian species, *L. aromatica,* a colossal tree in Valdivia, is the principle one used for flooring. The wood is never bored by insects, and is well able to stand exposure in the open air.

Poisons are by no means essential products of metabolism. In the sweet almond the power of producing amygdalin has been entirely lost. Vogel was unable to detect any quinine in cinchona plants grown in European hot-houses.† The hemlock may produce no conine in Scotland. It is stated that Indian hemp resin fails to produce toxic effects when grown in Europe (Easterfield and Wood, Camb. Phil. Trans., Proc. IX., 1896).

Alkaloids found in the same plant generally bear the closest relation to each other; often they form a homologous series; frequently they are isomers or even stereoisomers. The same alkaloid is rarely met with in different families, but not infrequently an alkaloid is characteristic of a family or even of a species. The small family Monimiaceæ is best represented in tropical South America, but is also found in tropical Asia, the Mascarene Islands, Australia, and Polynesia. There are twenty-two genera, containing 150 species; the genus Laurelia is confined to South America and New Zealand. The family contains only a few species to which attention has been directed by pharmacists and others. The leaves of *Peumus boldus,* an evergreen Andean shrub, are used in medicine under the name Boldo. Bourgoin and Verne (Journ. Pharm. et Chemie, xvi., 191, also in Journ. Chem. Soc., 1873, p. 179) have obtained from Boldo an amorphous powder which they state is slightly soluble in water, giving alkaloidal reactions and a bitter taste; soluble in alcohol, ether, chloroform, alkali, and benzene; soluble in acid; precipitated by ammonia, mercuric potassic iodide, and iodine solution. Concentrated nitric acid gives an immediate red colour, and sulphuric acid gives the same colour in the cold. There is no later reference in Beilstein to any alkaloid from boldo, but a glucoside, "an amber-coloured syrup," is described. (Chapoteant, Bl., 42, 291.) No analyses are given. Pascalleti (Terapia Moderna, 1891) describes the physiological action of boldine—"When injected hypodermically, boldine paralyses both the motor and sensory nerves, and also attacks the muscle fibres. As a local anæsthetic he believed it to be superior to caffeine but inferior to cocaine. When given internally in toxic dose, it produces great excitement, with exaggeration of the reflexes and of the respiratory movements, increased diuresis, cramps, disorder of coördination, convulsions, and finally death from centric respiratory paralysis, the heart continuing to beat long after the arrest of respiration, finally stopping in diastole." "According to A. T. De Rochebrune (Toxicol. Africaine, i., 1897) the tree *Monimia rotundifolia* of Australia, contains an abundant volatile oil, an alkaloid, and a glucoside, which are very similar to, if they be not identical with, those obtained from the Boldo, and may be substituted for the latter in therapeutics."

† Cf. also Howard (loq. cit.); quinine is only produced in favourable soil and environments, and at high elevations.

Bancroft (Proc. Royal Soc., N.S.W., Vol. xx., 1886, p. 69) records that the bark of *Daphnandra repandula, F. von M.*, a small Monimiaceous shrub which grows in the Johnstone River district of North Queensland, possesses a bitter taste, and is decidely toxic. From experiments with the alcoholic extract on cats, guinea-pigs, frogs, and grasshoppers, Dr. Bancroft concludes that—

1. The poison paralyses the motor nervous system;
2. That it does not affect the sensory nerves;
3. That it is not a muscle poison.

He finds that the same property exists in two other species of Daphnandra, *D. micrantha* and *D. aromatica.*

It, therefore, seemed desirable to investigate the chemistry of the compounds contained in the pukatea, and to isolate sufficient quantity to enable physiological experiments to be made. Dr. Malcolm, Professor of Physiology at Otago University, has kindly undertaken to do this. Accordingly, a small supply of the alkaloid melting at 200° was isolated and analysed. Analyses proved it to be a new alkaloid with a composition corresponding to the formula $C_{17}H_{17}NO_3$, for which the name "pukateine" is proposed.

Experimental.

Fresh bark, weighing 15 lb., from young and mature trees in the vicinity of Wellington, was obtained on 20th April, broken into small pieces, and steeped for twenty-four hours in 90 per cent. alcohol acidified with acetic acid. The alcohol was distilled off and the residue dissolved in water and filtered. The alkaloids were precipitated by the addition of sodium bicarbonate. The precipitate was dissolved in ether, the ether distilled off, and the residue dissolved in alcohol, which, upon spontaneous evaporation, deposited crystals. In this way about 8 grams of impure crystals were obtained, which on recrystallising from absolute alcohol were white, and melted sharply at 200° (uncorrected). A preparation was recrystallised from the solution of the acetate in water by the addition of sodium bicarbonate.

The yield of alkaloid was smaller than was anticipated, judging from the previous experience of the bark extracted in the spring. It was found that if the bark was allowed to stand for some months in a dry room little or no alkaloid could be obtained by the above method. Pukateine is a white, crystalline alkaloid, melting at 200° C. (uncorrected), insoluble in water, sparingly soluble in light petroleum and absolute alcohol, more soluble in hot alcohol. The freshly precipitated base is very soluble in ether and in chloroform. Pukateine is precipitated from its solution in slight excess of acetic acid by iodine in potassic iodide, picric acid, gold chloride, platinum chloride, bromine water, ammonia in slight excess, sodium bicarbonate, Mayer's reagent, disodichydric phosphate, and phosphomolybdic acid.

The following analyses were made:—

B. Preparation.—Recrystallised from dilute alcohol dried at 110° C. Melting point, 200° C.—

0·0741 gram. gave 0·1964 grams. CO_2 and 0·0411 grams. H_2O.
72·27% carbon 6·16% hydrogen.

C. Preparation.—Recrystallised from alcohol. Melting point 200° C.—

0·1259 gram. gave 0·3319 gram. CO_2 and 0·0676 gram. H_2O.
71·89% carbon 5·97% hydrogen.

D. Preparation.—Recrystallised from water—

0·0776 gram. gave 0·20545 gram. CO_2 and 0·0428 gram. H_2O.
72·2% carbon 6·12% hydrogen.

E. Preparation.—Recrystallised from absolute alcohol—

0·2558 gram. gave 10·8 cc. nitrogen at 764 mm. and 22° C.
whence 4·93% nitrogen.

F. Preparation.—

0·2181 gram. gave 9·6 cc. nitrogen at 769 mm. and 20° C.
whence 5·2% nitrogen.

$C_{17}H_{17}NO_3$ requires—

Carbon	72·08	per cent.
Hydrogen	6·01	„
Nitrogen	4·95	„
Oxygen	16·96	„
	100·00	per cent.

Molecular Weight Determinations.

Calculated for $C_{17}H_{17}NO_3$. M. equals 283.

0·1604 gram. depressed the melting point of 7·12 grams. phenol 0·6°. M. equals 277.

0·656 gram. depressed the melting point of 16·5 grams. phenol 0·925°. M. equals 303.

It was found that pukateine behaves anomalously with pyridine, in which the alkaloid is very soluble. In the experiments performed with this solvent (B.P. 117°) to determine the molecular weight by the boiling-point method—

0·6188 gram. raised the B.P. of 11·05 grams. pyridine 0·05°.
0·54 gram. raised the B.P. of 7·4 grams. pyridine 0·05°.

The research, which had been discontinued for want of material, was resumed on receipt of a supply of the bark collected in August, 1907, from trees in the Marlborough Sounds.

A quantity of alkaloid has been obtained which has enabled me to supply Professor Malcolm with one of its compounds. His preliminary report is appended.

In the following experiments the method of extracting *pukateine* ($C_{17}H_{17}NO_3$) from the bark has been modified. It was found that chloroform will extract the pukateine acetate from acid solutions. Bark fresh from the trees, weighing 166 lb., was thoroughly reduced to a fine pulp in a heavy edge runner mill, and steeped for seven days in methylated spirit containing ·5 per cent. acetic acid. The alcoholic solution was pressed off and the treatment repeated three times at the same interval. By this means 21·75 gallons of solution were obtained. The alcohol was distilled off and the residue taken up with hot water, cooled and filtered. The filtrate was shaken with choloroform which extracted the pukateine acetate. On distilling off the choloroform and taking up with alcohol the salt decomposes spontaneously, leaving white crystals of the pure base. An assay of the crushed bark yielded ·7 per cent. pukateine, but nothing like this yield was obtained in practice, as from the whole 166 lb. of bark, only 64 grams of approximately pure pukateine were obtained.

Dry Distillation of the Base.—On heating pukateine to redness with soda lime, ammonia and unrecognisable fumes are given off. On heating with zinc dust no smell of quinoline or pyridine could be detected.

Meth-oxy Groups.—Pukateine examined by Zeisel's method for meth-oxy groups gave negative results.

Hydroxyl Groups.—Pukateine, dissolved in pyridine, when treated with benzoyl chloride, gives a compound which is under investigation.

Nitro Derivative.—Pukateine dissolved in glacial acetic acid is easily nitrated by the cautious addition in the cold of a few drops of concentrated nitric acid. The crystalline nitro derivative has strong acid in function and dissolves in alkalies to an orange red solution.

Salts of Pukateine.—The hydrochloride, $C_{17}H_{17}NO_3HCl$, is easily prepared by dissolving the base in hot concentrated hydrochloric acid and rapidly filtering. On cooling, a crystalline hydrochloride separates out. This is filtered off and dried on a porous plate. The anhydrous salt is obtained by drying at a temperature of 50°-60° C., under reduced pressure.

Titration of the hydrochloride—

·5751 gram. took 18·02 cc. $\frac{N}{10}$ caustic soda = 11·37 % HCl.

·1842 gram. took 5·80 cc. $\frac{N}{10}$ caustic soda = 11·50 % HCl.

Calculated for $C_{17}H_{17}NO_3HCl$. 11·42 % HCl.

Chlorine estimation—

·1651 gram. gave ·075 gram. AgCl. = 11·22 % Cl.
Calculated for $C_{17}H_{17}NO_3HCl$. 11·11 % Cl.

The platinum salt, which crystallizes in warty masses from alcohol, is prepared by the addition of platinum bichloride to a solution of pukateine hydrochloride in water. On washing with hot water, and drying in a desiccator under reduced pressure—

0·148 gram. of the sale gave 0·0298 gram. platinum = 20·1 per cent.
Calculated for $C_{17}H_{17}NO_3)_2PtCl_6$ = 20·1 per cent.

Colour Reactions of Pukateine.

If a solution of bichromate of potash in concentrated sulphuric acid, prepared as for the strychnine reaction, be brought into contact in not too great an excess, with a few crystals of pukateine, a persistent purple colouration is produced. If excess of the reagent be applied, a greenish colour merely results. The colour which the reagent gives with strychnine cannot be confused with that given by pukateine. The former is a bright violet, quickly changing to purple, and finally to a bright red. At one stage the purple colour of the strychnine reaction closely resembles that of pukateine, but the ephemeral nature of the one precludes confusion with the other. Concentrated nitric acid dissolves pukateine with the formation of a dark red colour closely resembling that given by morphine.

Action of Concentrated Sulphuric Acid.

Pukateine dissolves slowly when macerated with concentrated sulphuric acid in the cold, and on diluting the syrupy solution with water an intensely insoluble amorphous white compound is formed, which up till the present has baffled all attempts to dissolve or crystallise it. It contains nitrogen. With gentle heating concentrated sulphuric acid will produce a dull violet colour with pukateine.

Action of Hydrochloric Acid in a Sealed Tube.

A gram. of the base was heated in a sealed tube for three hours to 110° C. with 5 cc. of concentrated hydrochloric acid. On opening the tube there was no pressure. The product had a glassy appearance, and its powder was pure white. It was insoluble in alcohol, ether, glacial acetic acid, aniline, pyridine, acetone, or ammonia. On washing with hydrochloric acid no pukateine could be recovered. The substance does not melt below 240 degrees C. It is probably the same substance as that formed by concentrated sulphuric acid, and contains nitrogen.

A gram of the base heated in a sealed tube with 10 cc. of water for two hours remained unchanged.

Pukateine is soluble in caustic soda solutions, and on concentrating the solution by boiling, the pure base crystallises out in characteristic prisms, melting at 200 degrees C. If a solution of pukateine in caustic soda be allowed to stand in an open test tube for a few hours the solution becomes greenish, and upon acidifying with hydrochloric acid the colouring matter may be extracted by ether, forming a purple solution. The experiment was repeated on the purest pukateine recrystallised from soda solution. The amount of colouring matter formed is too small to examine.

If one drop of a very dilute solution of potassium nitrite be added to a solution of pukateine in slight excess of sulphuric acid a dark red-brown or greenish solution is developed. The base remains unchanged in dilute sulphuric acid solutions.

It is perhaps too soon to say anything of the possible relationship of pukateine to the other alkaloids. It may be pointed out, however, that in empirical formula it is only two hydrogens less than morphine ($C_{17}H_{19}NO_3$), while a derivative, Morphothebain* (M.P., 190-1°), $C_{17}H_{15}NO\!<\!{}^{OH}_{OH}$, (Howard), has the same empirical formula.

Piperine ($C_{17}H_{19}NO_3$) is obtained from a species of a family (Piperaceæ) placed very near to Monimiaceæ in the natural system of classification.

A New Alkaloid.

Chloroform extracts from the neutralized alcoholic extract of the bark, a rubbery mass, which, on treatment with dilute sulphuric acid yields crystals of another alkaloid of which but a small quantity has

* Morphothebain is regarded by Freund (Berichte 32, 168) as $C_{17}H_{15}NO\!<\!{}^{OH}_{OCH_3}$.

been prepared. It dissolves to a dark brown solution in hot water, recrystallizing on cooling. Melts at 116°-118° C., turns pink on exposure to light, and gives the characteristic reactions with alkaloid reagents.

The above, and other basic organic bodies present in quantity in the alcoholic extract of the bark, will be the subjects of future investigation.

Professor Malcolm suggests that the predominance of the strychnine-like actions points to the nitrogen being in the trivalent form in the molecule.

Report on the Physiological Action of Pukateine, by Professor Malcolm, of the University of Otago, Dunedin.

"The following is a short account of my investigation into the action of the new alkaloid Pukateine:—

"The base itself is apparently inactive owing to its insolubility; the hydrochloride is soluble in water and has a mild toxic action.

"There are two groups of symptoms produced by alkaloids in general: (1.) Convulsions due to excitation of the nerve cells of the spinal cord. (2.) Loss of the power of movement due to paralysis of the terminations of motor nerves in muscle. In some alkaloids, of which strychnine is the chief type, the first set of symptoms is the more pronounced. In others, *e.g.* curare, the second set is predominant, but by appropriate means it can be shown that all alkaloids can produce both groups of symptoms, though in varying degrees of prominence.

"With pukateine hydrochloride the first set of symptoms is the more marked; a frog into which some of the drug has been injected becomes, in an hour or less, so affected that the least tap on the table calls forth a reflex spasm of the whole body. With strychnine itself the spasms last an appreciable interval of time, and are succeeded by separate (clonic) twitches. But in most cases pukateine hydrochloride causes a brief spasm of the muscles of the whole body, resulting in a momentary rigidity which is not followed by any further contractions. The curious nature of these spasms seems, from the result of one experiment, to be due to a failure on the part of the muscle to respond to a succession of stimuli. When an ordinary muscle is stimulated by a series of electric shocks it remains contracted for several minutes; but in this case the muscle gives a short contraction lasting about one second and gives no further response to the stimulation.

"Following the stage of increased excitability comes a stage in which there is no response on touching the skin of the frog. This is at first localised so that the fore limbs, back, or hind limbs may appear to be quite anæsthetic, while a general spasm may be elicited by touching other parts of the skin. This stage may be due to a local anæsthetic action analogous to the numbing sensation felt on application of the alkaloid to the tongue, but is more probably due to some action on the spinal cord.

"The paralysis of the nerve endings, corresponding to the second set of symptoms of alkaloidal action in general, is also caused by pukateine hydrochloride.

"Injection of relatively large doses (hypodermically) into rabbits caused some unsteadiness of gait, and in one case oral administration of about ·3 gramme caused convulsions resembling those of strychnine, which, however, lasted only for a short time. The animal recovered.

"Intravenous injection of ten milligrams into an anæsthetised rabbit caused sudden stoppage of respiration without convulsions; the heart continued to beat vigorously for a long time afterwards. Intravenous injection into pithed frogs caused at first slow, strong beats and then cessation of heart movements.

"Negative results were obtained in experiments on the influence of the alkaloid and its salt on yeast fermentation, conductivity of nerves, and on the pupil of a frog's eye.

"The investigation is still in progress.

"JOHN MALCOLM.

"Physiological Laboratory, University of Otago, Dunedin, 2nd June, 1908."

In conclusion, I must express my thanks to Professor Easterfield for the interest he has taken in this research (which is being continued), and for having defrayed a portion of the cost of the investigation from a grant made to him by the Royal Society of London for researches on the poisonous plants of New Zealand.

BIBLIOGRAPHY.

"Forest Flora of New Zealand," by T. Kirk, F.L.S., Wellington, 1899.

"Handbook of New Zealand Flora," by J. D. Hooker, London, 1867.

"Manual of the New Zealand Flora," by T. F. Cheeseman, Wellington, 1906.

"Dictionary of the Active Principles of Plants," C. E. Sohn, London, 1894.

"Watt's Dictionary of Chemistry," Vol. VI., 1883, p. 231, "Atherosperma."

"Indigenous Vegetable Drugs," by J. H. Maiden, Sydney, 1899.

"Transactions of the New Zealand Institute," Vol. I., 1868, essay by Colenso.

"Select Extra-tropical Plants," by F. Von Mueller, Melbourne, 1895.

"Physiology of Plants," Pfeffer.

"United States Dispensatory," 1907, Philadelphia.

"Vegetable Alkaloids," by Pictet. Translation by Biddle, New York, 1904.

2.—NOTES ON DIPPING FLUIDS: COMPOSITION AND CHANGE DURING USE; AND ANALYSIS.

By J. C. BRÜNNICH, F.I.C., Chemist to the Department of Agriculture and Stock.

In my last annual report to the Under Secretary of the Department of Agriculture and Stock I drew attention to the importance of conducting experiments with various dipping fluids. Since that time some careful observations have been made by a few of our inspectors, and as the result of all the experiences gained, I must emphasise the fact, that our Government standard formula, consisting of 8 lb. arsenic, 4 lb. caustic soda, 1 gallon stockholm tar, and 8 lb. tallow dissolved in 400 gallons of water, is in every respect absolutely satisfactory. The only drawback of the formula is the care required in the preparation of the fluid, and for this reason many concentrates have been put on to the market, which require simple dilution with water. According to the reports of our inspectors not one of the proprietary mixtures satisfies the conditions of a perfect dip as completely as our own formula.

The active ingredient in all dipping fluids, used for the destruction of our Queensland cattle tick *(Rhipicephalus annulatus, var. Australis)*, is arsenious acid, made soluble in the form of arsenite of soda. Experiences extending over many years taught us that only a solution containing ·2 per cent. or 8 lb. per 400 gallons can be relied on to kill all ticks within five days, without causing any ill-effect to the cattle dipped.

A few months back a dipping fluid was tested and was found to have hardly any effect on the ticks, although it contained nearly 10 lb. of arsenic. A more exhaustive analysis revealed the fact that nearly all the arsenic was in the form of ARSENIATE. Since that time all fluids are tested qualitatively for the presence of arseniate, and if any arseniate is found, the amount is determined gravimetrically.

During the last three months sixty-eight dipping fluids from all parts of the State have been tested, of which eleven contained high amounts of arseniate, whereas the others were absolutely free from arseniate and contained all the arsenic in form of arsenite. It is well known that the oxidation of arsenious acid into arsenic acid is accomplished by many oxidising agents, but it was not suspected that by blowing air through the solution of arsenites a change into arseniate would take place. Experiments undertaken with a view of ascertaining the effect of a current of air on dipping fluids, corresponding to the air which is continually churned into the liquid during the operation of dipping, showed that such oxidation will take place (see table I.), and that the presence of stockholm tar and of carbolic acid accelerates such oxidation. Of the dipping solutions tried, only the Royal Dip, practically a pure solution of arsenite of soda, showed no change during the experiments, but still several of the fluids which contained high amounts of arseniate were prepared from royal dip.

Whether the quality of water, used in the preparation of the solution, and soil and dirt have any influence on the oxidation, will have to be found out by further experiments.

For the DETERMINATION OF THE ARSENIC in the dipping fluids a simple and quick method was very desirable, as the gravimetric methods are too slow, and the preparation of a clear filtrate free from organic matters is very difficult. The fluids contain besides the arsenite various substances as fatty acids, glycerine, resins, phenols, hydrocarbon oils, sulphur compounds, &c., besides large amounts of soil and dirt brought into the dip during the dipping operation.

The method used in the New South Wales Agricultural Department's Laboratory (provisionally adopted by the Association of Official Agricultural Chemists of Australasia, August, 1906), based on

Gooch and Morris estimation ("Analyst," xxvi., 24), did not give with us concordant results, particularly with such dips which contained phenols and sulphur compounds. As the precipitation of the arsenic as sulphide presented also many difficulties, we tried some of the distillation methods. The estimation of arsenic in various materials is easily carried out by distillation as arsenious chloride. Odling ("Chemical News," July, 1863) proposed a method of distillation with ferric chloride and hydrochloric acid. The method was improved by Emil Fischer ("Berichte," 1880, p. 1778), who uses ferrous chloride in the distillation. The process was modified by Dr. J. Clark, Riecker, A. Gibb ("J.S.C.I.," March, 1901), and others so as to make it applicable for the estimation of arsenic and antimony.

The process of distillation, which gave us the best results and was therefore adopted, was carried out as follows:—10 cc. of the dipping fluid were boiled down to a few cc. in a distillation flask, 10 cc. of cuprous chloride solution (containing 62 grammes dissolved in 200 cc. HCl), and 10 cc. saturated CaCl solution, and ·25 grammes copperfoil were added, boiled and the distillate collected in an U-tube, containing a few cc. of water, kept cool in a water bath. A second distillation was carried on after the addition of 10 cc. HCl. Distillation was carried on until the residue in the flask began to spurt. The distillate was titrated with iodine solution in the usual way.

Already Rohmer ("Berichte," 1901) has recommended the distillation of arsenic with hydrobromic acid, and he uses both gravimetric and volumetric estimation of the arsenic in the distillate. Gooch and Phelp ("J.C.S.," Abstr., 1894, II., 477) recommend the distillation with KBr and HCl. On trying this method we found it to be much quicker than the other, but we again found that if the fluids contained appreciable amounts of phenols and sulphides the distillate could not be titrated directly with iodine solution for the estimation of the arsenic. Norton and Koch ("J.A.C.S.," 1905) recommended Kjeldahl's moist combustion with strong sulphuric acid for organic compounds containing arsenic. As in the digested residue the arsenic could be directly determined by titration with standard permanganate solution, O. Kühling ("Analyst," 1901), the digestion of the dipping fluids with sulphuric acid proved an excellent and rapid method. The titration with permanganate solution requires a good deal of practice to give good results, the permanganate must be added to the boiling hot liquid in certain amounts, and the liquid must be kept boiling until the slight pink colour disappears, and the titration continued until the pink remains permanent on continued boiling. Occasionally it was found that the duplicates, which as a rule agreed absolutely, did not agree, and came out lower than the gravimetric result. This fact was caused by certain dips containing arseniate, unsuspected at that time, which was not all changed into arsenite during digestion, and in other cases by a slight oxidation of arsenite into arseniate taking place in the digestion. No trouble was experienced in the presence of an excess of organic matters, and for this reason we always add before digestion a small amount of pure starch or sugar.

The titration with permanganate was also replaced by the much easier and sharper titration with potassium bromate solution, using methyl orange as an indicator, a method originally proposed by S.

Győry ("J.C.S.," Abstr., II., 554). This volumetric estimation of arsenious acid in connection with digestion was finally adopted as our standard method, which is carried out as follows:—10 cc. of the dipping fluid are measured into a Kjeldahl flask, 15 cc. pure sulphuric acid and a pinch of starch are added, the whole heated to boiling over a naked flame, and after a few minutes digestion 10 grammes of potassium sulphate are added and the digestion continued until the liquid is colourless. After cooling the residue is diluted with 50 cc. of distilled water, and boiled for about five minutes, or until all odour of SO_2 has disappeared. The hot liquid is titrated with N/50 potassium bromate solution, using two drops of methyl-orange solution as an indicator. Towards the end of the titration, when the liquid is nearly colourless another drop of the indicator is added, a few more drops of the N/50 standard solution should discolour the liquid. The reaction is exceedingly sharp, and very much better than with indigo-carmine as indicator. Contrary to the experience of others we found that the N/50 bromate solution keeps very well for any length of time.

A few of the numerous analyses according to different methods are recorded on Table II.

All our dipping fluids coming in to be analysed are at first tested qualitatively for the presence of arseniate, by adding a few drops of silver nitrate to a few cc. of the dipping fluid, previously clarified and discoloured by the addition of animal charcoal. The slightest trace of arseniate gives an orange tinge to the pure yellow precipitate of silver arsenite.

Another good test, not generally known, is lead acetate giving white precipitates with arsenite and arseniate, the latter being insoluble in acetic acid. If arseniates are present; the amount is determined gravimetrically, by treating 200 cc. of the dipping fluid with 20 cc. strong HCl, warming slightly to coagulate the impurities, and filtering; 55 cc. of the filtrate, corresponding to 50 cc. dip, are used for the analysis, ammonium chloride solution, ammonia, and magnesia mixture are added in excess, and the arsenic acid determined as magnesium pyro-arseniate.

I have to acknowledge my indebtedness to my assistants, Messrs. E. H. Gurney and N. C. Christensen, who carried out the experimental and analytical work.

TABLE I.

Oxidation of Arsenite into Arseniate by Blowing Air through Solutions.

—	Blowing air through for 3 days. % As_2O_3 changed into As_2O_5.	Same solutions after being diluted to contain ·2% As_2O_3.	Blowing air through for 2 days more. % As_2O_3 changed into As_2O_5.
Pure arsenite solution, 1%	·7		·3
Same, resin in solution added... ...	14·7		4·6
Same, 1% carbolic acid added... ...	·8		1·6
Same, 1% Stockholm tar in sol. added	36·8		53·9

TABLE I.—*continued.*

OXIDATION OF ARSENITE INTO ARSENIATE BY BLOWING AIR THROUGH SOLUTIONS—*continued.*

—	Solution contained % of As_2O_3.	Blowing air through for 3 days. % As_2O_3 changed into As_2O_5.
Agricultural Department Dip	·205	12·2
Royal Dip	·200	Nil
Queensland Cattle Dip	·203	17·1
Thomas' Carbolized Dip	·165	25·7

TABLE II.

ANALYSIS OF ARSENICAL SOLUTIONS.

—	Percentage of As_2O_3 determined. Distillation with— Titration of Distillate with Iodine. Cu & Cu_2Cl_2 HCl.	KBr & HCl.	Digestion with Sulphuric Acid. Titration with— Permang.	Bromate.	Direct Titration with Iodine.	Gravimetric as— $Mg_2As_2O_7$
Arsenite solution	·500	·500	·484	·489	...	·4950 ·5010
Arsenite solution containing some sulphide	...	...	·1320	...	...	·1321
Same, with tar added	...	...	·1335			
Same, with carbolic acid ...	...	...	·1350			
Arsenite solution containing arseniate	·200	-208	...	·230	...	·2320
Arsenite solution	...	..	·234	·296 ·281	·465 ·465	·4650
Same, digested 2 hours	...	...	...	·234 ·244		
Same, digested with sugar ...	...	...	...	·458		
Same, ,, ,, ...	...	...	...	·464		
Same, digested with Na_2SO_3	...	..	...	·464		
Dipping solution, nearly all arseniate	...	·243 ·241	·234 242 ·247	·243 ·243 ·247	...	·2458
Same, slightly diluted	...	...	·203	·229	...	·2310
Same, slightly diluted; starch added	...	...	·225			
Dipping solution, nearly all arseniate	...	...	·234 ·240 ·247 ·230	·247 ·238 ·241 ·242	...	·2893 ·2897 after permang. Titration, ·2895 ·2899
Same, sugar added	...	...	·280 ·288	·289 ·288	...	·2900 ·2902
Dipping solution, all arsenite ...	·208	.211	...	...	...	·2180

3.—EUPHORBIA PILULIFERA, *Linn.*

By JOHN LUNN, Pharmaceutical Chemist, Sandgate.

This well-known plant, which grows freely on waste lands, has long had a reputation as a remedy for asthma. When Mr. Watkins asked me to prepare a paper for this conference, and suggested Duboisia or *Euphorbia pilulifera* as subjects. I found references to Duboisia in several books, and the work of Ladenberg and others referred to. Of Euphorbia, on the contrary, I found no mention, so I chose the latter, and commenced by gathering a bundle of the flowering and fruiting plant in April last. One hundred parts of the green plant gave twenty-five parts of sun-dried drug in three days.

This lost a further three parts on being dried over a water bath and cooled over sulphuric acid for one day. That is, 100 parts of green plant lost 79 per cent. of moisture, and left twenty-one parts of dry drug, which, on incineration, left three parts of ash.

Ten grammes of the finely powdered dry drug were macerated in 100 cc. of petroleum ether of a low boiling point, the resulting solution was a fine translucent yellowish green colour, and, on evaporation, gave a green residue, with a nauseous smell, equal to 1·85 per cent.

This residue was in resinous drops, very tough and sticky when scraped with a knife. On being extracted with cold absolute alcohol most of it was dissolved, except a white opaque solid, which had a waxy character; an attempt to take the melting point showed that at about 140° Fahr. it softened, but did not completely melt. This waxy substance is probably derived from a deposit on the cuticular tissue, such as occurs in many plants as a protection from loss of moisture.

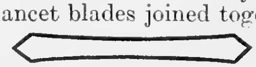
The alcoholic solution gave, on evaporation, a bright orange sticky resinous mass, equal to 1·35 per cent.

Ether.

The petroleum ether was filtered off and the marc dried. One hundred cc. of ether were used to macerate the marc, and dissolved an amount equal to 2·2 per cent., which, being treated with petroleum ether, suffered no loss.

The ether solution contained much chlorophyll, being blood red by reflected light, and a fine bright green by transmitted light. After treating the ether residue with water the balance was extracted with absolute alcohol, and a pale green amorphous substance obtained on evaporation equal to 1·7 per cent.

The direct product of the water from the ether solution was twice lost by accidents. I shook a portion out with acidulated water evaporated to dryness over a water bath; mixed with water and filtered, the filtrate gave a slight cloudiness with Mayer's reagent, and on evaporation I obtained a brownish residue, which under the microscope showed a number of crystals, some with a tendency to elongated hexagon-shape, others like two lancet blades joined together.



I redissolved this in water, and added a drop of ammonia, and shook out with ether; from the ether I got a white residue equal to 0·1 per cent. of the dried drug.

Absolute Alcohol.

After filtering off the ether and drying, the marc was digested in absolute alcohol. The portion soluble equalled 2·4 per cent.

Of this a portion equal to 1·7 per cent. was soluble in water. The watery solution gave a greenish tint with ferrosoferric iron, indicating tannin. The balance of the alcoholic residue was completely soluble in 2 per cent. ammonia; this was acidulated with acetic acid and dried over a water bath, then washed on to a filter with water. The precipitate dried and weighed equalled 0·3 per cent.

The filtrate did not reduce Fehling's solution, but after boiling for about an hour with a few drops of dilute sulphuric acid Fehling's solution was reduced.

The reaction with Fehling's solution was tried several times, at intervals, without result until the final experiment.

As this solution gave no indication of tannin, it seems probable that a glucoside exists in this plant.

Water.

The marc previously treated with alcohol, &c., was washed with alcohol and dried, then treated with water, yielding on evaporation a residue equal to 22·9 per cent.

This residue was not at all bitter, and gave no reaction, or only the faintest, for tannin.

Summary of Results.

Petrol ether			1·85
	Consisting of resin 1·35 and impure wax.		
Ether			2·2
	A pale green amorphous substance.		
	(?) Alkaloid	1·7	
	Chlorophyll	0·5	
Alcohol			2·4
	Tannin, &c. ...	1·7	
	Phlobaphene ...	0·3	
	(?) Glucoside ...	0·4	
Water			22·9
	Total in all solvents		29·35

4.—LOCAL MANUFACTURE OF CARBIDE OF CALCIUM AND CALCIUM CYANIMIDE.

By E. KILBURN SCOTT, A.M. Inst., C.E., M.I.E.E.

The amount of carbide of calcium imported into Australia during recent years has shown a remarkable increase. For example, the figures for 1904 to 1907 are as follows:—

Year.	Imports.			Exports.		
	Tons.	Value.	Price.	Tons.	Value.	Price.
		£	Per Ton.		£	Per Ton.
1904	2,404	42,649	17·73	111	2,475	22·24
1905	2,882	46,902	16·27	162	3,317	20·42
1906	4,299	64,601	15·1	294	5,847	19·3
1907	8,747	130,629	14·84	440	7,960	18·2

It will be seen that the value has trebled in four years, and it is, therefore, opportune to inquire into the question of its manufacture in Australia. At present all the imported carbide is used for making acetylene gas for illumination and working the Tyree spraying machine. The new fertiliser, calcium cyanimide, made from carbide of calcium, is, however, likely to be much used in the future, and there is no reason why it should not also be made here.

Carbide is made in the electric furnace from quicklime and coke, the calcium and the carbon combining at about 3.000 degrees Cent., in accordance with the equation—

$$CaO + 3C = CaC_2 + CO.$$

When water is added acetylene gas is given off thus:—

$$CaC_2 + H_2O = CaO + C_2H_2.$$

Professor Moissan, of France, and T. H. Willson, of Canada, were the first to produce carbide. Moissan's experiments were carried out in a small laboratory furnace, but Willson, who was quick to seize upon its commercial value, designed a special furnace. His American patent is No. 492,377, 21st February, 1893.

The main item of expense in making carbide is the cost of power, and on this account most of the factories are situated near hydro-electric power-houses. The Barron Falls is well situated for the supply of current to a carbide factory, situated at, say, Cairns, and such a proposal has been under consideration for some time. In 1906 the Queensland Government commissioned Mr. Wm. Corin, the city electrical engineer of Launceston, to report on the amount of power at Barron Falls, and cost of harnessing same, &c. Briefly, his conclusions were as follow:—

That a minimum flow of 50 cubic feet per second with the available head of 818 feet would provide 3,480 electrical horse-power at generator terminals for the full number of hours per year.

The first cost of harnessing this power with the transmission line to Cairns he gives as £80,260, and the annual cost, with interest, sinking fund, reserve fund, and maintenance, £10,076.

The 50 cubic feet per second allowed for in the above estimate is, however, very much below the average flow, since only on two days in the exceptional drought year of 1900 was the flow below that figure.

With a certain amount of water conservation a flow of 150 cubic feet per second could be depended upon, and this would give 10,440 electrical horse-power. Mr. Corin estimates the first cost for this amount of power, including £10,000 for storage dams, at £128,710, and the annual cost at £15,164.

One result of this investigation was that Mr. Tyree and others interested in the sale of carbide of calcium began to consider the question as to whether the establishment of a factory at Cairns would pay. Negotiations with the Queensland authorities induced the Government to make a definite offer to supply 5,000 electrical horse-power at Cairns for £2 15s. per electrical horse-power year. The writer, who has had some experience in connection with carbide manufacture in Norway, was asked to report on the matter. The report showed that 5,000 to 6,000 tons of saleable carbide could be made at a cost of under £8 per ton for an initial expenditure of about £25,000. Expenditure included step down, transformer, switch gear, furnace, grinding plant, &c.

Output.

The *Electro Chemist* for 1901 gave the production of carbide per electrical horse-power day as:—

7·4 lb. in a continuous furnace.
10·0 lb. in intermittent furnace.
10·2 lb. in Gin and Lelense furnace.
9·5 to 10·7 lb. in Deutsche G. and S. Anstalt furnace.

A test by C. F. Curtis at the Union Carbide Company plant at Niagara Falls gave 9·85 lb.

Now, 7·4 lb. per day is equal to 1 ton per year of 300 working days; it will be perceived, therefore, that, allowing for all manufacturing risks, a production of 1 ton of saleable carbide per electrical horse-power year is a certainty. With good management and first quality lime and coke, there should be a production of 1¼ ton when the factory has got into working order.

Materials.

As the anthracite in Australia contains a good deal of ash, it cannot be used for making carbide. Fortunately, however, a number of coke ovens have been built lately in New South Wales, and a good supply could be depended upon at a price not exceeding, say, 20s. per ton delivered.

It may be mentioned that several of the largest carbide works in Europe depend on England for their supply of carbon: Thus the Alby carbide works in Sweden use South Welsh anthracite at 21s. a ton delivered, and the Meraker Works, sixty miles east of Trondheim, buy English gas coke at 25s. a ton delivered.

Regarding the lime there, large quantities are available within easy reach of Cairns, and local coal for burning it could be obtained at 15s. a ton.

Professor P. A. Guye's Estimate of Cost per Ton of Carbide, without Packing.

	Frs.
1,000 kilos of lime at 15 frs. per ton	15
700 kilos of retort coke at 25 frs. per ton	17·50
20 kilos of electrodes at 35 frs. per 100 kilos ...	7
Electric power (1 kilo year) at 50 frs., giving 2·1 tons	23·80
Small expenses, wages (8 frs.), mechanical power for accessory work, transports, grinding (30 frs.) ...	38
General expenses	22
Depreciation at 8 per cent. on the plant, 75 frs. ...	6
Interest on the capital at 5 per cent. on 100 frs. invested	5
	134·30

Or £5 6s. 5d. per ton.

He gives £5 11s. a ton for the best situated works, and £7 6s. 7d. for those less favourably situated.

Approximate Estimate of Cost of Producing 5000 Tons of Carbide, by E. Kilburn Scott.

				£
Electric power, 5,000 E.H.P.	£2 15 0	...		13,750
Coke, 4,000 tons	£1 0 0	...		4,000
Lime, 6,000 tons	£0 18 0	...		5,400
Electrodes, per ton output	£0 10 0	...		2,500

Miscellaneous Items.

Refractory bricks for furnaces, iron casings for electrodes, oil, waste, belting, &c., current for motors and lighting, at 10s. per ton output	2,500
Management and office expenses, skilled labour (foremen, furnace and crushing room men, smith and carpenter), unskilled labour, at 22s. 6d. per ton output	5,625
Rates, taxes, and insurance, repairs and maintenance, at 15s. per ton output	3,750
Allowance for depreciation, 5 per cent. on £25,000	1,250
	£38,775

Equal to, say, £7 15s. per ton.

It will be noticed that the price for power is taken at £2 15s. per electrical horse-power year, this being a firm offer by the Queensland Government to the promoters of the carbide factory.

As a matter of fact, this price is higher than in Norway. At Sarpsfos, for example, the price is £2 7s. 6d., and at the new works of the Birkland Eyde Fixation of Nitrogen Works the record figure of 15s. per electrical horse-power year is said to be attained.

Manufacture by Intermittent Furnace.

There are three forms of furnace at present in use—namely, the *Intermittent*, as invented by Willson, and used at Foyers and Meraker in Norway, amongst other places; the *Continuous* furnace, by Dr. Rathenau, as used at Rheinfelden, in Germany; and the *Rotating* furnace, invented by Bradley and Horry, and used at Niagara.

The modern intermittent furnace consists of a steel truck lined with magnesite, and mounted on wheels. The upper carbon is drawn up automatically by a small motor, which is controlled by a solenoid mechanism not unlike that of an arc lamp. Fig. 1 shows such a furnace made by Siemens and Halske, which the writer worked with in Norway about seven years ago. Alternating current at 65 volts 2,500 amperes was supplied to three furnaces from a three-phase

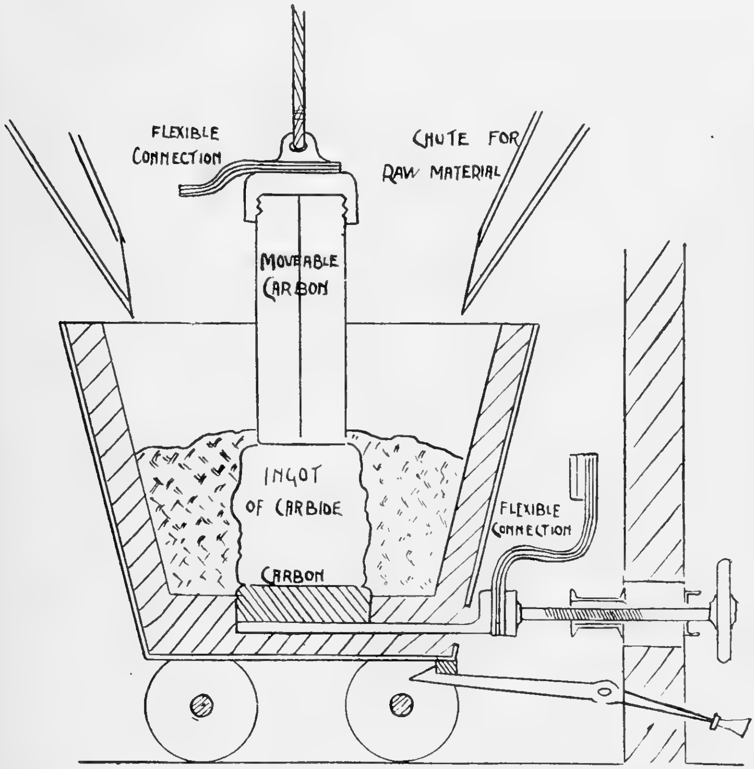


FIG. 1.—INTERMITTENT CARBIDE FURNACE.

alternator. As soon as an ingot about a foot square and 2 feet high was made, the solid copper connections to the two carbon electrodes were disconnected, the truck withdrawn from the furnace chamber, and another substituted. The ingot is broken up and sorted by hand, the partly-burnt material being returned to the furnace.

Continuous Furnace.

In the continuous process there is a chamber lined with magnesite which takes the place of the moveable truck. It has a tapping hole at the bottom, and the raw materials have sufficient excess lime to make the resulting carbide run freely. On this account the carbide is not so good as the best quality made in an Intermittent furnace, but it is very even in grade. Hand-picking is not required, and, if necessary, the ingots can be sold in the form in which they are cast in the moulds.

In the Continuous furnace care is taken to exclude air with a view to making the electrodes last longer. The price of electrodes is, however, much cheaper than in former years. They can be obtained for about 35s. a ton.

Rotating Furnace.

The rotating furnace consists of a wheel about 20 feet in diameter, which has an annular rim 3 feet in diameter. This rim forms the furnace, and it is closed in by semi-circular slats, which are readily removable. Only the lower half of the furnace has the rim completed with its slats.

The carbon electrode hangs down into the centre of the rim, and as the carbide is made, the slow rotation of the wheel recedes it away, thus leaving room for new material. The rim becomes filled with a solid core of carbide, surrounded with some uncombined material. When the wheel has turned sufficiently to bring this carbide to the side of the wheel opposite to the electrode, the slats are taken off and the carbide removed.

One of the great advantages of the rotating furnace is that no automatic adjustment of the carbon electrode is necessary. The rotation of the furnace and the supply of raw material are automatically controlled by an electric motor in such a way as to keep the current steady. About five days are required for the wheel to make a complete revolution.

Calcium Cyanimide.

The employment of carbide of calcium for the manufacture of the fertiliser cyanimide is an important development, and it will probably result in more carbide being used for that purpose than for acetylene lighting.

The manufacture of fertilisers will gain more and more importance with time, because at the present increasing rate of consumption the Chili nitrate deposits will become exhausted in about thirty years. In twelve years, from 1895 to 1907, the consumption of Chili nitrate increased by 75 per cent., and the yearly rate of consumption is now approaching 2,000,000 tons.

There are two reasons for this: The number of wheat-eaters in the world is steadily increasing, whilst the virgin land is as steadily decreasing. A few years ago the United States could take crops off her virgin lands without manuring, but the natural nitrogen in the soil has now become exhausted, and fertilisers have to be used. This will also take place with Australia's virgin soil.

In 1906 Australia imported Chili nitrate to the value of £36,000, the average price being a little over £10 per ton. With the increase of land under cultivation for wheat and cereals, and the intense culture which must follow the building of Barren Jack and Trawool dams, the demand for fertilisers will eventually be very considerable.

The discovery of calcium cyanimide resulted from an experiment by Bunsen and Playfair, when they obtained cyanides by passing nitrogen across a hot mass of carbon and alkalies. Professor Frank, of Charlottenberg, and Dr. Caro repeated the experiment, and found that the production of cyanide was preceded by the formation of carbide. They thereupon passed nitrogen across barium carbide and alkalies, and obtained barium cyanimide according to the equation—

$$BaC_2 + N_2 = Ba(CN)_2.$$

As barium carbide is expensive, they substituted calcium carbide, and found that at a temperature of 1000 degrees C. it would fix nitrogen direct without any alkalies being present. The reaction is given by the equation—

$$CaC_2 + N_2 = C + CaCN_2.$$

And it will be noticed that free carbon is given off.

Theoretically, the content of nitrogen in the calcium cyanimide should be 30 per cent., but on account of impurities in the carbide, and the changes which it undergoes during transformation, the actual content is about 20 per cent.

When united with water under high pressure all the nitrogen changes into ammonia, thus—

$$CaCN_2 + 3H_2O = CaCO_3 + 2NH_3.$$

This suggested the thought that cyanimide would make an excellent manure, and such has really been the case. When the cyanimide is mixed in the soil the above reaction takes place slowly, and the nitrogen is taken up by the plants.

The question is whether cyanimide can compete in price with Chili nitrate, sulphate of ammonia, and other manures. Professor P. A. Guye has investigated the matter, and the following is his estimate:—

Professor P. A. Guye's Estimate of Cost of Ton of Calcium Cyanimide that contains 20 per cent. Nitrogen.

	Carbide at— 140 Frs. £5 11s.		Carbide at— 185 Frs. £7 6s. 7d.
1 ton carbide, containing 80 per cent. CaC_2	140	...	185
200 kilos nitrogen	20	...	20
Manufacture, pulverisation of carbide, charge and discharge of retorts, heating retorts	20	...	20
Necessary repairs of mills, retorts, liquefying machines	25	...	25
General expenses	10	...	10
Packing	20	...	20
Transport	20	...	20
Depreciation and interest on capital invested	15	...	15
	270	...	315
Cost price per ton	£10 14 0	...	£12 11 2
Price of 1 kilo of nitrogen	1·35	...	1·57
	1s. 2d.	...	1s. 3½d.

The price will partly be governed by the market price of Chili nitrate. Until artificial fertilisers came on to the market and began to threaten the position which natural nitrate had so long held, there was a tendency for the latter to increase in price. Farmers have to thank engineers and scientists for this, and it may be that the competition that is springing up will result in the Chilian Government taking off some excise duty, and thus the price generally of fertilisers will decrease. The following figures are an attempt to compare the value of the various fertilisers according to the nitrogen content. They are, of course, only approximate, as the market price and nitrogen content are both variable:—

Name.	Percentage Nitrogen.	Price per Ton.	Value per Pound of Contained Nitrogen.
		£ s. d.	d.
Chili nitrate (natural)	16·5	10 7 0	6·81
Sulphate of ammonia (from gas works)	21·2	12 10 0	6·59
Calcium nitrate (made by Birkland Eyde electrical process)	...	10 14 5	5·45
Calcium cyanimide (made from carbide of calcium)	20·0	10 14 0	6·36 to 7·04

5.—THE OCCURRENCE OF STARCH IN THE BANGALOW PALM.

By W. E. DOHERTY, F.I.C., F.C.S., Department of Public Health, Sydney.

In the whole vegetable kingdom, with the exception of the Gramineæ, the order Palmæ is the most important to the human family. Manifold are the commodities produced by, and the uses of, this order. From the date palm of the East to the cocoa-nut, or, as it is now sometimes named, the koker-nut, of the South Seas, and right through the whole tropical, and even in temperate climes, members of this interesting and beautiful order contribute to the welfare and comfort of man. To give a history of the palm in its most interesting aspect would be to enter into a description of the manners and customs of a very great proportion of the human race from time immemorial. In some parts they supply man's staple food, and in others, to say nothing of products of general utilisation, they yield a most essential addition to his dietary.* Two well-known examples may be here noticed—namely, the before-mentioned date palm, which flourished in the gardens of the East long before our era, and which is now cultivated in all the countries bordering on the Mediterranean, particularly in North Africa and Palestine, and also in Arabia and Persia. The Arabs of the desert depend upon it almost solely for their food supply, and in a very large measure for shelter. In India and the East Indies, palms supply the much-prized sago in enormous quantities. This valuable food, which is used by all civilised nations of the earth, comes chiefly from the *Sagus Rumphii (Metroxylon Rumphii*, Mart.) and from the *Sagus Lævis Rumphii (M. læve*, Mart.). Sago is said to be the only starch food derived from the palmæ, and this statement is of interest here, as I am about to show that the occurrence of starch in a member of the order is the object of this contribution.

In our own continent of Australia, the indigenous palms are not otherwise used than as ornamental auxiliaries in our gardens, or in miniature to decorate the interior of our dwellings. Certainly in the past the cabbage-tree hat was a valued possession of our one-time *beau monde*, and later formed the headgear of the "fancy," but beyond these uses I do not think they have had any notable place in the commercial world. The bangalow palm is considered generally to be of little or no utility, though the split and dried timber has been used as a covering for rural dwellings. Many years ago there was a small trade in the seeds, which were sent to Europe to be grown in the palm-houses of the various botanical gardens. How they got on, or whether the trade in these seeds continued, I have not been able to learn.

Botanically the bangalow palm is known as the *Archontophœnix Cunninghamiana*, Wendl. and Drude (Syn. *Ptychosperma Cunninghamiana*, Wendl., and *Seaforthia elegans*, Hook). "It is a very tall and beautiful palm, with leaves attaining a length of several feet, the segments being numerous and more or less toothed or irregularly jagged at the end. The panicles are lateral, 1 to 1½ feet long and broad, branching into numerous spikes, very flexuose, the notches scarcely excavated. Male perianth about two lines long, the bud straight and obtuse, the outer segments about half as long. Stamens number from under ten to above twenty, the filaments shorter than, or, perhaps, ultimately as long as, the anthers. Female perianth spreading under the fruit to a diameter of about 3 lines, the inner segments not much longer than the outer. Fruit is ovoid-globose, nearly half an inch in diameter. Albumen deeply and irregularly ruminate."

It is a native of the coastal brushes of eastern New South Wales and Queensland, extending from as far north as Cape York in Queensland to as far south as Milton (a town more than 100 miles south of Sydney) in New South Wales.

A specimen from the stem of one of these palms grown in a gully at Eurimba Creek, New South Wales, came into my hands in June last. It had been freshly cut from a rather large palm, but from what position on the stem I omitted to discover, and have not since been able to obtain the information. It was quite fresh, and appeared somewhat like loose-grained timber until cut into with a knife, when it was found to be very soft and pithy, though it hardened on drying. Packed in between the fibres a whitish substance was seen on the dried portions, and this substance I found to be starch. I estimated the quantity of starch at 4·8 per cent. on the sample as received; but as the sample contained 70 per cent. of moisture, the dried stem would yield 16 per cent. of starch.

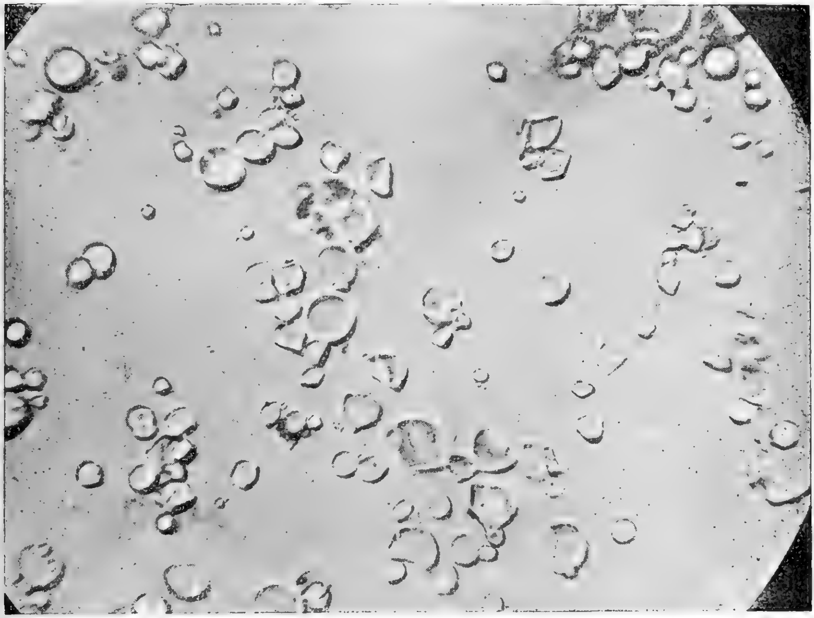
The starch granules were of various shapes and sizes. Some appeared on first sight to be circular, and others ellipsoidal, but this regular, rounded appearance was due, I think, to the apex of certain truncated cells being turned towards the point of vision. A great abundance of truncated cells of the elongated kettle-drum and cone-shaped pattern were present. Bell-shaped cells, symmetrically formed, were also seen, together with polygonal forms closely resembling those derived from maize. Others, again, united the rounded and polygonal forms in the same granule. On most of the granules the hilum was situated at the apex of the rounded portion of the truncated form, and in some instances was very conspicuous, giving one the impression of an air-bubble or of some substance different in refraction from starch. Other granules had a dark spot, or a slit sometimes crossed, on the hilum. Concentric rings, formed round the hilum, were very distinct, though some of the cells were apparently devoid of structure. Polarised light gave the cross very distinctly on all the granules. In the light field the cross showed faintly. The starch appeared to be more translucent than usual. The sizes of the cells varied from ·005 mm. to ·05 mm. (·0002 inch to ·002 inch) in diameter, the greater number being in the direction of the larger dimension.

Since writing the above I have received from the same Eurimba district another piece of palm wood. This was cut in October from a tree 60 feet in height over all, at a point 50 feet from the ground. This piece was much richer in starch than that previously examined, and contained less water (50 per cent.). The starch from this piece bore strong general resemblances to both tapioca and sago. (Sago, by the way, seems to be in process of replacement by tapioca, in Sydney, and what is generally sold as sago is really not such.)

A writer on palms, probably without any special knowledge of those of Australia, has stated that there is no species which is not capable of being applied to some use. Now, this remark is probably true also in respect of our Australian species, though we have yet to learn the value of these beautiful but despised members of our forestry. We may be fortunate in some measure, perhaps, if we acquire this knowledge before ignorance and vandalism have made it useless. I am speaking here generally, and do not mean to infer that this particular finding of starch is of any real value, but I think I might remark in this connection that we, as a people, do not seem to wish to know the true value of our inheritance, in the vegetable world at least.

Such slight excursion into the subject as this simply indicates the desirability of making our indigenous vegetation a subject for serious and systematic research. Mr. J. H. Maiden, who was the President of our chemical section when this Association last met in Brisbane, eloquently struck the chord of which this is but an echo. If we except the valuable work on the Eucalypts by Mr. Smith, of the Sydney Technical College, but little or nothing has been done during the long years that have intervened. Those of us who have the will have seldom the opportunity, being compelled by the ever-increasing duties of office, or business, to spend our energies in matters of routine. The great value of such an Association as this is, that it brings these matters into prominence and sets the seed which may, like the palms of other lands, one day grow and flourish for the material benefit of mankind.

Attached is a micro-photograph of starch on portion of slide from specimen first examined, for which I am indebted to Mr. Robert Grant, of the Micro-biological Bureau. To Mr. Maiden, Director of the Sydney Botanical Gardens, for kindly giving me the botanical appellation of the palm, I tender my acknowledgment.



Micro-photograph of the Starch of the Bangalow Palm.
The concave or cup-shaped appearance of some of the cells is due to optical exaggeration.

6.—BRANDY.

By WILLIAM M. HAMLET, F.I.C., F.C.S., State Government Analyst for New South Wales.

For more than three centuries a certain form of alcoholic liquor or ardent spirits variously known as eau-de-vie, aqua vitæ, branntwein, or brandy has been world-famous as a stimulant, restorative, and intoxicant, particularly that special variety named after its place of origin, Cognac, in the Charente district of France, where manufacturers exist to-day proudly dating their foundation from 200 to 250 years ago. Such are Augier Frères, 1660; Martell, 1715; Hennessy, 1760; Sazerac de Forges, 1782; and Otard Dupuy, 1795. So deep an impression has this famous drink made upon English-speaking peoples, that it has been scoffingly remarked that Cognac is the only French word properly pronounced by the average Briton, American, or Australian.

The demand for this concentrated alcoholic beverage is still enormous, notwithstanding the fashion that set in some forty years ago, when its great rival—whisky—took the lead—a vogue led off by the medical profession, who are now veering back again towards the introduction of Cognac on account of its greater virtues

K

and supposed instantaneous action. So enormous is the present demand that more brandy comes from Cognac than can be legitimately accounted for.

In the year 1876 a great disaster befell the trade in the wholesale destruction of the vines of France by the *Phylloxera vastatrix*, but still the world was supplied with Cognac!

Sir Charles Cameron and Professor Smith, President of the Royal Institute of Public Health, give some very interesting statistics on this aspect of the supply of French brandy. They say:—

"It is both interesting and instructive in this connection to consider certain figures which have been obtained from official sources relative to the extent of land under cultivation, and the amount of wine produced in the Charente Inferior, from which it will be seen that since 1876, when the vines were attacked by Phylloxera, the amount of wine produced has been seriously diminished, whilst in parallel columns will be seen the amount of brandy produced in those districts and the amount of brandy shipped to England and other countries and consumed in France. The difference between the quantity of brandy produced and the amount sent to England speaks for itself, and gives rise to the natural question, From which source was the extra amount of brandy shipped obtained?

Table showing the extent of land under cultivation, and the amount of wine produced therefrom, together with the quantity of brandy produced and the quantity exported, &c., in the districts of the Charente and Charente Inferior:—

Year.	Abstracted from Wine Trade Review and Ridley's Wine and Spirit Trade Circular.		From Mr. Bashford.		
	Hectares under Cultivation.	Hectolitres of Wine Produced.	Hectolitres of Brandy Produced	Hectolitres of Brandy Shipped (to England and other Countries) and Consumed in France.	
1875	Did not publish for this year	12,662,944	2,355,682	1,883,766	Calendar Year.
1878	256,961	6,686,261	...	...	Calendar Year.
1887	65,399	673,543	...	...	Calendar Year.
1892	Figures not published	466,464	78,881	1,720,450	Calendar Year.
1893	Figures not published	1,095,345	180,131	1,721,467	Calendar Year.
1894	Figures not published	628,491	89,784	1,754,394	Calendar Year.
1895	Figures not published	743,342	60,567	2,289,670	Year ending 30 Sept.
1896	Figures not published	1,182,913	48,947	2,347,086	Year ending 30 Sept.
1897	56,967	307,758	93,273	2,028,022	Year ending 30 Sept.
1898	56,815	845,592	40,267	2,349,980	Year ending 30 Sept.

This shows a decrease under cultivation of over 200,000 hectares; or, in other words, only about one-fifth of the land is now under cultivation, compared with the pre-phylloxera period, when only genuine brandies were shipped.

"In 1876 the vines were attacked by Phylloxera.

"1893 was best vintage since Phylloxera.

"1875: Wine made 12,662,944 hectolitres = 278,584,768 gallons.

"1898: Wine made 845,592 hectolitres = 18,603,024 gallons.

"Deficiency ... ... 259,981,744 gallons."

Of the varieties of genuine Cognac, such as the Grand Champagne, Petite Champagne, Fins Bois, Bons Bois, and Bois Ordinaires, I have nothing to say, more than this—namely, that the world's consumption is now so large that other varieties from Les Borderies, Le

Midi, Armagnac in Gascony, Spain, and Algiers, have been brought into requisition to cope with the demand. No doubt for those who can pay for them these may be classed as genuine brandies, but there is also a large trade done in what, from the dealer's point of view, is pleasantly called "blending," but which, in blunt English, may be more fitly termed adulteration. Given some white spirit, eau-de-vie, silent spirit, clear spirit, Berlin spirit, neutral spirit, spirit of wine—for under these terms the alcohol-basis is known—and what is easier than to take some *liqueur* and a vanishing quantity of real Cognac? and, hey, presto! you have commercial brandy ready for the wholesale market. The publican and bar-keeper have also a stake in the fraud, but, as a rule, nothing further than tap-water is added, distilled water being used by the better class of hotel proprietor.

"Is protection called for in the case of spirits? Whatever may be said of whisky, rum, and gin, it certainly is, we maintain, in regard to brandy. Genuine brandy has long been recognised by the medical profession and the public as possessing certain medicinal qualities not enjoyed by other spirits. Thus, if in illness a stimulant is indicated it is generally brandy that is employed. Indeed, probably the majority of people never drink brandy unless it is for medicinal use, and undoubtedly fine old brandy has been most valuable for this purpose, and the phrase "eau-de-vie" is not altogether an unjustifiable title. To this day good brandy is regarded as *par excellence* the medicinally valuable spirit. Its reputation in this regard has been founded on experience, and the composition of brandy shows important characteristics absent in whisky and other spirits upon which the medicinal value undoubtedly largely depends. This being so, when a person asks for brandy he ought to be supplied with the genuine article, a grape-derived or wine spirit, all else being regarded, in the words of the Sale of Food and Drugs Act, as 'not of the nature, quality, and substance demanded.' In this sense we regard genuine brandy as a valuable drug which should be procurable in accordance with a standard."

It seems to me to be altogether doubtful whether the subject of this paper can, after all, be of much importance since the liquid sold to the consumer is so artfully imitated, and he is so ready to pay for what appears to him to be real brandy that he goes on his intoxicating way with the mental suggestion that what appears to be brandy, and is served out to him as the ancient product brandy, must really be so in fact. It will intoxicate, and that will suffice for the craving of the inebriate.

But what of those medical practitioners who, though few, still exist in the present age when the dietetic or therapeutic value of alcohol is now much discounted? When he asks for brandy for a patient the genuine article should be forthcoming and obtainable as easily as any other medical comfort. The consumer asks for brandy, and he is certainly entitled to get it, and not be compelled to take a substitute, however much that substitute resembles the real article. So to the question, Do we get exactly the thing we ask for when we demand brandy? I think a negative answer must be given. In discussing this subject, I have been met with the counter statement that it does not much matter so long as a fairly pure alcohol with an appropriate flavour is supplied. Then, all that will be required is for the hotel-keeper to have white spirit on tap, and have a series of flavouring essences near at hand with which he can—like the conjuror on the stage—draw forth gin, rum, whisky, and brandy from one and the same bottle!

These are questions of ethical, chemical, physiological, and psychological importance, and I cannot attempt to do more than speak of the chemical side of the question.

The mobile ethyl radical is at the bottom of all aspects of the liquor question, whether as the hydrate in ethylic alcohol or oxidised as ether and acetic acid or subtly combined as the ubiquitous ester, much to the mystification alike of judges and barristers trying a brandy case.

With the rapid advance of carbon chemistry it is possible to make a pure ethyl alcohol betraying no sign of its origin. Here it is, ready for whomsoever will buy it, to be used for a thousand different purposes. What is there to prevent the brandy-maker from flavouring, colouring, esterising, diluting, and electrically ageing the same until he has a product which so closely resembles brandy as to be called, as it is for that matter, synthetic brandy? Put it into bottles with the label bearing the design of a few bunches of grapes and a French name, and the thing is done. Absolutely there is nothing to prevent him. Nay, he may go further, and get it shipped from a French port, so that invoices, bills of lading, and Customs certificate, including the famous white certificate, all join in declaring it to be French brandy. Obviously no analyst can stand such an array of rebutting evidence, often as not regrettably backed up by a commercial analyst's sworn testimony and the professional taster, who has been tasting synthetic brandy all the time. Thus two sets of circumstances have conspired to bring spurious brands on the market: the Phylloxera and the synthetic essences, coupled with the commercial production of pure alcohol electrically aged and matured.

In the face of such long odds, what can be said to be known about genuine brandy? Fortunately we live in a country where the vine flourishes, and wines are distilled for brandy production. In Australian brandy we have a sure basis to work upon, and it is open for the inquirer to see the steps in the production of brandy from the grape to the finished product.

What then are the characteristics of genuine brandy? A true brandy, an eau-de-vie-de-vin* is the matured middle distillate from wine, the earlier and the end-products being separated and rejected. The colour derived wholly from the cask, dark if from an old wine cask, and pale if from a new cask, hence the origin of the pale and dark varieties.

The flavour is wholly and entirely derived from the impurities, and is largely dependent on the mode of distillation; if from the ancient pot-still, the ratio of impurities is relatively high; if derived from the patent still, it is low and sometimes so feeble that the art and ingenuity of the blender consists in the admixture of a certain volume or proportion of the pot-still variety with a larger quantity of patent-still brandy spirit. The resulting bouquet, aroma, flavour, and gusto are then and there determined, modified first by the variety of grapes used and the time the brandy is kept in store. The professional taster now passes his opinion, and the market value of the brandy is fixed.

* By eau-de-vie is now meant mere colourless alcohol or silent spirit, the term eau-de-vie-de-vin being reserved for true brandy—the genuine grape product.

The precise scientific value of the flavour, however genuine the brandy may be, is an unknown quantity. Medical evidence is frequently adduced in supporting the theory that the entire therapeutic value depends on the impurities. Against this we have also the medical opinion that it is the alcohol and the alcohol alone that is of value, and some go so far as to say that pure white spirit is just as efficacious and of equal value to the finest spirit ever produced from the grape.

In fairness to those who incline to the latter opinion it is only right to say that the conclusion arrived at by the Departmental Committee on Whisky went to show that pure alcohol—that is to say, silent spirit—is, if anything, a more healthful beverage than the ordinary drinking spirits—*barring the necessary flavour.*

Curiously enough the only thing the public seem concerned about is the mode of origin of the spirit, and not so much the flavour, so long as the traditional flavour of rum, schnapps, whisky, and brandy is apparent.

Brandy, therefore, may be classed as to its origin as follows:—

1. It may be wholly derived from wine.
2. It may be entirely synthetic.
3. Or chiefly composed of grain or beet spirit, with ten, twenty, or more per cent. of real old brandy, the amount of the latter determining the price to be paid, the mark of value indicated by one star, two, three, or five stars, for which the consumer pays a few shillings, or a pound sterling, or more, per bottle.

The consumer, therefore, pays more for the label in stars than for the alcoholic contents. In a word, he pays for the flavour. Now, the analyst cannot separate and estimate so intangible a phenomenon as a fleeting flavour and enter it among his results even in milligrammes.

Since ethylic alcohol is the same the world over, he can give the quantity by weight and volume pretty correctly, and must rely on the non-alcoholic contents or the alcohol derivatives to enable him to pronounce as to its genuineness or otherwise. He must look to the secondary products as the index of purity, and it is just here that his path is fraught with dangerous pitfalls. First, the absolutely genuine brandy is marked by a high co-efficient of impurity. Secondly, he is pitted against the synthetic brandy chemist, who is on the alert to satisfy the analyst with a clever admixture of alcohol and impurities known as "oil of Cognac." With a sufficiency of burnt sugar and artificial esters the trick is done, and a brandy may be manufactured to suit any standard that any authority or Act of Parliament may devise. So that when the "trade" of any State welcome and even ask for a brandy standard, we shall be no further forward, for it will certainly happen that the brandy makers will export a brandy that will meet all the requirements of a standard. The only remedy I see is to track the brandy from its place of origin. Obviously, France, Spain, Portugal, and Algiers are, for economic and geographical reasons, beyond ordinary facilities. Fortunately, Australia is a wine-growing country, and can produce genuine brandy beyond question or suspicion, and Australian brandy should, if properly made, rival the best output from Cognac.

South Australia and New South Wales are already producing absolutely genuine brandy, and as prejudice disappears there will be no need to import brandy from Europe. For comparison, I give herewith some results of analysis of Australian, Spanish, and the famous French brandy:—

COMPOSITION OF VARIOUS BRANDIES.

*By W. M. Hamlet, F.I.C., Government Analyst, Sydney, **N.S.W.***

Form or Statement of Aanlysis.	Typical well-matured Genuine French Brandy.	Genuine Brandy. Bourdelais variety.	Spanish Brandy.	Australian Brandy. New South Wales.	Ordinary Brandy sold in Sydney as French Brandy.	Adulterated Brandy.
General Results—						
Alcohol (percentage by volume)	50·000	50·85	47·45	47·0	52·6	61·6
Non-alcoholic liquid	0·500					
Water	48·000					
Solid matter (extract)	1·500					
Special Detailed Results—						
Specific gravity of the distillate at 60°	0·9343	·9327	·9391	·9393	·9291	·9097
Absolute alcohol by weight ...	42·500	43·30	40·10	40·00	44·95	53·8
Percentage of proof spirit ...	87·6	89·1	83·64	83	92·2	108
Alcoholic strength in usual trade terms	12·4 U.P.	11 U.P.	$16\frac{3}{4}$ U.P.	17 U.P.	$7\frac{3}{4}$ U.P.	8 O.P.
Volatile acids per 100,000 of alcohol	60 to 400	205	57	56	76	5·5
Fixed acids per 100,000 of alcohol	80 to 100	90	80	105	85	Nil
Furfural " "	0·8 to 2	1·2	1·4	1·0	0·72	Nil
Esters " "	96 to 200	190	107	220 to 260	66·5	25
Extractives % of alcohol	0·1 to 1·5	·26	·36	1·45	...	...
Appearance of residue in a silver dish	Smooth with fragrant odour	Pleasant odour	Fragrant and fruity	Smooth and fruity	Rough and rank	Nauseous
General Remarks	Standard brandy	Genuine	Genuine	Genuine	Adulterated	Fictitious; from grain spirit

7.—NOTE ON THE REACTION BETWEEN PHOSPHORUS TRICHLORIDE AND ANHYDROUS OXALIC ACID.

By H. T. REVELL.

ABSTRACT.

One of the recognised methods for the preparation of phosphorous acid is that in which phosphorus trichloride is heated with anhydrous oxalic acid under a reflux condenser. (Hurtzig and Geuther, Watt's Dictionary (Morley and Muir), Vol. IV., page 151.)

A preliminary experiment showed that phosphorous acid prepared in this way contained phosphoric acid, together with a yellow substance which did not dissolve in water and might have been phosphorus or a suboxide. It appeared worth while to examine the action in greater detail.

I. Excess of redistilled phosphorus trichloride was placed in a flask with carefully dried oxalic acid. No perceptible reaction took place in the cold, but when the temperature was raised to 60 degrees the action became vigorous, and a white scum appeared on the surface of the trichloride. When the temperature was raised to 70 degrees the scum assumed a yellowish colour, and separated as a ring round the flask. The heating was now continued for an hour, the temperature of the bath rising gradually to 100 degrees. At the end of this time no further evolution of hydrochloric acid gas was noticeable, and the scum had become bright yellow in appearance. After the experiment the liquid in the flask was poured off and distilled under diminished pressure. It was completely volatile at the ordinary temperature, except a minute trace of phosphorous acid, which remained as a residue, and gave the ordinary qualitative tests.

The scum above alluded to became a hard, brittle substance on cooling. After freeing from all traces of phosphorus trichloride it was completely soluble in water, except for a small quantity of a bright yellow substance, which readily ran through an ordinary filter paper, though it was retained by papers of specially close grain. This substance was at first taken to be amorphous phosphorus, but the fact that even after washing it evolved for weeks the odour of phosphine suggested that it was a compound of phosphorus, probably a suboxide. A quantitative analysis of the solution obtained above showed that it contained both phosphorous and phosphoric acids.

The yellow substance mentioned above was purified for analysis by frequent decantation washings. It was then collected and dried in vacuo for several days. Two analyses gave 79·63 per cent. and 77·74 per cent. of phosphorus. These numbers agree appreciably with the value required for the suboxide P_2O, which requires 79·23 per cent of phosphorus, and which was obtained by Besson by the interaction of phosphorus trichloride and phosphorous acid. (J. Chem. Soc.,

Abstracts, 11, 216-1898.) It is, however, recorded in the abstract of Besson's paper, which is at my disposal, that the oxide is stable in water.

II. The reaction between phosphorus trichloride and anhydrous oxalic acid was also examined by allowing the substances to react at various temperatures in sealed tubes from which the air had been exhausted. After the tubes were cooled the evolved gases were collected over mercury and analysed, the requisite corrections for the vapour pressure of phosphorus trichloride being made from the data given by Regnauet. Experiments were made at 17 degrees, 66 degrees, 78 degrees, 100 degrees, and 150 degrees. Only in the first of these cases did a clear solution result. The ratio of gases evolved is given in the following table:—

Temp.	Ratio of Gases—HCl : CO : CO_2.	Remarks.
Degrees 15	... ...	No gas evolved; no detectable change in four weeks
66	·99 : 1 : ·98	A colourless solution formed. The solution on long standing separated into two layers, the lower of which eventually turned light yellow
78	1·11 : 1 : 1·02	Slight yellow substance separated
100	1·24 : 1 : 1·04	Bright yellow powder
150	1·30 : 1 : 1·03	Bright yellow powder.

The results indicate that the first action of excess of phosphorus trichloride on anhydrous oxalic acid is in accordance with the equation given by Hurtzig and Geuther—

$$3\,C_2H_2O_4 + PCl_3 = P(OH)_3 + 3\,CO + 3\,CO_2 + 3\,HCl$$

According to which equal volumes of the three gases are produced. A slight rise of temperature, however, appears to cause a second action between the excess of phosphorus trichloride and the phosphoric acid already formed. If this second action were represented by the equation—

$$3\,P(OH)_3 + PCl_3 = P_2O + 2\,H_3PO_4 + 3\,HCl$$

then for every molecule of phosphorous acid originally formed $\frac{1}{3}$ molecule of hydrochloric acid gas would result, or the volume of hydrochloric acid gas resulting from the second action should be a third of that resulting from the first. Examination of the above table shows that at 150 degrees this is approximately the case. At temperatures higher than 70 degrees the total reaction may be represented by the equation—

$$9\,C_2H_2O_4 + 4\,PCl_3 = P_2O + 2\,H_3PO_4 + 9\,CO + 9\,CO_2 + 12\,HCl.$$

8.—NOTE ON THE PHYSICAL CHEMISTRY OF PHOSPHOROUS ACID.

By T. H. EASTERFIFLD and H. T. REVELL.

ABSTRACT.

Phosphorous and glacial acetic acids are miscible in all proportions. The temperature lies at about 7 degrees, and corresponds to a mixture containing 36 per cent. of phosphorous acid.

The rate of fall of the freezing point of acetic acid due to the addition of phosphorous acid obeys a straight line law for concentrations not exceeding 3 per cent. The mean value for the molecular weight of phosphorous acid deduced from four determinations was 82·4, the minimum being 80 and the maximum 85; the value calculated for the formula $H_3PO_3=82{\cdot}0$.

At concentrations above 6 per cent. the fall in freezing point produced by the successive additions of phosphorous acid is also directly proportional to the amounts of substance added, but the rate of fall is now only one-third as great as was the case at concentrations below 3 per cent. The molecular weight of the acid is thus three times as great in concentrated as in dilute solution. The mean value of the molecular weight of phosphorous acid at concentrations between 6 and 20 per cent. was found to be 244, the maximum value observed being 259, the minimum 225.

The formula $(H_3PO_3)_3$ requires a molecular weight of 246.

Phosphorous acid is readily soluble in moist ether, but practically insoluble in ether which has been dried over sodium, and no suitable solvent has been found for determining the molecular weight of phosphorous acid by Ebbulioscopic methods.

9.—THE OCCURRENCE OF PODOCARPIC ACID IN NEW ZEALAND RED AND WHITE PINE.

By MISS A. I. SLOWEY, M.A. (Wellington, N.Z.).

ABSTRACT.

Podocarpic acid $C_{17}H_{22}O_3$ is the chief constituent of the heart-resin of *Podocarpus cupressina, var. imbricata*, a native of Java; it was isolated by Oudemans (Annalen, 170, 213), in 1870, but does not appear to have been observed in any other tree. Of the New Zealand timber trees the Red Pine or Rimu *(Dacridium cupressinum)*, the White Pine, or Kahikatea *(Podocarpus dacridioides)*, and the Matai *(Podocarpus spicata)* are known to contain heart-resin.

A preliminary note on rimu resin has already been published by Easterfield and Astor (Chemical Society Proceedings, 1903, 190). These authors found that the portion of the resin soluble in alcohol consisted of a crystalline acid which they called rimuic acid, and to which they ascribed the formula $C_{18}H_{24}O_3$, the percentage composition of which is nearly identical with that of podocarpic acid.

The present investigation was undertaken at the suggestion of the last-named authors, with the object of ascertaining whether rimuic and podocarpic acids are identical, whether White Pine and Matai resins also contain the same acids, and whether the formulæ ascribed

to podocarpic and rimuic acids are correct. Pure podocarpic acid was prepared from a sample of the Java resin kindly supplied by Dr. Treub, Director of the Botanical Gardens at Buitenzorg. In each case the resin was treated with ether, and after removal of the solvent the residue was crystallised from dilute alcohol until a product of constant melting point was obtained.

The resin of *Podocarpus spicata* was found to be practically insoluble in ether; it, therefore, contained no podocarpic acid (*see* following communication on matai-resinol).

The product obtained from *Podocarpus cupressina* was found to be identical in composition, in melting point (192 degrees, uncorrected), and in specific rotation (136 degrees), with the acid from *Podocarpus dacridioides* and from *Dacridium cupressinum*; titration with standard alkali gave in each case a molecular weight corresponding to the formula ascribed by Oudemans. Rimuic acid being thus identical with podocarpic acid, its name should be deleted from chemical literature.

10.—MATAI-RESINOL.

By T. H. EASTERFIELD and JAMES BEE, MA., M.Sc.

[ABSTRACT.]

The Matai (*Podocarpus spicata*, natural order Taxaceæ), is a fine timber tree occurring freely in the forests of the North and South Islands of New Zealand. The timber is straight in the grain, and is chiefly used for floor boards. The heartwood of old trees often exhibits cracks or shakes, and these are not infrequently lined with a yellow deposit sometimes amorphous, at others exhibiting a crystalline structure. This deposit is almost insoluble in ether, but dissolves fairly easily in hot alcohol, from which it separates in a crystalline state on cooling the solution.

Analysis and molecular weight determinations show that the carefully purified substance has the formula $C_{19}H_{20}O_7$; it is thus isomeric with pinoresinol, a compound discovered by Bamberger in the resins of *Pinus laricio* and *Picea vulgaris*, and the name Matai-resinol is proposed for it.

Matai-resinol resembles pinoresinol in many respects; both compounds contain two hydroxyl groups and two methyl groups. The most marked difference lies in the behaviour with potash. Matai-resinol yields no sparingly soluble potash salt, whereas the potash salt of pinoresinol is sparingly soluble even in boiling alcohol.

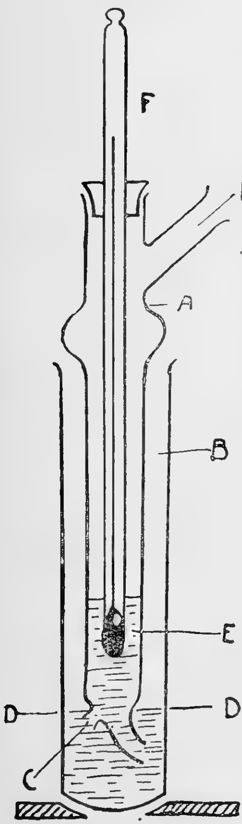
Matai-resinol melts at 119 degrees, its specific rotation *(a)* in acetine solution is 4·89 degrees, and is practically independent of the concentration. From alcohol it crystallises with one molecule of alcohol of crystallisation. It is a lactone and the corresponding oxy-acid can be prepared by adding acetic acid to the cold solution of the substance in caustic soda. The oxy-acid is immediately reconverted to the lactone by the action of mineral acids.

11.—NEW TYPES OF EBBULIOSCOPES.

By Prof. T. H. EASTERFIELD, M.A., Ph.D., F.I.C., Victoria University College, Wellington, N.Z.

[ABSTRACT.]

The apparatus, at present in use for determining molecular weights by observation of the elevation of the boiling point of a solution, belong as is well known to two types. In one of these, due primarily to Beckmann, super-heating is prevented as far as possible by means of a number of balls of suitable material which act as buffles, and lead to uniform heating of the liquid. In the second type, first put into practical form by Landsberger and improved by Walker and Lunsden, equilibrium between the solvent and its vapour is maintained by passing the vapour of the boiling solvent through the solution, which rapidly rises to its boiling point. The convenience of the second method has led to its general adoption in the laboratory of the organic chemist.

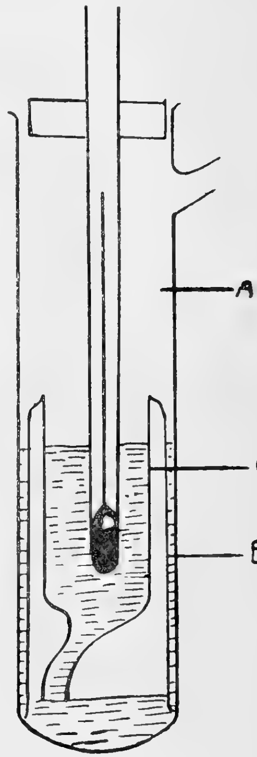


It is evident that an intermediate type of ebbulioscope is possible; one in which the boiling liquid has two free surfaces, an upper and a lower. If after the bubbles of steam have broken at the lower surface the vapour pass through the upper portion of liquid, the upper portion should arrive at its true boiling point, superheating being entirely obviated.

To test the workableness of the idea the simple apparatus here figured was constructed. Upon the tube A a small bulb was blown, so that it would not pass into the boiling tube B, and the two tubes were fixed in position by means of a rubber band. The lower end of A was drawn out and cut off, as shown, and a hole blown at the point C. D is a side tube adapted to a condenser, F a thermometer graduated in 20ths, and held in position by an ordinary cork.

To use the apparatus it was mounted over a hole in a tile of compressed asbestos, protected from draughts by a small cylinder of tinplate, a measured quantity of solvent introduced, and heated by a small luminous flame. To prevent bumping a fragment of clay tobacco-pipe was introduced before each heating; the construction of the tube A allows the piece of pipe clay to fall to the bottom of the boiling tube.

The working of the apparatus is obvious. The bubbles which form in the lower portion of the boiling liquid break upon the free surface D-D, and pass through the hole C, thus maintaining the column of liquid E in a state of equilibrium with its own vapour. An improved form of ebbulioscope is shown on the second sketch.



Into the boiling tube A there slides a somewhat narrower tube B, which has a narrower tube C sealed into it. The tube C is drawn out at its lower end as shown. The joining of B and C is one of the easiest of joints known to the glass-blower.

It will at once be seen that the column of liquid between A and B forms an efficient seal, and that all steam when the liquid is boiling will pass from the steam chamber between B and C through the column of liquid in C. The liquid boils over at the top of C. Using boracic acid as a test substance, the following results were obtained:—Calculated molecular weight, 63; with 20 cc. water found 68, 65; 15 cc. water found 67, 64, 64, 66.

Results with mannite and other organic substances were equally satisfactory.

No details of measurements of the apparatus described have been given, because experiments are still in progress to determine the minimum size which will give satisfactory values.

12.—OLEONE, THE KETONE FROM OLEIC ACID.

By Prof. T. H. EASTERFIELD and Miss C. M. TAYLOR, M.A.

[Abstract.]

The most usual method for the preparation of ketones of the type CnH$_2$nO is the distillation of the calcium or barium salts of the corresponding acid. But, with the one exception mentioned below, I have been unable to find any reference to the application of this method to the preparation of unsaturated ketones of the type CnH$_2$n—40. *Vide* Beilstein, Edition III., p. 1006; Beilstein Supplement—(literature to June, 1900); Journal of Chem. Soc., Index, 1883-1892; Journal of Chem. Soc., Index, 1892; Journal of Chem. Soc., yearly Indexes to 1907.

In the old edition of Watts' Dictionary of Chemistry, Vol. IV., p. 193, the statement is made that "oleic acid distilled with lime gives an oily liquid which is regarded by Bussy as the acetone of oleic acid. It has not, however, been obtained pure."

Oleic acid is an unsaturated acid which is produced commercially in every city in Australasia, and is therefore available in large quantity. Hence it appeared that it would be interesting to study the action of heat upon barium oleate in order to find whether a ketone of the type $CnH_2n—4O$ could be obtained, and what compounds other than the ketone would be produced. Further, it appeared that if oleone is capable of existence, it should be a compound of interest from the following points of view:—

I. It should, according to the Wislicenus hypothesis, be capable of existence in three stereo-isomeric forms, there being two ethylene linkages in the compound. Two of these should yield one oxime each, the mixed ketone should yield two oximes.

II. The ketone should yield a tetra brom. compound which might be expected to give up hydro-bromic acid yielding a still more unsaturated ketone of the type $CnH_2n—8O$, of which no members are known.

III. Since the distillation of a mixture of the barium salts of two different saturated acids produces a mixed ketone, the distillation of a mixture of the barium salt of oleic acid with the barium salt of a saturated acid might be expected to yield a ketone, $\substack{x \\ y}\!\!>\!CO$, containing only one ethylene linkage.

The following is a summary of the results so far obtained:— On distillation of barium oleate under diminished pressure an oily liquid was produced, which, on cooling, deposited crystals. The distillate was fractionated under diminished pressure, and the higher boiling point products were cooled and filtered. The crystalline product thus obtained was recrystallised from alcohol, and was shown by the analysis and molecular weight determination to have the formula $C_{35}H_{66}O$, thus agreeing with that calculated for oleone. From this compound an oxime was prepared and a determination of the nitrogen made. The value obtained indicated that the nitrogen compound was an oxime $C_{34}H_{66}C=NOH$.

A determination of the bromine absorption of the ketone in chloroform solution showed that it had combined with two molecules of bromine. It was considered possible that the filtrate from the crystalline ketone might contain an isomeric liquid ketone. An analysis of this filtrate indicated that its composition could almost be represented by the formula $C_{35}H_{66}O$; the bromine absorption, however, was somewhat lower than that required by the pure ketone.

The lower boiling point fractions obtained in the distillation of the barium oleate were refractioned repeatedly, but with the quantities available no product of constant boiling point could be isolated.

Attempts to prepare mixed ketones from mixtures of the barium salts of oleic acid with the salts of acetic and benzoic acids were unsuccessful.

13.—ISO-RETENE.

By Prof. T. H. EASTERFIELD and R. E. RUDMAN, M.A.

[ABSTRACT.]

By heating sulphur with colophony, retene $C_{18}H_{18}$ has been obtained by various chemists, notably Kelbe, Tschirch, and Veslerberg. Other chemists have stated that another substance melting at 85·86 (Retene melts at 98·5) is produced, and have ascribed such formulæ as $(C_{10}H_{11})x$ and $(C_5H_6)y$ to the compound.

Investigation has shown that the second substance to which the authors ascribed the name iso-retene is produced if the sulphur be present in large quantity, but that with the quantity of sulphur mentioned in Kelbe's paper on resin oil retene is formed.

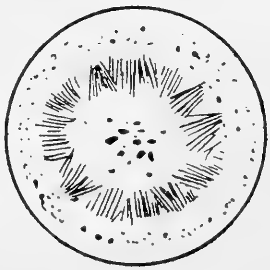
Numerous analyses and molecular weight determinations, carried out with carefully purified material, have shown that iso-retene, like retene, has the formula $C_{18}H_{18}$. It differs from retene in solubility, melting point, and in the colour and melting point of its picrate and the quinine which it yields upon oxidation. Like retene quinine the quinine from iso-retene gives the orthodiketone reaction, so that it is probable that it still retains the phenanthrene structure.

14.—THE PHASES OF SULPHUR.

By CLARA M. TAYLOR, M.A., Government Research Scholar in Victoria College, Wellington, N.Z.

[ABSTRACT.]

A sample of commercial benzene handed to me for investigation left a crystalline deposit on evaporation. On examination under the microscope this residue was found to consist of two kinds of crystals. The outer part of the deposit consisted of needles, while in the middle the crystals were of octahedral form. The residue thus obtained from the benzene proved on further investigation to be sulphur. It is a well-recognised fact that when crystallisation can occur in more than one form, the metastable phase is the first to appear. In this case, apparently during the more rapid evaporation, the metastable monoclinic form is deposited, while during the slower evaporation the stable octahedral form is the one produced. The fact that crystallisation had occurred in the manner described suggested the possibility of devising a lecture experiment in which the crystallisation of sulphur in more than one form from the same solution could be demonstrated. If a cold saturated solution of sulphur in benzene or toluene be diluted with its own volume of the solvent, a cubic centimetre of this solution placed on a watch glass gives a crystalline deposit of sulphur when spontaneously evaporated. This deposit, when examined under the microscope, is found to have the appearance indicated in the diagram.



I. Round the outer edge small globules of amorphous sulphur had been first deposited.

II. Within the deposit of globules monoclinic sulphur had crystallised, the needles radiating from centres toward the centre of the watch glass.

III. In the middle of the watch glass octahedral sulphur had been deposited, the number of crystals being comparatively small. Around each crystal or group of crystals was a clear space, and where an octahedral crystal had been deposited among the monoclinic crystals, a clear space surrounded the crystal, indicating that the more stable form was growing at the expense of the less stable, the octahedral form being at ordinary temperatures less soluble than the prismatic variety. The watch glass with the deposit of sulphur crystals is capable of being used as a lantern slide, giving a good lecture illustration of the fact that the different phases of sulphur can be thus obtained from the same solution.

15.—ON THE DETECTION OF THE ADULTERATION OF HONEY WITH INVERT-SUGAR.

By W. PERCY WILKINSON, Commonwealth Analyst, and O. WILLGERODT, Analyst in Customs Laboratory.

16.—THE DETECTION OF ADDED WATER IN MILK BY THE REFRACTOMETRIC METHOD.

By W. PERCY WILKINSON, Commonwealth Analyst.

17.—PROBABLE OCCURRENCE OF PITCH BLENDE IN NEW SOUTH WALES.

By T. H. LABY, B.A.

NOTE.—This paper was published in the Journal of the Royal Society for New South Wales in June, 1909.

18.—GLUCOSIDES AND THEIR PHARMACEUTICAL IMPORTANCE.

By R. C. COWLEY, Director, Pharmacy College, Brisbane.

19.—THE INFLUENCE OF CERTAIN DRUGS ON THE DIGESTIVE ORGANS.

By G. J. MACKAY.

20.—MODERN PROGRESS IN RELATION TO OLD REMEDIES.

By E. MERCK.

21.—ACETANILIDE IN HYDROGEN PEROXIDE.

By DR. J. M. FRANCIS, Detriot, U.S.A.

22.—THE FREEZING POINT OF MILK: ITS USE IN THE DETECTION OF ADDED WATER.

By J. BROWNLIE HENDERSON, F.I.C., Government Analyst, Brisbane.

Since the beginning of food analysis there has been a very keen search for a method of determining with certainty whether any sample of milk has or has not been adulterated by the addition of water.

Until recent years it was quite impossible in many cases to certify to the addition of water, though the analyst was morally certain it had been added. The adoption of the 8·5 per cent. solids not fat legal standard, instead of tending to keep the milk supply pure, has largely resulted in the milk (which is as often over 9 per cent. solids not fat as under 8·5 per cent.) being watered down to this low standard. In fact, a defendant has in court in England stated that he did not add more water than "the Government allowance."

Many methods have been proposed for the determination of this vexed question, but owing to the great variation in the quality of the genuine milk from various cows little headway has been made until recently.

The well known fact that the composition of milk serum does not vary much, and from the nature of its origin from the blood of the cow cannot vary much, has opened up what seems to be a good path leading to the solution of the problem.

There are several methods of dealing with the question in this direction, and these may be summarised as follows:—

(*a*) Determination of the specific gravity of the milk serum;

(*b*) Determination of the electrical conductivity of the milk serum;

(*c*) Determination of the refractive index with the Zeiss Immersion Refractometer;

(*d*) Determination of the freezing point of the milk.

Of these methods the first three require the preparation of the milk serum, whereas the freezing point can be determined in the presence of the fat, which, not being in solution, does not affect the freezing point. This gives the freezing point method a very great advantage over the others in a working laboratory where many samples have to be done in a day.

So far as I can learn, sufficient work has not yet been done on the specific gravity and the electrical conductivity of the milk serum to make either of these methods useful in the ordinary working laboratory. The refractive index of the milk serum, as determined by the Zeiss Immersion Refractometer, has however given results which promise fairly well. Unfortunately, the method is tedious, owing to the trouble involved in preparing the serum, and to the great difficulty, especially in warmer climates, in keeping the solutions exactly at the stated temperature of 17·5° C. As even 0·2° C. makes an appreciable difference in the readings, anyone who has worked with a difference of 10° C. between the atmospheric temperature and that of the solution knows how very great are the difficulties of getting correct readings. I have found it fairly easy to keep the cooling bath constant to 0·1° C., but difficult to keep the solution and the prism of the refractometer exactly constant in temperature. Apart from these working difficulties we have the fact that the variations in the refractometer reading from different samples of genuine milk are rather great. According to Leach, they vary from 39 to 44·5; according to McCrae, using the same method, from 39 to 46·5; and, according to Ackerman, from 38·5 to 40·5. Then, according to Leach's work, 1 deg. on the refractometer is equivalent to about 4 per cent. of added water; and, according to Ackermann, to about 6 per cent. of added water. This means that, to a good milk of high refractometer reading, about 20 per cent. of water could be added without bringing the milk under the minimum of 39 deg.

This is, I think, the most important objection to this process.

The freezing point of milk was, as long ago as 1895, affirmed by Winter to be practically constant; as a result of thousands of tests it has now been found that the mixed milk of herds of cows never varies beyond – 0·55° and – 0·56° C., the mean being – 0·555° C.

Winter's process of determining the freezing point of the milk is easy and accurate. The freezing point of 12 samples of milk can easily be determined in an hour, and in testing the process the following results were obtained:—Six results obtained by three operators, each doing two, varied from – 0·555° to – 0·557°, or a maximum variation of ·002° C. Similarly three results on one sample gave ·000° C. variation, and three other tests in triplicate gave ·001°, ·001°, and ·001° C. maximum variation.

The working error in the process is, therefore, very small, being equivalent to less than 0·4 per cent. of added water, while the maximum variation in the milk of different herds is equivalent to less than 4 per cent. of added water.

That such an easy and delicate process for the determination of added water should have been ignored for so long by English-speaking chemists is a standing monument to their conservative instincts.

Although much work has been done in this direction on the Continent, I can only find one reference to it in England, that by Atkins in the "Chemical News" for 1908, Vol. 97, page 141, and in that short article no mention whatever is made of the work already done in this direction.

Towards the close of 1907 I made a few experiments on the freezing point of milk, testing milks of known purity and milks with known added water, and the results were so satisfactory that I continued the work as occasion permitted. Finally, about seven months ago, I determined to utilise the method for checking all those milks which were of doubtful quality. I append the results in the following table. As none of the samples were curdled, the acidity was rarely determined. It is evident that in the case of at least eight of the samples sufficient acidity had developed to lower the freezing point, as the added water calculated from that figure is less than that calculated from the 8·5 per cent. solids not fat standard, and in each case the figures for nitrogen and ash indicate that the greater proportion of water was actually present. When the milk becomes acid the fermentation causes the splitting up of the larger molecules into a number of smaller molecules, and thus increases the osmotic pressure and lowers the freezing point.

I believe a correcting factor has been established for calculating the true freezing point from the freezing point found and the acidity, but I have not been able to obtain the factor, and it is doubtful if it would be reliable, as the fermentation products would most probably vary with the nature of the prevailing ferment present and the time and temperature of the reaction, and it is not probable that the acidity would in all cases be a true measure of the decrease in freezing point.

It will be noticed that if the mean result is taken of the added water in all those milks giving less than 8·5 per cent. solids not fat calculated first on the 8·5 basis, and then from the freezing point, the mean added water as determined by the freezing point is 3 per cent. greater than that calculated from the 8·5 standard.

The whole of the samples quoted were obtained by inspectors in the ordinary manner under the Health Act, and the analyses made in the usual manner.

It will be noticed that the fat contents of some of the milks is much higher than is usually recorded. I find in Brisbane that high fat contents are the rule. In February last year, our wettest month, when there was plenty of green grass, and the yield in quantity of milk was therefore above the normal, and the fat supposed to be below normal, the results of the testing of eleven dairies was as under, the milking being done in presence of two inspectors, who also saw the samples were correctly taken:—

TABLE A.

(1)	32	cows	... ...	4·9	per cent. of fat.
(2)	12	,,	... ...	5·1	,, ,,
(3)	9	,,	... ...	4·5	,, ,,
(4)	7	,,	... ...	5·0	,, ,,
(5)	20	,,	... ...	4·1	,, ,,
(6)	35	,,	... ...	4·0	,, ,,
(7)	16	,,	... ...	4·8	,, ,,
(8)	36	,,	... ...	5·0	,, ,,
(9)	30	,,	... ...	4·8	,, ,,
(10)	9	,,	... ...	5·0	,, ,,
(11)	35	,,	... ...	4·8	,, ,,

Yields of over 5 per cent. butter fat in samples taken by inspectors are by no means uncommon, and samples have been received giving as high as 5·65 per cent. butter fat.

The most important point to be noted in the results in Table B is that in every instance where the solid not fat result is below 8·5 per cent., the addition of water is also proved by the freezing point.

TABLE B.

Sp. Gr. 15·5° C.	ANALYTICAL RESULTS.						ADDED WATER CALCULATED FROM—				
	T.S.	Fat.	S.N.F.	N.	Ash.	F.P. —°C.	Solids not Fat, 8·9	Solids not Fat, 8·5	Ash, 0·7	N., 0·5.	F.P., —·55°C.
1·031	11·67	3·1	8·57	..	...	·545	3·7	...	...	...	0·9
1·0313	13·6	4·8	8·8	...	0·71	·545	1·1	...	...	...	0·9
1·0305	12·65	4·1	8·55	...	0·67	·545	3·9	...	4·3	...	0·9
1·0293	12·00	3·6	8·4	...	...	·544	5·6	1·1	...	...	1·1
1·0311	13·6	4·9	8·7	...	0·68	·543	2·2	...	2·8	..	1·3
1·0305	13·76	5·0	8·76	...	0·70	·542	1·5	...	..	...	1·4
1·0305	13·5	4·9	8·6	...	0·68	·540	3·4	...	2·8	...	1·8
1·0299 5	14·14	5·6	8·54	...	0·71	·540	4·0	..	...	...	1·8
1·0295	11·7	3·6	8·1	·444	0·66	·537	9·0	4·7	5·7	11·2	2·3
1·0292	11·4	3·4	8·0	·415	0·68	·535	10·1	5·9	2·9	7·0	2·7
1·0311	13·5	4·9	8·6	...	0·65	·533	3·4	..	7·1	...	3·1
1·0305	12·26	3·7	8·56	...	0·	·532	3·8	...	...	...	3·3
1·0308	13·7	5·0	8·7	...	0·72	·530	2·2	...	...	...	3 6
1·0307	12·07	3·6	8·47	...	...	·528	4·7	0·35	...	...	4·0
1·0286	11·72	3·8	7·92	·422	0·63	·528	11·0	6·8	10·0	15·6	4·0
1·0306	14·1	5·3	8·8	...	0·7	·527	1·1	...	...	...	4·1
1·0274	10·6	3·0	7·6	·42	0·63	·527	14·5	10·5	10·0	16·0	4·1
1·0296	13·5	5·1	8·4	...	0·66	·525	5·6	1·1	5·7	...	4·5
1·031	12·9	4·2	8·7	...	0·68	·525	2·2	...	2·8	...	4·5
1·0302	12·15	3·7	8·45	...	...	·523	5·0	0·58	...	...	4·8
1·0300	13·22	4·8	8·42	...	0·64	·522	5·6	0·9	8·5	...	5·0
1·0298	13·2	4·65	8·55	...	0·68	·517	3·9	...	2·8	...	5·4
1·0301	13·0	4·6	8·4	...	0·68	·517	5·6	1·1	2·8	...	5·4
1·0292	11·2	3·2	8·0	·44	0·66	·516	10·1	5·9	5·7	12·0	6·3
1·0292	11·85	3·75	8·1	·451	0·62	·510	8·9	4·7	11·4	9·8	7·2
1·0298	12·63	4·3	8·33	..	0·64	·508	6·4	2·0	8·5	...	7·6
1·0301	13·04	4·6	8·44	...	0·61	·502	5·1	0·7	12·8	...	8·7
1·0291	12·55	4·2	8·35	·445	0·63	·502	6·2	1·7	10·0	...	8·7
1·0280	11·74	4·0	7·74	·440	0·58	·502	13·0	8·9	17·1	...	8·7
1·0272	10·24	2·8	7·44	·413	0·63	·502	16·4	12·4	10·0	17·4	8·7
1·0299	11·64	3·3	8·34	·48	0·63	·500	6·3	1·8	10·0	4·0	9·1
1·0289	13·25	5·0	8·25	...	0·65	·500	7·3	2·9	7·1	...	9·1
1·0270	10·8	3·25	7·55	·400	0·65	·499	15·2	11·2	7·1	20·0	9·3
1·0285	13·07	4·95	8·12	...	0·63	·495	8·7	4·4	10·0	..	10·0
1·0279	10·8	3·1	7·7	·445	0·63	·492	13·6	9·4	10·0	11·0	10·5
1·0285	11·0	3·1	7·9	·45	0·64	·490	11·2	7·1	8·5	10·0	10·9
1·0284	12·2	4·0	8·2	·465	0·65	·487	7·9	3·5	7·2	7·0	11·4
1·026	11·6	4·05	7·65	·46	0·68	·487	14·6	10·6	2·8	8·0	11·4
1·0291	11·15	3·0	8·15	-42	0·66	·481	8·6	4·1	5·7	14·0	12·5
1·0280	11·93	4·1	7·83	·44	0·58	·480	12·0	7·8	17·1	12·0	12·7
1·0278	11·3	3·65	7·65	·42	0·56	·480	14·0	10·0	20·0	16·0	12·7
1·026	10·2	2·9	7·3	·415	0·61	·477	18·0	14·1	12·8	17·0	13·2
1·0272	11·13	3·5	7·63	·426	0·62	·475	14·3	10·2	11·4	14·8	13·6
1·0282	12·34	4·3	8·04	·47	0·64	·472	9·6	5·4	8·5	6·0	14·1
1·0273	11·0	3·3	7·7	·425	0·62	·469	13·5	9·4	11·4	15·0	14·7
1·028	11·1	3·2	7·9	·434	0·62	·467	11·2	7·1	11·4	13·2	15·1
1·0260	12·2	4·7	7·5	·422	0·61	·455	15·7	11·7	12·8	15·6	17·3
1·0267	9·7	2·4	7·3	...	0·62	·455	18·0	14·1	11·4	...	17·3
1·0257	10·1	2·9	7·2	·416	0·60	·451	19·1	15·3	14·2	16·8	17·9
1·0244	9·63	3·0	6·63	·345	0·56	·450	25·5	22·0	20·0	31·0	18·1
1·0268	11·8	4·35	7·45	·442	0·58	·447	16·3	12·3	17·1	11·6	18·7
1·0252	10·0	3·0	7·0	·413	0·56	·432	21·3	17·6	20·0	17·4	21·1
1·0242	9·56	2·8	6·76	·385	0.57	·425	24·0	20·4	18·5	23·0	22·7
1·0244	8·9	2·2	6·7	·375	0·56	·420	24·7	21·1	25 0	20·0	23·6

In discussing the question of abnormal milks with the Government Agricultural Chemist, Mr. J. C. Brünnich, F.I.C., he undertook to get as many abnormal milks as possible, and have them tested. The following results were practically all from samples analysed in Mr. Brünnich's laboratory. It is interesting to note that the passing of the milk through the separator had, as expected, no effect on the freezing point.

TABLE C.

Herd.	Number of Cows.	Samples.	Specific Gravity.	Total Solids.	Fat.	Solids not Fat.	Nitrogen.	Ash.	Phosphoric Acid.	Acidity.	Freezing Point.
Half-bred Jersey	9	No. 1, as received	...	...	...	...	...	...	...	14·0	— ·556
		No. 1, after 1 day's storage at 0° C.	...	...	...	...	...	...	...	18·0	— ·565
		No. 1, after 2 days' storage at about 25° C.	...	...	...	...	...	...	...	78·0	— ·680
		No. 1, after 7 days' storage at about 25° C	...	...	...	...	...	...	...	thick	— ·795
		No. 1, after separation ...	...	...	...	...	...	...	...	...	— ·555
		No. 2, as received	...	11·79	3·78	8·01	·455	·689	·194	13·5	— ·554
		No. 2, after 1 day's storage at 0° C.	...	11·84	3·60	8·24	...	·664	·202	16·0	— ·560
		No. 3, as received	1·0293	12·19	4·0	8·19	·458	·719	·201	14·0	— ·550
		No. 3, after 2 days' storage at about 25° C.	...	...	...	...	...	...	...	21·5	— ·573
		No. 3, after separation ...	1·0333	8·75	·39	8·36	...	·742	·201	...	— ·550
Mixed Herd (Grass fed)	26	No. 4, as received	1·0290	11·61	3·50	8·11	·527	·761	·206	15·5	— ·559
		No. 4, after 1 day's storage at 0° C.	...	...	...	...	...	...	...	17·2	— ·562
		No. 4, after 1 day's storage at about 25° C.	...	...	...	...	...	...	...	78·0	— ·680
		No. 4, after separation ...	1·0345	9·12	·65	8·47	...	·756	...	...	— ·560
Mixed Herd (Hand fed)	...	No. 5, as received ...	1·0305	12·20	3·75	8·45	·468	·769	·219	...	— ·555
	...	No. 5, after separation ...	1·0340	9·12	·40	8·72	...	·781	·219	...	— ·555
Mixed Herd...	10	No. 6, as received	1·0302	11·90	3·75	8·15	·463	·683	·222	15·5	— ·556
Mixed Herd...	...	No. 7, as received	1·0320	11·85	3·70	8·15	...	...	...	17·0	— ·563
Beauty ...	1	No 8, as received	...	11·41	3·40	8·01	...	...	..	16·0	— ·558
Daisy... ...	1	No. 9, as received	...	10·90	3·10	7·80	...	...	...	14·0	— ·553
Full-bred Jersey	12	No. 10, as received	1·0307	13·56	5·00	8·56	...	·688	·203	13·5	— ·556
		No. 10, after 1 day's storage at 0° C.	...	...	...	...	...	...	...	14·0	— ·558
		No. 10, after 2 days' storage at about 25° C.	...	...	...	...	...	...	...	...	thick
		No. 10, after separation ...	1·0352	9·27	·30	8·97	...	·700	·200	...	— ·554
Kerry Cow ...	1	No. 11, as received	1·0333	12·69	3·50	9·19	...	·758	·236	16·5	— ·568
Mixed Herd...	15	No. 12, as received	1·0323	11·95	3·45	8·50	·514	...	...	15·0	— ·548
Nugget ...	1	No. 13, as received... ...	...	12·90	4·30	8·60	...	...	...	15·0	— ·563

The most striking feature of all these results, and the one which I specially wish to call attention to, is that genuine milk from six different sources has been found to give less than the legal amount of solids not fat, but that while strong suspicion is thereby raised as to their genuineness the freezing point determination indicates the purity of the sample. There is, therefore, no doubt whatever that if a milk is received fresh from the Inspector a definite pronouncement can be made as to whether or not water has been added to the milk. In England, where "the appeal to the cow" is allowed, this is a matter of great importance—in those countries where a definite standard has been adopted it does not matter quite so much. In connection with the milk supply, by far the most important aspect of the question is that from the consumer's standpoint. It matters nothing to the child that is being starved through a supply of poor milk whether the starvation arises from adulteration of the milk with water or through the milkman keeping a bad breed of cows or through his starving a good breed. The offence is equally serious in all cases. Of course, the dairyman with the herd giving a poor yield is not morally on the same plane as the one who deliberately adulterates the milk, but, judging from the consumer's standpoint, he certainly should be prohibited from selling such genuine low-grade milk to the public.

I might state that in only one case, so far, has an Inspector brought me a sample of milk which was genuine but below our legal standard. The magistrate convicted and fined the defendant, but, of course, the fine was not so heavy as it would have been had there been deliberate adulteration.

Given, then, fresh samples of milk, a determination of the acidity and the freezing point will easily distinguish between "natural poverty" and adulteration with water.

To insure the getting of the samples in a fresh state, the State health inspectors in Queensland pack the samples in ice if they have to travel any distance to this laboratory, and the third, or magistrate's sample, is immediately on arrival in Brisbane put into the cold storage and kept at about − 2° C. By this means, even when a case is not brought on for a month or two, the magistrate's sample is produced in a fit state for analysis.

Mr. Brünnich made a series of experiments on these milks, with a view to using a preservative which, while it would prevent an increase in acidity in the milk for a few days, would not lower the freezing point. All the results obtained are given in Table D, as it is nearly always advisable to publish full details of work, lack of such details often leading to much work of only negative value being done over and over again by different workers.

The numbers of the samples refer to the same milks as in Table C, and the various methods of treatment and the results obtained are shown in the table. The first column shows the freezing point of the sample in its original state, the second column shows the rise through the addition of 5 per cent of water. The figures in the third and fourth columns show that ·01 per cent. or ·015 per cent. of mercuric chloride in alcohol solution does not prevent change while it materially depresses the freezing point, while columns 5 and 6 show the effect on the freezing point of the addition of 5 per cent. and 10 per cent. of water to the milk sample containing ·015 per cent. of mercuric chloride in alcoholic solution. Columns 7 and 8 show that the use of potassium bichromate and formic aldehyde in quantities less than sufficient to preserve the sample materially depresses the freezing point. Columns 9 and 10 show that ·01 per cent. or even ·02 per cent. of mercuric chloride, while not materially depressing the freezing point, will keep the milk for about two days. This dry mercuric chloride was added to the milk by running a few drops of very strong alcoholic solution of mercuric chloride into the bottle into which the milk was to be put, the number of drops to contain mercuric chloride equivalent to ·01 per cent. on the amount of milk to be added to the bottle. The alcohol quickly evaporates, and can be blown out of the bottle, leaving a deposit of dry mercuric chloride in a very fine state of division, in which it is easily and quickly dissolved. The depressing effect of the alcohol on the freezing point is thus avoided. While this method of preserving might be useful for collecting ordinary samples, it could not be used by inspectors taking samples under the Health Act, as any addition of this kind would certainly lead to disputes in court.

TABLE D.

Herd.	Number of Cows.	Samples.	Freezing Point as Received.	+5 % Water.	+·01 % $HgCl_2$ in Alcohol.	+·015 % $HgCl_2$ in Alcohol.	+·015 % $HgCl_2$ in Alcohol +5 % Water.	+·015 % $HgCl_2$ in Alcohol +10 % Water.	+·05 % $K_2Cr_2O_7$.	+·06 % Formalin.	+·01 % $HgCl_2$ Dry.	+·02 % $HgCl_2$ Dry.
Half-bred Jersey	9	No. 1, as received ...	−·556	−·528	−·565	...	...	...	−·585	−·590		
		No. 1, after 1 day's storage at 0° C.	...	−·535								
		No. 1, after 2 days' storage at 25° C.	...	...	−·570	...	...	...	−·588	−·590		
		No. 1, after 7 days' storage at 25° C.	...	...	−·615 (sour)	...	...	...	−·600 (sour)	·607 (sour)		
		No. 2, as received ...	−·554									
		No. 2, after 1 day's storage at 0° C.	...	−·529	−·580	−·595	...	...	...	...	−·560	−·569
		No. 2, after 2 days' storage at 25° C.	...	...	−·580	−·590	...	...	...	...	−·560	−·565
		No. 3, as received ...	−·550	...	...	...	...	...	...	...	−·552	−·555
		No. 3, after 2 days' storage at 25° C.	...	...	...	...	...	...	...	...	−·552	−·548
		No. 3, after 5 days' storage at 25° C.	...	...	...	...	...	...	...	...	−·648	−·550
Mixed Herd (Grass fed)	26	No. 4, as received ...	−·559	...	...	−·592	−·564					
		No. 4, after 1 day's storage at 25° C.	...	...	...	·600	·571					
Full Bred Jersey	12	No. 10, as received ...	−·556	−·525	...	−·575	−·544	−·510				
		No. 10, after 1 day's storage at 0° C.	...	...	...	−·575	−·545	−·512				
		No. 10, after 2 days' storage at 25° C.	...	...	...	−·580	−·544	−·527				

Summary.—The results recorded in Tables B and C show that the determination of the freezing point of a milk which has not fermented affords a ready means of determining whether water has been added to the milk or whether the milk is naturally poor.

23.—NOTES ON LECTURE AND LABORATORY APPARATUS.

By PROFESSOR J. A. SCHOFIELD, University of Sydney.

I.—Apparatus for Showing the Composition of Nitrous and Nitric Oxides.

This apparatus was devised for showing the relation between the volume of nitrous or nitric oxide, and the volume of the nitrogen left after the removal of the oxygen by heating sodium in the gas according to Sir Humphrey Davy's original method.

Attempts to carry out the decomposition in a bent glass tube, according to the text-book illustrations, always ended in a violent explosion; no explosion has occurred with the apparatus described, although it has been used for several years.

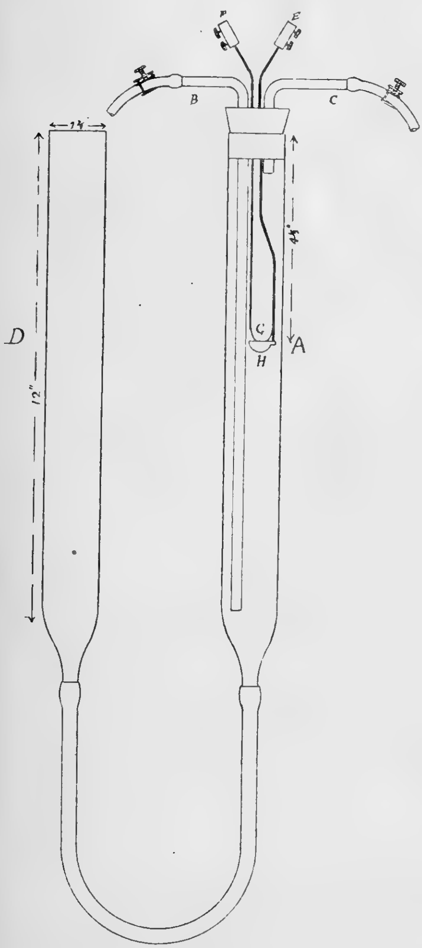


Fig. I

A (Fig. 1) is a glass tube $1\frac{3}{8}$ in. in diameter and about 12 in. long, drawn off at the bottom and connected by I.R. tubing to the levelling tube D. A is closed at the top by an I.R. cork through which pass two narrow glass tubes B and C. The gas is introduced through B and escapes through C; each tube can be closed by a screw clip on a piece of pressure tubing. Through the cork also pass the stem of a deflagrating spoon (E) and a piece of stout copper wire (F); these are joined at the bottom, just above the level of the spoon, by a piece of platinum wire soldered to E and F about $\frac{3}{4}$ in. above the spoon. In the apparatus the plane of these two wires is at right angles to that of the tubes, but for purposes of illustration they are shown in the same plane. On attaching the terminals of a battery to the binding screws at E and F the platinum wire can be made red hot. The sodium is placed in the deflagrating spoon H. In the case of nitrous oxide the platinum wire is wound in the form of a spiral of about four turns, the diameter being about that of the inside of the cup. To carry out the experiment mercury is poured into D until it is at the level of the lower end of the tube B in both A and D. A piece of freshly cut sodium (cube of about $\frac{3}{8}$ in. edge) is then placed in the deflagrating spoon, and arranged in the case of nitric oxide so that the platinum wire touches it, but in the case of nitrous oxide in the centre of the spiral. The cork is then introduced and the gas passed in through B, both clips being open, until it issues in a pure form from C; in the case of nitrous oxide this can be tested by a glowing splint, and in the case of nitric oxide by the absence of red fumes in the tube A. The clips on B and C are then closed, and wires from a battery connected to E and F. On increasing the current until the platinum wire is red or white hot, the sodium takes fire and burns. After the tube has cooled, in the case of nitrous oxide, the volume of the gas will be the same as at first, but in the case of nitric oxide it will be half the original volume.

In the latter case H must be kept above half the distance between the original level of the mercury and the cork. In this case also mercury must be poured into D to keep the level in both tubes the same, or else D must be lowered when starting until its open end is about level with the spoon in A, it being then about half full of mercury; as the combustion proceeds, the tube D can be raised to keep the mercury at the same level in both tubes.

The sodium ignites very readily in the nitric oxide, and once it has started continues to burn until the end of the experiment, but in the case of nitrous oxide ignition does not take place so readily, and it sometimes requires the application of further heat from the spiral to keep the combustion going.

Instead of an ordinary I.R. cork to close the tube A, it would be better to use an ebonite cork surrounded by a rubber ring, in order that the wires E and F may not shift when introducing the cork into the tube.

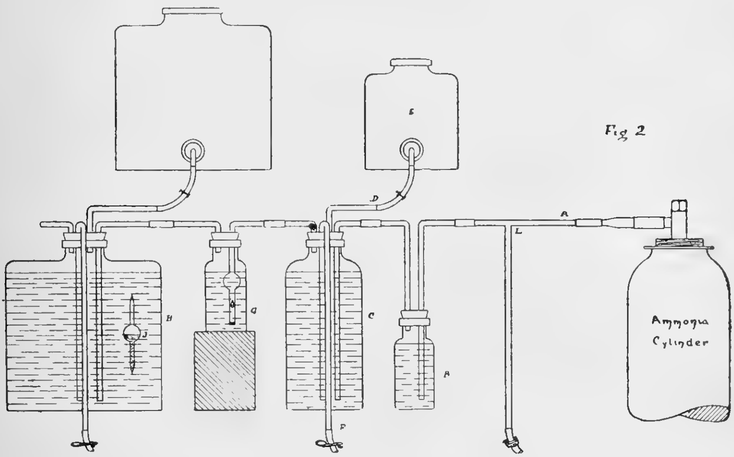
II.—Apparatus for the Preparation of Ammonium Hydrate Solution, Concentrated and Dilute, from Liquid Ammonia.

Having experienced some difficulty in obtaining ammonium hydrate of sufficient purity in Sydney, the following apparatus, Fig. 2, was devised for preparing it from liquid ammonia, largely used for refrigerating purposes.

The ammonia cylinder is, of course, placed with the valve at the top. The gas is led through the $\frac{1}{4}$ in. glass tube A into the wash-bottle B. At L is a side tube closed at the bottom with a piece of I.R. tubing and a screw clip. Ammonia gas can be drawn off from this tube for lecture purposes. It is also advisable to leave the clip open if the apparatus is unused for a considerable period.

The water in the wash-bottle B soon becomes saturated with the gas, and hence there is little tendency for the water to be drawn into the tube A.

From B the gas passes into the bottle in which the saturated solution of NH_4OH is made. At the beginning this bottle should not be more than one-half full, since the solution increases considerably in bulk as the NH_3 is absorbed. Fresh water is introduced into this bottle through the tube D connected to the bottle E above. The saturated ammonia solution is drawn off for use through the siphon F. If the column in this siphon breaks it can be started by blowing through D with a pair of bellows. From C, after the solution is saturated, the gas passes into the second wash-bottle G, fitted with a valve opening downwards; this is to prevent non-saturated solution being drawn back into C and so weakening this solution. This happens if C is connected direct to H, C being completely filled with water from H as soon as the ammonia is shut off. From G the gas passes into H of about 10 litres capacity. In this, NH_4OH of any required strength can be made. In this laboratory 5E (approximately five times normal) NH_4OH is the strength made in this vessel. The strength is indicated by a rough specific gravity bulb J, made from a piece of glass tubing and loaded with coloured water.



The ammonia is passed in until this bulb sinks, the strength then being 5E. As the solution cools the specific gravity will rise, and more ammonia must be run in. When starting, the vessel H should be not more than three-quarters full to allow for expansion. The solution is drawn off, and fresh water added in the same way as in C. Ammonia escaping from H can be absorbed in another vessel of water, and this weak solution can be used for filling H.

At the time the apparatus was fitted up liquid NH_3 could be purchased for 1s. 6d. per lb., making the price of ·880 NH_4OH about 6d. per lb.; so-called ·880 NH_4OH could be purchased for $4\frac{1}{2}$d. per lb., therefore the NH_4OH made in the above apparatus was apparently dearer; but this, it is believed, is more than counterbalanced by the loss in transferring and diluting the purchased ·880 NH_4OH. On more than one occasion, in hot weather, the whole of a Winchester quart has been lost through the rapid escape of the NH_3; the transferring of the ·880 NH_4OH from a Winchester quart is also an objectionable operation.

The apparatus has been in use for several years without any trouble being experienced. All the joints are made by means of I.R.

pressure tubing, and I.R. corks are used in all the jars. Gaseous NH_3 does not act rapidly on india rubber, although the solution acts very quickly; hence siphons are better than openings in the base of the jars for drawing off the solution.

III.—A Rapid Form of Condenser for Distilled Water.

This condenser was designed to give a rapid supply of distilled water with a boiler fed with hot water from the top of the condenser.

With the ordinary worm condenser, even of 1 in. diameter, if the distillation was at all rapid, pressure was produced in the still, and water was forced back through the bent pipe into the condensation vessel; the worm did not present sufficient cooling surface to rapidly condense all the steam.

In this condenser, which is practically a reversed tubular boiler, nine ½ in. tubes (tin) 1 ft. long form the condenser, thus presenting a large condensing surface.

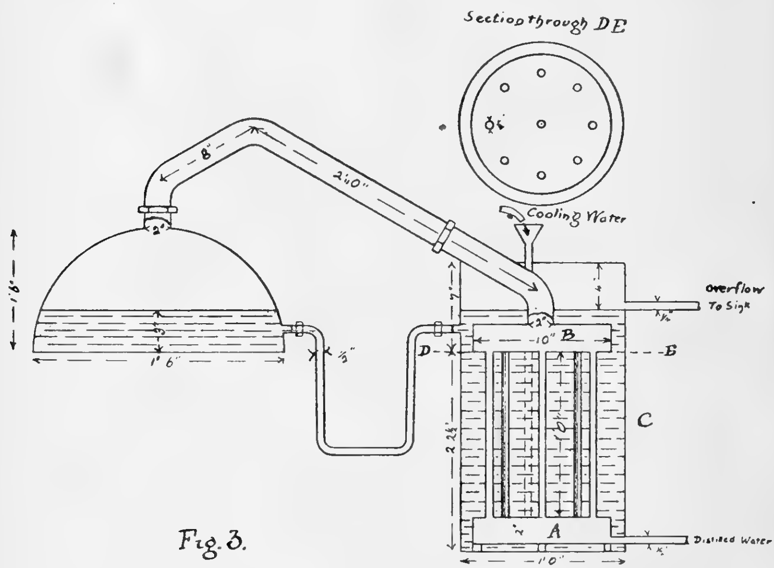


Fig. 3.

Fig. 3 sufficiently explains the construction of the condenser. The drums A and B are of copper, tinned inside, the tubes connecting them are of tin, the outer vessel C is of copper.

The only trouble experienced has been in the joints between the tin tubes and the copper drums, but these can be readily soldered again.

The condenser will yield 7,000 cc.'s per hour without causing back pressure in the boiler. With gas at 4s. per 1,000, the cost is about 2d. per gallon, but no claim is made on the score of low cost; this depends more upon the effective jacketing of the boiler.

IV.—A Cheap Demonstration Balance.

This balance, Fig. 4, is an ordinary balance made to take a load of 1,000 grams (catalogue price £2 18s. 6d.) fitted with a light aluminium pointer A about 21 in. long playing over a cardboard scale B. The scale and pointer are turned towards the class, the ordinary scale and pointer being towards the lecturer. The pointer can be made of any length suitable to the distance between the lecturer and the class, and is counterbalanced by a binding screw C clamped on the ordinary index. The cardboard scale is made so that the readings of the pointer on the scale coincide with those of the ordinary index and scale. One arm of the balance is graduated for use with a ·1 gram rider.

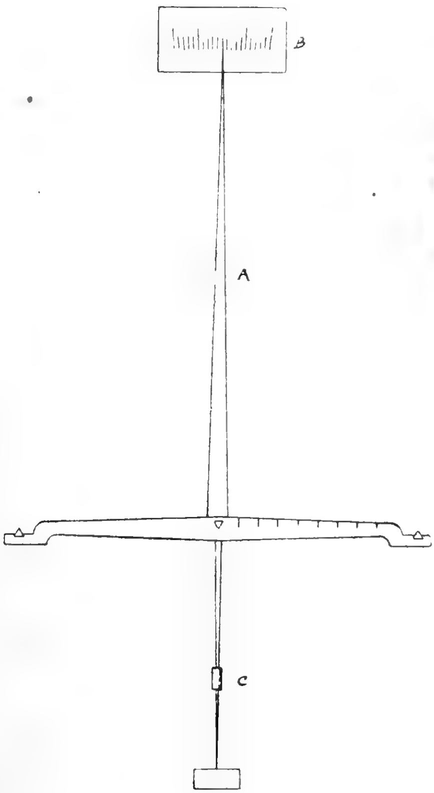


Fig. 4.

The balance is provided with a glass case, the aluminium pointer and support for the scale passing through the roof. The balance has proved very useful in demonstrating, to large classes, the method of determining small weights by vibrations, as well as for general lecture experiments. The pointer and scale in no way interfere with its use for ordinary purposes.

V.—Nickel Crucibles for the Lawrence Smith Method of Determining Alkalies in Silicates.

These nickel crucibles, Fig. 5 (price 3s. each) were obtained through Messrs. Gallenkamp and Co., of London. They are used by students in place of expensive platinum ones (about £8 each), for the determination of alkalies in silicates by decomposition with $CaCO_3$ and NH_4Cl. The same Bunsen burner and stand are used as with the platinum ones.

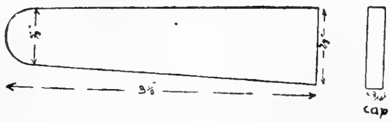


Fig. 5.

The crucibles are acted on by the $CaCO_3$ and NH_4Cl during the heating, but all the nickel is removed in the first operation (dissolving in water and filtering), and causes no further trouble.

Duplicate determinations, using the nickel crucible in one case and the platinum crucible in the other, give the same results.

Section C.

GEOLOGY AND MINERALOGY.

ADDRESS BY THE PRESIDENT,

PROFESSOR ERNEST W. SKEATS, D.Sc., A.R.C.Sc., F.G.S.

THE VOLCANIC ROCKS OF VICTORIA.

Introduction.

The Volcanic Rocks of Victoria cover an area probably exceeding 10,000 square miles. They form the level plains of the Western District, they occur as mountain masses near Warburton, Healesville, and Marysville in Central Victoria; the rugged areas near the Snowy River in Gippsland are largely composed of ancient volcanic rocks, while flows of Newer Basalt have been met with hundreds of feet below the surface in several of the deep lead mines. Not only have they a wide geographical distribution but among them are representatives of very varied geological age and distinct petrological types, giving rise to diverse types of scenery where they are exposed at the surface. The geological literature dealing with Victorian volcanic rocks is now fairly extensive, and is scattered through a variety of publications. A general account is included in Murray's work on the "Geology and Physical Geography of Victoria" (5), but the last edition was published 14 years ago, and the chemical and petrographical aspects receive scant treatment.

The early work of the Geological Survey laid firmly the foundations of our knowledge of the boundaries and stratigraphical relations of the volcanic rocks, and the work of Selwyn, Ulrich, Murray, and others is recorded in the Survey Reports and the official maps. Our knowledge of the chemical and microscopical characters of Victorian volcanic rocks has been mainly due to the remarkable work of the late Dr. Howitt. Commencing his investigations in the early seventies he was the pioneer in Australia of scientific petrography, yet his work, both chemical and microscopical, was characterised by such accuracy and thoroughness that the great bulk of it will probably stand with scarcely any modification.

In Victoria, in recent years, the investigators in this branch of research have increased in numbers, and foremost in importance is the work of my predecessor, Professor Gregory.

During the last four years my own research has been largely concerned with Victorian volcanic rocks. In this work, and in teaching the subject, I have felt the need of a modern general account which should summarise the present position of our knowledge. The present paper is an attempt to meet this requirement, and it is hoped that it will prove useful not only to workers in Victoria, but also to others interested in volcanic rocks who may not have access to all the literature. During the preparation of this paper I have made a bibliography of the most important papers dealing with the subject, and this is added as an appendix. In the preparation of the bibliography I have to acknowledge considerable assistance from Messrs. H. J. Grayson and H. S. Summers, M.Sc., of the Geological Department of the University, while Mr. Grayson and Mr. H. C. Richards, B.Sc., have also helped me in the preparation of the map and sections which accompany this paper.

It is hoped that this account of the Volcanic Rocks of Victoria will not only serve to show in a general way what is at present known concerning them, but, by revealing the considerable gaps in our knowledge, will serve to direct attention to those rocks and areas in which further research is required before our knowledge of them can be regarded as even approximately complete.

In order to emphasise their geological relations the volcanic rocks will be described according to their age, all those of a given geological period being grouped together.

The oldest rocks in Victoria are probably two areas of metamorphic rocks, consisting of schists and gneisses outcropping in the one case near the Western border of the State in county Dundas, and in the other forming a belt of country in Gippsland, in N.E. Victoria.

They have been regarded as altered Ordovician rocks, but, in recent years, the opinion has been gaining ground that they are not only Pre-Ordovician, but, probably, of Archæan age. Very little is yet known of their petrological characters or original composition, and, while it is possible that highly metamorphosed volcanic rocks are represented among them, we have at present no evidence of their existence. (*See* Plate I., Fig. 2, and Plate II., Fig. 1.)

BASAL ORDOVICIAN. (?)

The "Heathcotian" Series.

Geographical Distribution (*See* Map, Plate 4).

The oldest known volcanic rocks of Victoria consist of a series of diabasic rocks associated frequently with cherts. The best known and type locality is Heathcote, from which town a narrow belt of these rocks stretches northwards for about 30 miles, forming the Colbinabbin Range, and ending near L. Cooper. Some miles south of Heathcote and east of Lancefield similar rocks occur, and the same association is met with near Mount Stavely in W. Victoria (24), near Tatong (33), and Dookie in N.E. Victoria (17 and 22), and, according to Mr. Dunn (28), just N. of Nowa Nowa at the head of L. Tyers, in Gippsland. A serpentinous diabase with chert occurs at the Hummocks, a few miles N. of Casterton in W. Victoria. The serpentine of Mount Wellington, Gippsland, and the diabase occurring W. of Geelong may belong to the same series, and the serpentine near the Limestone R. in Benambra is regarded by Mr. Dunn as probably Heathcotian (30), The cherty and slaty rocks of the phosphatic deposit near Mansfield, of Edi, on the King R., and on the Divide, W. of the Macalister R., as well as some rocks near Egerton, have been claimed by Mr. Dunn as probably Heathcotian (7).

Geological Relations (*See* Plate I., Figs. 1 and 2).

At Heathcote the diabase outcrops between the Silurian rocks which form high ground to the east, and the series generally regarded as Lower Ordovician, which forms undulating ground to the west. Black cherts are developed at intervals near the contact with the diabase. They generally occur to the W. of the diabase, but in one or two localities come between the diabase and the Silurian rocks.

The age and stratigraphical relations of the rocks of Heathcote have been the subject of considerable controversy. Mr. Dunn (13), described the igneous rocks as in the main lavas and tuffs, and stated that they, with the black bedded cherts, formed a Pre-Silurian (Pre-Ordovician) series. Later (7) he refers to them as Cambrian.

The late Dr. Howitt (19) claimed the bulk of the igneous rocks as altered intrusions, maintained that the black cherts were Ordovician sediments altered by the intrusion of the diabase, and stated that the diabase was also intrusive into the Silurian rocks along their junction with the Ordovician series.

According to Howitt the cherts are altered Ordovician rocks, while the diabase he regarded as probably of Devonian age. Lidgey (16), who mapped the bulk of the area, at first agreed with Dunn's interpretation, but afterwards sided with Howitt's view. Professor Gregory (24) agreed with Howitt that the bulk of the igneous rocks are intrusive into the cherts, as to whose origin he expressed no opinion. In respect to the relations between the Ordovician and the cherty series he claimed that the evidence of the geological mapping of Lidgey and Whitelaw was inconsistent with Howitt's view that the cherts were Ordovician rocks, and really showed that both cherts and diabase consist of an older series upon which the Ordovician was laid down unconformably. The absence of diabase dykes in the Ordovician he regards as evidence that the diabase is Pre-Ordovician. Lidgey had pointed out that chert fragments occur in the Silurian conglomerates, and Gregory stated that diabase fragments were to be found in the Silurian sandstones, thus demonstrating that both diabase as well as cherts are of Pre-Silurian Age and not Devonian as maintained by Howitt. Later (9) Prof. Gregory describes the "Heathcotian" series as of Pre-Cambrian Age (p. 412), and also as U. Archæan (p. 596), but gives no reasons for stating that they are older than Cambrian. The fact that such competent observers as the above have come to such different conclusions as to the age of the series is no doubt partly due to the comparative poverty of exposures, especially near the contacts of different rocks, partly to the alteration which the rocks have undergone, but it is also a tribute to the inherent complexity of the problem. It will be noted that Howitt described the cherts as Ordovician, and the diabase as Devonian. Dunn describes both as Pre-Ordovician, while Gregory first states that both series are Pre-Ordovician, and later more precisely defines them as Pre-Cambrian and Upper Archæan.

Recently (36) I have been led by evidence in the field and laboratory to the conclusion that both cherts and diabase are probably basal members of the Ordovician series. The reasons for this view are briefly as follows:—The great bulk of the diabasic rocks near Heathcote consist of two types. The most abundant is a somewhat platy or foliated rock which, both in the field and under the microscope, is fragmental and consists of an altered diabase tuff. Agglomerates occur in one or two localities, and north of Heathcote amygdaloidal altered lavas are abundant. Only minor bosses among the tuffs and lavas were recognised by me as intrusive, and the diabase, in the main, I regard as a series contemporaneous with the adjoining sediments to the West. While the relations of the cherts to the diabase were not very clear, in several places there appeared to be a passage from one series to the other. The cherts are, in the main, finely bedded, and under the microscope several sections showed strong evidence that they are silicified tuffs. The presence of Radiolaria in the cherts was suggested. Later observations, confirmed by Mr. Chapman, have demonstrated their presence, so that I regard the cherts as silicified submarine tuffs, practically contemporaneous with the diabase, which I believe to have been partly subaerial, partly submarine in origin. The important question of the relation of the cherts to the normal Ordovician sediments I studied closely in view of their uncomformable relations suggested by Prof. Gregory, largely on the evidence of the geological maps. I have elsewhere given reasons for regarding the mapping as misleading in part, for silicified finegrained diabase has been mapped as normal Ordovician. The relations are, I maintain, such as one would expect to find if a basal Ordovician series of lavas, agglomerates, and tuffs of variable thickness gradually passed by cessation of volcanic activity into normal marine sediments, and were subsequently folded and denuded. It is significant that the Ordovician shales near the diabase contain nodules of magnesite indicating probably an admixture with diabasic material. If the cherts and diabase were Pre-Ordovician one would expect the cherts to differ from the Ordovician in dip and strike, and one would expect to find a marked conglomerate at the junction between the cherts or diabase and Ordovician, such as one finds to the east at the junction of the Heathcotian and the Silurian. Close examination in the field led me to the conclusion that no such conglomerate existed, and that while in going from S. to N. changes in strike of both series were noticeable, at any one point the strikes of the cherty series and the Ordovician sediments were in substantial agreement. Furthermore in several places as one passed from the black cherts towards the normal Ordovician shales less and less cherty rocks were met with. In places where black cherts do not occur at the junction of the diabase with the Ordovician the sediments are silicified, but to a lesser extent. The evidence in the field convinced me that the cherts as maintained by Dr. Howitt are simply highly altered Ordovician bedded rocks. A visit to the similar area east of Lancefield showed in that locality that this is the true explanation. West of the diabase occur dense black bedded cherts, and in a quarry a section is exposed showing the interbedding of the cherts with less silicified shales, from which the Lower Ordovician graptolites typical of the Lancefield horizon as defined by Dr. Hall have been obtained.

The precise age of the shales and cherts which junction with the diabase at Heathcote is still a matter of some doubt. Mr. Ferguson found a few trilobite remains which were named Dinesus ida by Mr. Etheridge, who regarded it as having affinities with Cambrian forms, and these Dinesus beds, cherty in part, were for a time described as Cambrian. A later find of more trilobite fragments was examined by Prof. Gregory, who described a new genus Notasaphus. Some obscure markings resembling Bryograptus were later referred to algae, and poorly preserved Brachiopods were regarded by Mr. Chapman (18) as Ordovician, and even showing affinities with the Upper Ordovician. With this additional evidence Prof. Gregory regarded it as safer to include the Dinesus beds as forming the lowest part of the Ordovician.

My own search resulted in the finding of Radiolaria in the black cherts, and also in some of the Dinesus beds. Some indeterminable sponge spicules were also noted in this series, and a few feet above what had been mapped as their upper limit, while numerous spicules of Protospongia were found in the Dinesus series and in the Ordovician rocks just west of them. I find that Mr. Etheridge has recorded Protospongia as occurring with Dinesus ida. (Geol. Surv., Vict., Month. Prog. Rep., Feb., 1900, p. 23.) This genus occurs with the L. Ordovician graptolites of Lancefield, so that there seems no valid reason on the available evidence to regard the Dinesus series as other than L. Ordovician. The black cherts and diabase which immediately underlie them I regard for the reasons given above as conformable with them. It is possible that they may be U. Cambrian, and that there is here a conformable passage between Cambrian and L. Ordovician, but in the present state of our knowledge it seems to be safer to regard them as forming the base of the Ordovician series in Victoria. If the term Heathcotian is to be retained in Victorian geology, it would, I think, be better to define it not as a distinctly Pre-Ordovician series but as a new horizon of the Lower Ordovician whose cherty upper limit passes into the Lancefield series, while its lower limit would be defined as the base of the diabase series. Palæontologically it should, I think, include not only the Radiolaria in the cherts, but also the fossils of the Dinesus beds—namely, Dinesus, Notasaphus, Protospongia, and other sponge spicules, Radiolaria and the Brachiopods identified by Mr. Chapman, viz.:—Siphonotreta (2 species), Chonetes concinna, sp. nov., Strophomena flabelloides, sp. nov., five species of Orthis, Camarotoechia (?), and the bivalve Modiolopsis (?), knowsleyensis, sp. nov.

Evidence from other Areas in Victoria.

In some of the areas referred by Mr. Dunn to the Heathcotian, cherty rocks occur unaccompanied by diabase, and some of these areas have since been shown to belong to younger series.

Near Edi, on the King River, black slates with turquoise have yielded graptolites (25), including Diplograptus, Didymograptus, and Glossograptus, and have been referred by Dr. Hall to the Upper Ordovician.

Mansfield.—The phosphate deposits near Mansfield described by A. M. Howitt (26) are associated with black cherts and dark shales. Trilobite fragments and other organisms from them have been examined by Prof. Gregory, and he has referred them (9) to Olenellus and Salterella, and described the beds in consequence as Lower Cambrian. Mr. Summers and myself on a recent visit to the locality examined the occurrence in some detail, and we hope to publish an account of our observations shortly. Among the fossils we found in black shales interbedded with the cherts and phosphate bands were a number of well-preserved graptolites, including Diplograptus, Coenograptus, Glossograptus, Tetragraptus, and Didymograptus, allied to D. caduceus. This association of forms suggests that they belong either to the Darriwill series at the top of the Lower Ordovician, or to the base of the Upper Ordovician series. As some of these graptolites were taken only a few yards away from the locality where the trilobites were found it would appear that a re-examination of the trilobite material is advisable since the evidence of the graptolites points unmistakably to the beds belonging to the Ordovician.

Egerton.—Grey and reddish cherty rocks with small ramifying quartz veins occur on a hill near Egerton, and are surrounded by Ordovician rocks. Mr. Dunn (31) on lithological grounds has referred them to the Heathcotian, but in the absence of stratigraphical and palæontological evidence it would seem to be safer to regard them as modifications by silicification of the Ordovician series.

Eastern Gippsland.—Near the Iron Mask Mine, and on the Mount Tara Goldfield, near Buchan, are rocks whose relations to the Ordovician have not been determined, but which Dunn (28) on lithological grounds has classed with the Heathcotian. In a few localities diabasic and serpentine rocks unaccompanied by cherts have been referred to the Heathcotian series.

West of Geelong.—Two outcrops of diabases and amphibolites occur to the west of Geelong which Gregory (24) has correlated with the Heathcotian series. The stratigraphical relations of these rocks to the Ordovician series in the district is obscure.

Limestone Creek, Benambra.—Siliceous schists $2\frac{1}{2}$ miles from the hut on Limestone Creek and at Serpentine $\frac{1}{2}$ mile east of gap between Limestone Creek and Mount Leinster Station are by Dunn (30) doubtfully referred to the Heathcotian.

Mount Wellington District, North Gippsland.—The Serpentine of this district has been shown by Thiele (34) to be older than the U. Ordovician which rests on its flanks, and it is possible that it may belong to the same period as the basic rocks of Heathcote. It is probably in the main an *intrusive* mass.

Some areas remain to be noticed in which both cherts and diabases are associated, and in which therefore a correlation with the type area can be attempted with rather more confidence.

Nowa Nowa.—Just North of Nowa Nowa, at the head of L. Tyers, in Gippsland, is an outcrop, so Mr. Dunn informs me, of diabases associated with cherts. I have not visited the precise locality, but Mr. Dunn tells me the relations of the rocks are similar to those of Heathcote, and he refers them to the same age.

Tatong.—The cherts and associated diabases at Tatong, near Benalla, in N.E. Victoria, first referred to by Howitt (25) on lithological grounds as probably Heathcotian (Pre-Ordovician) have been more recently described by Summers (33), who has shown in places that chert passes into diabase and in other areas is interbedded with normal shales which have been on lithological grounds grouped with the Ordovician. The evidence available suggests that the rocks may be Heathcotian, using that term in the sense of basal Ordovician.

Dookie.—The rocks of Mount Major, North of Dookie Agricultural College, were shown by Ferguson (17 and 22) to be lithologically similar to the Heathcote rocks. Gregory (24) included them among the Heathcotian (Pre-Ordovician) areas. Recently Mr. Summers and myself have examined the area, and intend to publish a note on the relations of the rocks. I may state here that we found clear evidence that the diabase and cherts were interbedded, suggesting that they consisted originally of submarine lavas and tuffs, respectively. South of Mount Major cherty rocks containing obscure graptolites were also found. All the available evidence points strongly to the Dookie rocks being of the same age as those of Heathcote.

Mount Stavely, Western District.—Gregory (24) has pointed out the similarity between the igneous and cherty rocks of Mount Stavely and those of Heathcote. A recent visit to the locality by Mr. Summers and myself has served to confirm the impression, and we noted that the cherts passed gradually into the unaltered shales which have been mapped as Ordovician, although no fossils have been found in the area.

The Hummocks.—About 5 miles N. from Casterton, near the western border of Victoria, is an outcrop of a basic rock in part diabasic, in part serpentinous. Its relations to the Ordovician (?) rocks of the district are not clear, but on the flanks of the hill Mr. Summers and I found a bedded chert which suggests that we may here also be dealing with another outcrop of Heathcotian rocks.

A reference to the map (Pl. 4) accompanying this paper will serve to show the localities and areas of the rocks dealt with above, while sections (Pl. 1) indicate the probable structural relations. If my view of the basal Ordovician age of the Heathcotian series be correct, it may be possible to explain the present distribution of the rocks at the surface, on the view that they only crop out from below beds higher in the series along the axes of much denuded anticlinal folds. If this view is correct the location of these anticlinal areas may prove of considerable help in interpreting the structure of the Ordovician rocks of Victoria, especially in those large areas in Western Victoria from which up to the present no fossils have been obtained.

Petrological and Chemical Characters of the Heathcotian Series.

Howitt (19) has given the most detailed petrographic description of the igneous rocks of Heathcote. Many of the rocks have been so altered that their original characters are hard to determine. Howitt has described diabase-porphyrites, compact diabase, diabase-schists, breccias, and "regenerated rocks," while diorite, aplite, granophyre, and felspar-porphyrite were recognised among the intrusive rocks, and the cherts were described as adinoles.

Gregory accepted Howitt's determinations with the exception of that of the aplite, which he describes as a fine-grained granodiorite.

Undoubtedly, intrusives, lavas and pyroclastic rocks are all represented, and I have agreed with Dunn that the bulk of the rocks are tuffs, agglomerates, and lavas. I have suggested that Howitt's aplite may be termed a microgranite in a broad sense, and that it may represent the final most acid intrusive rock of the diabase series. The term diabase is here used in a broad way to cover a number of more or less altered basic rocks, some of which are intrusive, while many are lavas and consolidated tuffs. The minerals of the diabase include augite, enstatite, secondary hornblende, andesine to labradorite among the felspars, quartz, sphene, ilmenite, and magnetite. Secondary minerals besides hornblende are calcite, chlorite, epidote, albite, quartz, zeolites, chalcedony, &c. The bedded cherts, hitherto regarded as altered sedimentary rocks, I have referred to as probably in great part silicified submarine tuff. Some of the minerals of the diabase series, volcanic fragments and Radiolaria have been recognised in them. The foliated diabase of Red Hill (Howitt's diabase schist or schalstein) is also fragmental, and may be an altered subaerial tuff. The alterations undergone by the diabase rocks are remarkable and interesting. The tuffs have been foliated, and the bulk of the rocks have been recrystallized. In many cases metasomatic changes have been superimposed upon the purely structural and mineralogical rearrangement of the rocks. Secondary silicification of the diabase is in places complete. In one locality the foliated diabase is altered almost completely to a mass of minute quartz crystals; in other places silicification has replaced the diabase and produced red and green and black jasperoids, and all stages of the process can be seen in the field and in rock sections. There is little doubt that the silicification was due to solutions passing through the rocks after the consolidation of the diabase, and that the same solutions altered the bedded tuffs to black bedded cherts.

In other places the diabase has been more or less completely replaced by carbonates, while in another place it occurs as a mixed carbonate and chert rock.

A peculiar alteration at the margin of the diabase north of Heathcote has given rise to a green substance named "Selwynite," formerly thought to be a mineral, but now known to be a rock consisting of a green chrome-bearing micaceous mineral, chromite, pyroxene, and another highly birefringent micaceous mineral. Corundum was found by me in association with the selwynite, and also as pseudomorphs in one of the jasperised diabases. Much less is known of the petrology of the other districts referred to. The Hummocks and Mount Wellington areas consist of diabasic rocks more or less completely altered and recrystallised as serpentine. At Mount Stavely diabases and porphyritic rocks of a rather less basic type occur. The rocks of Dookie, Tatong, Limestone Creek, and Nowa Nowa have not yet been subjected to microscopic examination.

There remain the Lancefield and Geelong areas. The rocks of the aboriginal quarries of Mount William, N. of Lancefield, are described by Gregory (24) as amphibolites and impure nephrites. They represent diabases which have been completely recrystallised. The rocks west of Geelong have been described as gabbros and also as diabase. According to Gregory enstatite-diabases, epidiorites, and amphibolites occur. The latter consists of needles of green hornblende, zoisite, and altered felspar.

The Chemical Composition of the Heathcotian Rocks.

Most of the diabases have suffered such chemical as well as structural changes that chemical analyses would afford little evidence of the original composition of the rocks. I know of only one analysis of a rock, described as a greenstone (diabase) from Geelong, but the exact locality is not stated. (3.)

Greenstone (diabase), Geelong.

SiO_2 ...	50·84	MgO ...	10·97
Al_2O_3 ...	12·92	K_2O ...	1·83
Fe_2O_3 ...	0·52	Na_2O ...	tr.
FeO ...	6·99	H_2O ...	0·71
CaO ...	14·35		
		Total ...	99·13

Silurian (Yeringian).—We have no evidence of volcanic activity during any part of the Ordovician period above the Heathcotian in Victoria. This is strange, as andesites have been referred to the Ordovician near Bathurst, in N.S.W., and in many parts of the world vulcanicity was vigorous throughout the period. This period of quiescence in Victoria appears to have continued throughout the lower or Melbournian horizon of the Silurian. In the upper or Yeringian series, however, Chapman (38) has described the microscopic characters of some limestones from the Thomson River district, in Gippsland, in the matrix of one of which under the microscope he recognises flakes of biotite and pale green chlorite, and here and there some contorted bands of tuffaceous fragments. He says "this clearly suggests the outburst of tuffaceous andesitic ejectamenta contemporaneously with the deposition of the limestone, as illustrated, for example, by the calcareous organic tuffs forming in the proximity of volcanic islands at the present day." This is so far the only evidence we have of vulcanicity in the Silurian rocks of Victoria, and even in this case the fragments may possibly be detrital in origin.

DEVONIAN.

Lower Devonian (?)

"SNOWY RIVER PORPHYRIES." (*See* Plate 4.)

Geographical Distribution and Physiography.

This group of Volcanic Rocks was first described and its geographical extent first indicated by the late Dr. A. W. Howitt (43). Later information by Murray (46), O. A. L. Whitelaw (78), and Ferguson (75) has added something to our general knowledge of this formation, but in all essentials no advance upon Howitt's reports of 1876 and 1877 has been made. In view of the interest and importance of this series it is curious that Howitt never published any later work on this formation. Apart from his early general description the petrographical characters of the rocks remain undescribed, and as far as I know no chemical analyses have been made.

The geographical development of this series lies in the mountainous district of N.E. Victoria, and the largest area is a belt of country which, commencing in New South Wales, occupies at the boundary a breadth of about 20 miles near the head of the River Murray. The western limits include the Cobberas Mountain, and runs south to Mount Nowa Nowa, near the head of L. Tyers, while the eastern boundary is parallel to and slightly eastward of the Snowy River.

Outlying areas included with this series occur near the valley of the Mitta Mitta River, and near Corryong, in the extreme N.E. of the State.

A series of rocks near Whitfield in country Delatite has been correlated by Kitson (74) with this group, but for reasons given later I prefer to group them with the dacite and quartz-porphyry series. The highest elevations in the Snowy River porphyry series occur near the N.S. Wales boundary, the Cobberas, for example, being over 6,000 ft. in height, and the general level falls southwards till at about 1,000 ft. above sea level the rocks are hidden beneath the Tertiary coastal belt of S.E. Gippsland. The scenery is rugged in the more elevated areas, while gorges and waterfalls occur in parts of the course of the Snowy River and some of its tributaries.

Geological Relations (*See* Sections, Plate II., Fig. 1).

The rocks of this series consist of acid lavas and fragmental rocks, in places over 2,000 ft. in thickness, ejected from a series of Palæozoic volcanoes which Howitt describes as probably developed along meridional fissures in the Lower Palæozoic rock foundations near a subsiding coast line. The age and character of this foundation for the volcanic rocks varies. In places it consists of the complex of gneisses and schists possibly of Archæan age. Elsewhere it consists of Ordovician sediments and of granitic rocks. Near the Limestone River Howitt (58) describes the porphyries as resting on the upturned edges of shales and intercalated limestones and marbles. These yielded obscure fossils which McCoy described as probably U. Silurian, and on this account Howitt regarded the porphyries as of Post-Silurian age. The evidence of the relations of the two series in this area is not very clear, and there is some doubt as to the age of the limestone, which may possibly be related to the Mid-Devonian series of Buchan and Bindi. It is therefore difficult to speak precisely of the age of the base of the porphyries, especially as Howitt describes the boundary with the older rocks in some parts as a fault junction. We can speak more positively of the relations of the upper part of the series with the overlying sediments. Near Buchan, Bindi, and one or two other areas the volcanic rocks are succeeded by marine limestones containing typical middle Devonian fossils, and in some localities a gradual passage occurs between the volcanic tuffs and ashes of the Snowy River porphyries through calcareous felsite breccias and submarine tuffs into typical marine limestones. It is clear therefore that the upper stratigraphical limit of the porphyries is Mid-Devonian. The lower limit is certainly Post-Ordovician, and possibly Post-Silurian. No Lower Devonian sediments are known in Victoria, and the Snowy River porphyries are generally regarded as occupying that horizon. Until the relations of this series with the underlying rocks, however, can be more precisely defined, the possibility of the basal part of the series being of U. Silurian age cannot be dismissed, especially in view of the occurrence of volcanic rocks in that series near Yass, in New South Wales.

Petrological Characters.

Very little microscopic examination of these rocks has been undertaken. Howitt (43) has given a preliminary description of a few rock sections, but a great deal remains to be done before any comprehensive account of the petrology of the series can be written. Howitt has shown that the oldest rocks consist mainly of lava flows, while the later series consist chiefly of tuffs and agglomerates with minor outpourings of lava. The lower rocks are described as quartz-porphyries. Some of them with fluidal structure should probably be grouped with the rhyolites. The upper more fragmental rocks he refers to as felstone-porphyries, felstone ash, and agglomerates. Many of the pyroclastic rocks have suffered secondary silicification, a change which has more or less disguised the characteristic matrix of the rock under the microscope.

Some of the higher mountains in the Snowy River porphyry area Howitt regards as the denuded centres of volcanic activity. In these cases a central deeper-seated mass of quartz-porphyry is surrounded by lava flows and pyroclastic rocks.

The Cobberas, Wombargo Mountain, and Mount Hotham show this structure.

Outside of the present area of the Snowy River porphyries occur a number of hills of granite-porphyry rising through older rocks. Mount Taylor, Mount Alfred, and Mount Lookout, near Bairnsdale; Mount Nowa Nowa, at the head of L. Tyers; and Mount Raymond, east of the Snowy River mouth, are examples of hills of this type. From their general petrographical resemblance to the central porphyritic rocks of the Cobberas, &c., Howitt suggests that the above-mentioned hills may represent the plugs of some of the volcanoes from which the Snowy River porphyries were derived.

Chemical Characters.—These can only be inferred from the microscopic determinations, as no analyses of this series appear to have been made.

LOWER DEVONIAN (?)

The Alkali Rocks of Eastern Victoria.

In three distinct areas in Eastern Victoria there occur rocks of an alkaline character which have been described by Howitt, but which have not hitherto been definitely placed among the alkali series. The districts in which they occur are near Mount Leinster station, in Benambra; Frenchman's Hill, near Omeo; and Mount Elizabeth, Noyang, near where the road from Bruthen to Omeo first crosses the R. Tambo.

The Mount Leinster Rocks in Benambra.

Geographical and Geological Relations.

Mount Leinster forms a prominent landmark in Benambra, rising 1,500 ft. above the surrounding country, and about 4,000 ft. above sea level (58). It lies about 25 miles in a N.E. direction from Omeo, and Mount Leinster station is situated to the north of its northern slopes.

The rocks of Mount Leinster rise above, and in part rest upon a considerable area of quartz-diorites. In Howitt's view they are genetically related to the diorites, and form the latest and most acid of the series of igneous rocks intruded into the district probably in Devonian times. They are the youngest rocks in the district, and show chemical and petrological resemblances to the Mid-Kainozoic alkaline rocks of the Macedon District. and further evidence as to their age is needed.

Petrological and Chemical Characters.

Howitt describes several allied types among the rocks of Mount Leinster, but only names one rock which he analysed. This consists essentially of orthoclase and augite with subordinate ferric hydrate and plagioclase, and is described by Howitt as a syenite-porphyry. The porphyries of Mount Leinster, according to him, consist essentially of orthoclase and augite, with accessory triclinic felspars and occasional quartz crystals, and a small amount of ores of iron. They are, therefore, to be classed as "Augite-syenite-porphyries."

The following is the analysis of the syenite-porphyry described above:—

SiO_2	60·57	K_2O	6·29
Al_2O_3	19·05	Na_2O	5·55
$Fe\ O_3$	5·29	H_2O	1·60
CaO	0·92		
MgO	1·56	Total	= 100·83

In connection with this rock, Howitt remarks that, though the felspar appeared to be mainly orthoclase under the microscope, yet the analysis suggests the presence of a large percentage of a triclinic felspar near to, if not in fact, albite.

I have examined Howitt's rock sections from this locality, and find that a large amount of the felspar identified by Howitt as orthoclase has the optical character of anorthoclase. The augite also is green and slightly pleochroic, and is a variety of ægirine-augite, while a little of a blue soda-hornblende occurs interstitially. These observations serve to bring the microscopical characters into agreement with the results of the chemical analysis, and to show that, while structurally the rock resembles a syenite-porphyry, mineralogically and chemically it is allied to the alkaline intrusive rocks of intermediate composition In a short visit made to the district in company with Mr. Dunn (30) we noticed that near Mount Leinster homestead a hill is composed largely of pyroclastic rocks of a trachytic character, through which a number of dykes penetrate. I hope to publish a petrological account of these rocks shortly. At present it may suffice to say that solvsbergites are present among the Mount Leinster rocks, while others are allied to the bostonites, and among the pyroclastic rocks the most abundant fragments are those of an alkaline rock with a trachytic texture, probably an alkaline trachyte.

Howitt's analysis shows a close agreement with those of the alkaline trachytes from the Western District, Macedon and Omeo, to be referred to later.

The Rocks of Frenchman's Hill, Omeo.

Geographical and Geological Relations.

This area lies just to the North of Omeo township, in Eastern Gippsland. Between two confluents of Livingstone Creek there rises a somewhat abrupt hill to the height of 500 ft. above the level of the streams. It is locally known as the Frenchman's Hill. The only published description is by Howitt (57). The geological sequence, according to him, is as follows:—The oldest rock is a mica-schist. Intrusive into this are masses of quartz-diorite, followed by granites, aplites, felspar quartz dykes, quartz felspar dykes, and quartz veins.

Subsequent in age to these are the intrusive rocks of Frenchman's Hill, which differ in structure and composition from the granites, but are regarded by Howitt as a later part of the same plutonic series. In addition to the main mass there are two apophyses or dyke-like masses which extend westwards across Livingstone Creek. A number of dykes also radiate from the central mass. Although these apophyses are regarded by Howitt as intrusive rocks, the geological map published with his paper suggests the possibility of their being lava flows. In a short visit which I made to the district in company with Dr. Howitt, this view was strengthened by the evidence seen in the road cutting where the larger tongue-like mass from the hill crosses the road. The rock is here trachytic in character and apparently fragmental, suggesting to me either a coarse trachyte-tuff or a lava flow crowded with fragments, while Howitt interprets it as due to movement before final consolidation. The evidence as to the age of these rocks is not very satisfactory. It is clear that it is the youngest igneous rock in the district, but how much younger it is than the granite is not evident. In view of its petrological and chemical similarity to the trachytic rocks of Macedon, its grouping with the Devonian volcanic rocks must be regarded as tentative only.

Petrological and Chemical Characters.

The rocks are all pale in colour, and vary considerably in texture. Near the top of the hill they are fairly coarsely porphyritic and more plutonic in appearance, except that a distinct ground mass is present. Away from the centre of the hill the texture is finer and more trachytic, while the radial dykes are very fine grained. All the rocks are described by Howitt as "Orthophyres," and the porphyritic felspar identified as orthoclase. Six analyses were made by him, three of which are recorded here.

	1. Road Cutting.	2. S.W. Side.	3. Dyke, N. Side.
SiO_2 ...	60·68	66·02	67·40
Al_2O_3 ...	18·36	17·55	18·14
Fe_2O_3 ...	1·59	3·28	0·53
FeO ...	3·28	0·56	..
MgO ...	1·15	0·35	0·27
CaO ...	1·25	1·80	0·44
Na_2O ...	5·16	5·59	7·12
K_2O ...	6·03	5·20	5·12
H_2O ...	2·31	0·32	0·35
CO_2 ...	...	0·26	...
TeS_2 ...	...	...	0·08
Total ...	99·81	100·93	99·45

Howitt experienced the same difficulty with these rocks as with those from Mount Leinster in reconciling the identification of the felspar as orthoclase with the high percentage of soda in the analysis. The explanation is, as before, that much of the felspar is anorthoclase, and a soda-hornblende is also present in some of the rock sections.

Some of the felspars are rectangular in outline, giving a typical orthophyric structure to the rock. In others flow structure is prominent and the habit typically trachytic. In such cases the rock is best described as an alkali-trachyte (Analysis I., for example). Some of the intrusive material is allied in structure and composition to the solvsbergites (Analysis 2). The latter more acid dykes contain a little free quartz, sometimes granular, sometimes in graphic intergrowth with felspar. One of the radial dykes examined (Analysis 3) is mineralogically and chemically in agreement with the typical bostonites.

The field evidence combined with microscopic and analytical examination shows that the later intrusions from this alkali centre became progressively more acid in character.

The Rocks of Noyang, in Dargo.

Geographical and Geological Relations.

The area over which the alkali rocks occur lies to the east of the Tambo River, with the exception that above the Noyang Ford, now known as Tambo Crossing, a big offshoot from the main mass extends from near Mount Elizabeth to the westward of the river, and along the course of the Haunted Stream. The great bulk of Mount Elizabeth, rising to nearly 3,000 ft. above sea level, forms the central mass of the rocks to be described, and from it many prominent dykes extend in a radial manner. As described by Howitt (52), older Palæozoic sediments comprise the fundamental rock of the district, into which were intruded a succession of igneous rocks, at first plutonic quartz-mica-diorites, and succeeding these but genetically related to them was a succession of intrusive and volcanic rocks of progressively more acid composition. These are described by Howitt as quartz-mica-porphyrites and quartz granophyrites (spherulitic quartz-porphyrites), succeeded by quartz-porphyrites, and these by quartz-felsophyrites. Later dykes of diorite and diabase were intruded, and are regarded by Howitt as possibly belonging to the same geological period, although the evidence is slender. *The alkali rocks* of this area comprise the following:—(1) The quartz-porphyrites and quartz-granophyrites, which occur as dykes and masses penetrating the quartz-mica-diorite. (2) The quartz-porphyrites which occur as milk-white close-grained masses and dykes representing the magma freed from its basic elements and consisting of felspar and quartz alone. (3) The quartz-felsophyrites may also be of alkaline character, although no analyses have been made of this rock, and few minerals are developed. It occurs as a volcanic focus, shows well-defined flow structure, and is flanked by breccias consisting of the altered sediments of the district. It probably represents the plug of the vent from which the earlier intrusions radiated. Many of these observations I have had the opportunity of verifying in the field under the guidance of the late Dr. Howitt.

Petrological and Chemical Characters.

The names given by Howitt to these rocks do not at once suggest their derivation from an alkali magma. His descriptions of their mineralogical contents and a glance at the analyses which he made of them, however, show their relationships with the group of the ceratophyres, and, indeed, Howitt has given that name to several of the rock-sections which he had prepared from this series.

Three analyses which he made are here recorded:—

	1.	2.	3.
SiO_2	72·39	77·66	78·77
Al_2O_3	14·42	12·30	12·44
Fe_2O_3	0·56	0·61	0·95
FeO	0·30	0·17	...
MgO	1·85	0·73	0·02
CaO	0·85	0·16	0·53
Na_2O	5·93	6·96	6·79
K_2O	1·23	0·19	0·24
H_2O	1·13	0·46	0·26
P_2O_5	tr	tr	...
MnO	0·01	...	...
Total	98·67	99·24	100·00

* SiO_2 determined indirectly.

1. Quartz-Mica-Porphyrite (Quartz-Ceratophyre), Navigation Creek.
2. Quartz-Mica-Porphyrite (Quartz-Ceratophyre), Navigation Creek.
3. Quartz-Porphyrite (Quartz-Ceratophyre), Mount Elizabeth Creek.

Quartz-mica-porphyrite (Quartz-ceratophyre).—This rock shows a microcrystalline granular ground mass of quartz and felspar with minute microliths of chlorite replacing probably amphibole. The porphyritic constituents are as follows:—

Oligoclase of an acid variety showing both albite and Carlsbad-twinning.
Quartz in corroded and fractured crystals.
Chlorite pseudomorphs after a magnesia-iron-mica.

Associated with this type are the rocks described by Howitt as quartz-granophyrites. These in the field occur as dyke-like masses, but their microscopic characters are similar to those shown usually by acid lava flows. Fluidal structure is sometimes seen, the rocks appear to have been originally glassy, and subsequent devitrification has produced large spherulitic areas and a somewhat granophyric intergrowth of quartz and felspar. In some of the less spherulitic varieties porphyritic felspars occur. Most of these are acid-oligoclase, but some have the optical characters of anorthoclase, and the rock is clearly a spherulitic variety of quartz-ceratophyre.

Quartz-porphyrite (Quartz-ceratophyre).—These in the field consist of dykes of a milk-white colour. Under the microscope it is seen that quartz and felspar are the only constituents. The fine-grained ground mass of quartz and felspar has a few porphyritic crystals of the same minerals scattered through it. The felspars were too kaolinised for precise determination, but the analysis shows that they were soda rich, and that the rock is a quartz-ceratophyre.

Quartz-felsophyrites.—This rock is probably younger than those just described, it is flanked by breccias, it is intensely hard and flinty in character, of a black or greyish black colour, and includes numerous fragments of the ceratophyres and of the sedimentary rocks which give it a porphyritic appearance. Under the microscope the ground mass is a dark yellow brown glass, showing very marked fluidal structure. In places the glass is replaced by a cryptocrystalline aggregate. The larger constituents of the rock include angular fragments of glass, fractured and corroded crystals of quartz, twinned and fractured felspars, and some chloritic material. Howitt suggests that the ground mass of the rock agrees with that of a pitchstone. It seems to me that the marked fluidal character allies it rather with the rhyolites, and I prefer to describe it as a soda-rhyolite.

LOWER DEVONIAN.

The Dacite and Quartz-Porphyrite Series.

Geographical Distribution and Physiography (See Plate 4).

Rocks belonging to these petrographic types occur in large masses, covering very considerable areas in Central Victoria. About 40 miles N.W. of Melbourne occurs Mount Macedon, a very considerable portion of which is composed of dacite. About 20 miles E.S.E. of Melbourne another considerable area of dacite and quartz-porphyrites forms the hilly area of the Dandenong Hills.

The largest single area of dacites, quartz-porphyrites with some granite-porphyries, commences at Healesville, about 40 miles N.E. of Melbourne, stretches S. to Warburton, and N.E. past the Black's Spur and Narbethong to Marysville and the Cerberean Range. The northern parts of the Strathbogie Ranges, south of Violet Town, consist of similar rocks, while to the east of this and south of Benalla there is a large area of rocks, including Mount Samaria and Whitfield, which have been correlated with the Snowy River porphyries (74), but which, I think, are more probably related to the dacite, quartz-porphyrite series. All these areas mentioned are more or less mountainous in character. Mount Dandenong is just over 2,000 ft. in height, Mount Macedon just over 3,000 ft., Mount Juliet, near Healesville, 3,600 ft., while several of the mountains near Warburton exceed 4,000 ft. in height. In most cases these volcanic and intrusive masses rise well above the levels of the granodiorites and the Lower Palæozoic sediments with which they are associated. Professor Gregory (83) regards them as volcanic masses, probably of Lower Kainozoic age, poured out over and rising above a platform of granodiorite and Lower Palæozoic sediments which before the outpouring of the dacites, &c., had been reduced practically to a peneplain. For reasons which will be stated later, I believe the dacites to be a much older series, into which the granodiorite was intruded, and that the present surface relations and the exposure of the granodiorites at the surface is the result of long-continued differential denudation of the sediments and igneous rocks. The level-topped, plateau-like character of the dacites of Mount Macedon, and of the Dandenong Ranges in particular, suggests the possibility that these may be the remnants of a former extensive peneplain developed by long-continued subaerial denudation of the igneous and sedimentary rocks before Mid-Kainozoic times. Later movements of uplift led to the dissection of this peneplain and the formation of another at a level of only a few hundred feet above sea level, the softer sediments being easily base levelled, and the more resistant dacites preserving remnants of the older peneplain. The present surface features of the surrounding sediments are the result of a still later uplift, and the erosion of the sediments consequent upon it.

Geological Relations (See Plate III., Fig. 1).

The relations of the dacites and quartz-porphyrites with the granodiorites on the one hand and with the palæozoic sediments on the other are the chief points of interest, and bear closely on the age of the volcanic series.

Relations with the Granodiorites.

Selwyn (39) and the officers of the early Geological Survey expressed the view that a gradual passage could in places be traced between the "Traps" (dacites, quartz-porphyrites, &c.) and the granitic rocks, and they regarded them as being intrusive rocks of Palæozoic age. Professor Gregory (83) maintains that at Macedon they are quite distinct in composition and origin from the granodiorites, and are quite unaltered near the contact with them. He regards them as volcanic rocks poured out over a denuded Palæozoic platform of sedimentary rocks and granodiorite, and that in consequence they are far younger than the granitic rocks, and may be of Lower Kainozoic age.

I have been investigating the relations of these two series in Victoria for the past four years, and the evidence I have obtained at the south of the Dandenong Hills, at Warburton, and at Marysville has led me to come to different conclusions from previous observers. I hope to publish this evidence in detail shortly, and meanwhile present a brief summary. Mr. Summers (91) has come to similar conclusions on evidence he has obtained in the Strathbogie ranges, while detailed examination of the Macedon district by Mr. Summers and myself affords similar results. The evidence from these areas will be published in detail shortly, while a short summary will suffice for the purposes of this communication. The geological relations of each of the areas mentioned above is, in my opinion, as follows:—

The Dandenong Hills.—Dacites, quartz-porphyries, and quartz-porphyrites are represented among the rocks of this area, but it has not been found possible to map the boundaries of each. The rocks appear to be in part intrusive in character, as fairly coarsely crystalline dacites occur near Aura, on the Gembrook Railway Line. The bulk of them are lava flows, with some pyroclastic rocks. The junction with the granodiorite runs nearly east and west from about 2 miles south of Ferntree Gully to the railway line just west of Emerald. In 1905 I discovered a remarkable belt of gneissic rocks between the normal dacite and the granodiorite, on the Monbulk Creek, South of Belgrave. I have traced this belt for some miles both to the west and to the east nearly to Emerald. It varies in width up to about 400 yards. Several junctions of the gneiss with the granodiorite have been found, and everywhere the junction has been quite sharp and distinct. Near the junction in several places pegmatite and quartz veins have been found cutting the gneissic series. While the junction with the granodiorite is everywhere sharp, no such junction with the normal dacite has been seen, but there appears to be a gradual transition from a gneiss through less and less gneissic dacites to the normal rock. This I regard as strong evidence that the dacite is the older rock, and that the subsequent intrusion of the granodiorite into the already consolidated dacite has altered the latter rock near the contact to a gneiss, while in the final stages of consolidation of the granodiorite, pegmatite and quartz veins penetrated the gneissic rock.

The Warburton District.—A somewhat similar belt of gneissic rocks was found by me in 1906 to separate the granodiorites which lie to the South from the normal dacites lying to the North of Warburton. These are best seen in Pheasant Creek, about a mile to the east of the township. A sharp junction with the granitic rock occurs, but apparently they merge into the unaltered dacites to the north.

At "Nyora," between Healesville and Launching Place, and about 2 miles north of the latter, the granodiorite and dacite also junction. In this locality no gneissic band intervenes, but acid veins can be seen running into the dacite from near the junction with the granodiorite.

The Black's Spur and Narbethong areas.—On the Geological Survey Map of Victoria (1902), on the scale of 8 miles to the inch, a junction between the two series is shown, close to the Hermitage, between the Black's Spur and Narbethong. Prof. Gregory states that here the dacites rest on the granodiorite. I spent three days in the locality looking for this junction, but it does not occur where it is shown on the survey map. The map indicates a great mass of granitic rocks extending from near Narbethong through Marysville, north-east to Mount Torbrech, whereas over most of this area the rock is certainly dacite.

The Marysville District.—Dacite is widely spread near Marysville. The rock is mineralised in places. Gold has been worked in a creek running only over dacite, near the Wood's Point road, about 7 miles to the east of Marysville.

Six or seven miles to the S. of Marysville and on the south of the divide wolfram and scheelite have been worked. On a visit to the wolfram workings, which I made in 1908, I found that they occurred near the junction of the dacite with a granite-porphyry. The actual junction was not seen, but there is little doubt that the granite-porphyry is intrusive into the dacite, since acid veins and quartz veins carrying wolfram and scheelite penetrate the dacite near the contact, and some of these have been worked for these minerals.

The Cerberean Range, north of Marysville, also consists of dacite.

The Macedon Area.—Prof. Gregory, as mentioned above, regards the dacites as younger volcanic rocks, with minor intrusions, poured out over the denuded surface of sedimentary rocks and granodiorite. Mr. Summers and myself have mapped the whole district, and find that, although no gneissic rocks occur near the junction, minor structural and mineralogical changes occur in the dacite at the contact. We also find tourmaline and acid granitic rocks developed at the contact, and small acid pegmatitic veins in the dacite near the granodiorite, and for these reasons regard the dacite as the older rock, and the granodiorite as intrusive into it.

The Strathbogie and Whitfield Areas.—Mr. Summers's work in the northern part of the Strathbogie area (93) has shown that near Mount Samaria there appears to be a gradual passage from granitic rocks through granite-porphyries to quartz-porphyry. In the same paper he states that in the Tolmie and Toombullup Ranges the porphyries are clearly older than Carboniferous, since sandstones of that age rest on the porphyries and show no signs of contact metamorphism. Some of the hypersthene-bearing dacites of the Strathbogies contain abundant garnets, and in the Whitfield area Kitson has described (74) porphyries, also garnetiferous, and correlated them with the Snowy River porphyries. Their geographical and petrological relations suggest, however, that it would be safer to group them with the dacites and porphyries of the northern part of the Strathbogies, and I have therefore referred to them in this place.

Relations of the Dacites and Quartz-Porphyrites to the Palæozoic Sediments.

All observers are in agreement that the dacite series is younger than the Ordovician and Silurian sediments with which it comes into contact. Prof. Gregory states that evidence of contact metamorphism near the junction of dacite and Ordovician was sometimes found in the Macedon area, but sometimes the Ordovician rocks were quite unaltered. He referred the alteration where seen to the intrusion of the granodiorites, and hence regarded the dacites as rocks of superficial origin.

Mr. Summers and I have found evidence of contact metamorphism wherever we have seen the sediments in contact with the dacites in the Macedon area, and sometimes several miles away from the outcrop of granitic rock at the surface. While it is possible the granitic rock may be concealed beneath a thin cover, we are inclined to regard some of the contact effects as due to the dacite, and to regard it as in part of intrusive character.

I have not studied the contact with the sediments in the Dandenong area except south-east of Bayswater, where no granitic rock occurs and the sedimentary rocks are altered near the contact.

In Marysville township for a considerable distance from the contact with the dacites the palæozoic sediments are considerably altered and indurated. No granitic rocks occur at the surface near here, and I think a good deal of the Marysville dacite must be regarded as intrusive rather than effusive.

The Age of the Dacites and Quartz-Porphyrites.

Selwyn described this series as Palæozoic "Traps" passing gradually into granite. Prof. Gregory regards them not only as later than the Silurian and Ordovician sediments, but also as far younger than the granodiorites and possibly of Lower Kainozoic age.

For the reasons above given I believe them to be younger than the Silurian and Ordovician sediments, but slightly older than the granodiorites. The evidence Mr. Summers has obtained in the Strathbogie Ranges is important as showing that Lower Carboniferous conglomerates and sandstones rest upon the northern development of the dacite-quartz-porphyry series. This fixes their age in that locality as Pre-Carboniferous. If, as is generally believed, the bulk of the Victorian granodiorites are of Devonian age, it is probable that the dacites are Devonian also, and may belong to the lower part of the Devonian and be practically contemporaneous with the acid lavas of the Snowy River porphyries.

Petrological and Chemical Evidence.

Practically no microscopic or analytical work had been done on these rocks prior to Prof. Gregory's paper. The recognition of these rocks as dacites and their first description are due to Prof. Gregory. With his description of the minerals present and of the structures of the Macedon dacites, Mr. Summers and myself are in almost complete agreement. He distinguished, however, the Macedon rock from those of other areas in Victoria on account of its supposed higher percentage of alkalies, as indicated by an analysis quoted in his paper. On this account he grouped it with the alkali-trachytes of the district, and gave it the specific name of geburite-dacite after the native name for Mount Macedon. The minerals quoted by Prof. Gregory as present in the rock do not, however, indicate alkaline affinities, and in fact are precisely similar to those occurring in other Victorian dacites. There can be no doubt that its separation from the other dacites is not justified, and a later analysis of the same rock by Messrs. Lewis and Hall, of the Mines Department (266), shows that the composition of the rock is quite normal.

The Macedon dacite as shown by Gregory is commonly porphyritic when examined microscopically, due to the presence of hypersthene and plagioclase ranging from oligoclase to bytownite. There is a fine granulitic base of quartz, acid felspar, and minute biotite crystals. Ilmenite occurs both as phenocrysts and in the base of the rock.

Prof. Gregory refers to the occurrence of dykes and of agglomerates and ashes on Mount Macedon. Our observations have failed to substantiate this. There occur on the mountain above Upper Macedon what are described by Gregory as dykes, agglomerates and ashes. Mr. Summers and I refer these to the recent surface disintegration and weathering of the dacite on the steep hillside.

On the north foot of the mountain west of Hesket, however, we found an example of a rock which appeared to be fragmental, but which may be due to differential flow of coarser and finer parts of a lava. The Dandenong dacite differs from that of Macedon not at all in chemical composition, but with a similar ground mass generally contains phenocrysts of quartz and biotite, as well as hypersthene and plagioclase. Where the rock becomes gneissose near the contact with the granodiorite, structural and mineralogical changes of an interesting character are seen under the microscope. A gradual banded structure is developed by recrystallisation, hypersthene passes into bastite with a marginal fringe of secondary biotite developed partly from the hypersthene, partly from the quartz and acid felspar of the ground mass. The ilmenite, too, develops secondary biotite as a marginal fringe. A little blue soda-hornblende is also developed. Near the granodiorite these changes become complete, so that the gneissic rock consists entirely of biotite, plagioclase, quartz, and ilmenite. It still shows a ground mass which is granulitic, but much coarser in grain than that of the original dacite, and quite unlike the typical hypidiomorphic fabric of the granodiorite, although composed of the same minerals. Somewhat similar structural and mineralogical changes appear to be characteristic of sections of the rocks of the gneissic fringe near Warburton. This view of the mineralogical changes in the dacite is strengthened by H. C. Richards' work (94) on the separation and analysis of the minerals of the dacite of Upwey.

At Macedon, Nyora and Marysville, no gneissic structures are developed at the contact of the two series. The alteration appears to have been much less intense and complete, and consists in production of a tendency to parallel arrangement in the minerals and the production of secondary biotite at the expense of the hypersthene. Some of the rock sections of the dacites show flow structure as well as a granulitic ground mass. These can be referred to a superficial origin as lava flows with considerable probability. Other types are probably intrusive, but no microscopic criteria are available for recognition, except that the rocks with a coarser-grained ground mass are probably of deeper-seated origin. The nearest approach to a plutonic type occurs at Aura, on the Gembrook Railway line, where a comparatively coarse-grained holocrystalline dacite comes into relation with the granodiorites.

At Dandenong Hills, Narbethong, Marysville, and the Strathbogie Ranges, the dacites in places appear to pass by increase of quartz and diminution or disappearance of hypersthene into quartz-porphyries and quartz-porphyrites. No sharp junctions have been noticed, and it is inferred that the change is a gradual one.

Chemical Analyses.

Analyses of four dacites are recorded here, and with them an analysis of a granodiorite from Braemar House, Macedon, for comparison with that of a dacite from the same locality. The close agreement in composition suggests a close genetic relationship in the two rock types.

	1.	2.	3.	4.	5.
SiO_2	65·80	63·27	62·56	62·54	64·04
Al_2O_3	16·87	16·50	16·60	16·66	15·58
Fe_2O_3	3·97	0·74	1·02	1·04	0·80
FeO	1·08	5·10	5·98	5·54	4·47
MgO	2·01	2·48	2·71	2·68	2·64
CaO	3·16	4·18	4·30	3·92	3·52
Na_2O	3·45	2·36	2·98	2·66	2·42
K_2O	2·54	2·68	2·57	2·47	2·80
H_2O+	1·05	0·53	0·68	0·46	0·38
H_2O-	...	0·09	0·18	0·17	2·25
TiO_2	...	1·30	1·10	1·20	0·80
P_2O_5	...	0·15	0·17	0·20	0·18
MnO	...	0·03	tr.	tr.	tr.
Lc_2O	...	tr.	tr.	tr.	tr.
Cl_2	tr.	S=0·16	tr.	tr.	tr.
Total	99·93	99·57	100·85	99·54	99·88

1. Dacite, Black's Spur N. of Healesville. Analyist—H. C. Jenkins.
2. Dacite, Upwey. Analyst—H. C. Richards (94).
3. Dacite, Willimigonggong Creek, Macedon. Analysts—Lewis and Hall (266).
4. Dacite, Braemar House, Macedon. Analysts—Lewis and Hall.
5. Granodiorite, Braemar House, Macedon. Analysts—Lewis and Hall.

MIDDLE DEVONIAN.

THE BUCHAN SERIES.—THE FELSITES.

In the Buchan district as stated above, Howitt (43, 48), has shown that in places a mixed series comes between the Snowy River porphyries and the Middle Devonian Buchan limestones. This mixed series Howitt describes as the Lower Buchan Beds and the limestones as the Upper Buchan Beds. The lower series generally consists of calcareous tuffs, felsitic tuffs, breccias, and conglomerates with intercalated felsite flows. Howitt links this series with the Middle Devonian limestones since it shows in several places a gradual passage from volcanic material up into pure limestone. He separates it, however, from the Snowy River porphyries for several reasons. The porphyries are a sub-aerial series, while the Lower Buchan series he regards as subaqueous. The presence of water-worn conglomerates, consisting partly of igneous and partly of L. Palæozoic sedimentary rocks, indicates different conditions of deposit from those of the fragmental rocks of the Snowy River porphyries. In some places the junction of the two series is bounded by a fault. The thickness of this series has been estimated by Howitt at 750-1,000 ft.

Petrographical and Chemical Characters.

A specimen from Gellingal (described by Howitt) may be taken as illustrating the character of one of the intercalated lava flows.

The ground mass is yellow, felsitic, and shows fluidal structure in waving bands of irregular width. Felspar prisms including some plagioclase, irregular and defined quartz crystals, a little magnetite and a chlorite pseudomorph probably after hornblende occur in the ground mass. No name was given to the rock by Howitt, but the description suggests that it should be grouped with the porphyritic rhyolites. Most of the rocks of this group are of fragmental origin even when appearing compact in the field. An example from Butcher's Creek showed under the microscope that a large number of irregular felsitic fragments are arranged in bands and that these, together with fragmentary crystals of quartz and orthoclase, are set in a compact felsitic base. The rock was probably a banded tuff which has been indurated possibly by secondary silicification. No chemical analysis of any of the lavas has been made. From the calcareous tuff at the base of the Buchan limestone, however, Howitt selected a sample, dissolved out the carbonates, and made an analysis of the residue in order to arrive at a conclusion as to the character of the igneous fragments in the rock. The result of the analysis here given indicates its derivation from fragments of a rhyolite-quartz-porphyry.

SiO_2	= 79·62	K_2O	= 3·94
Al_2O_3	= 9·99	Na_2O	= 2·64
Fe_2O_3	= 3·22		
CaO	= ·37	Total	= 100·00*
MgO	= ·22		

* The total amounted to 101·58, from which the above was calculated.

The Diabases or Andesites of the Buchan District.

Geographical and Geological Relationships.

In two or three localities in the Buchan district, notably at Murendal, at Back Creek, and at Moore's Crossing of the Snowy River, the felsitic fragmental rocks just described are directly succeeded not by the Buchan limestone but by a more basic series of igneous rocks. These have been described by Howitt (51) as diabases and diabase-porphyrites.

At Murendal these rocks are intrusive into the Lower Buchan felsitic series. At the Back Creek and at Moore's Crossing of the Snowy River they underlie the calcareous Upper Buchan limestones with apparently passage beds between the two series. At Murendal they appear to be dykes, while in the other localities they occur as lava flows. Their stratigraphical relations are clearly fixed as coming between the Lower Buchan felsitic rocks below and the Mid-Devonian Buchan limestones above.

Petrological and Chemical Characters.

Most of the rocks are free from olivine, but in the adit of the Murendal South Mine olivine bearing basic rocks occur which he groups with the other basic rocks of the Buchan district, but also compares with the Upper Devonian or L. Carboniferous diabase of the Snowy Bluff.

At the Murendal mine the diabase contains tabular plagioclase, colourless augite, and magnetite as the most abundant phenocrysts in the order mentioned, while minute plagioclase prisms, magnetite and apatite needles occur in the ground mass, which has, in addition, a little pale yellow to colourless glassy base.

An analysis of this rock by Howitt is as follows:—

SiO_2	48·48	K_2O	1·77
Al_2O_3	14·57	Na_2O	3·33
Fe_2O_3	11·68	H_2O	1·72
FeO	2·83	CO_2	1·27
CaO	9·56	P_2O_5	·45
MgO	5·55		
		Total	101·21

A rock from Moore's Crossing, Snowy River, is described by Howitt as a diabase-porphyrite, phenocrysts of plagioclase, diopside, enstatite altered to bastite and magnetite were present, while the ground mass consisted of minute plagioclase prisms, magnetite, and a little glassy base.

The analysis of this rock is as follows:—

SiO_2	53·39	K_2O	1·84
Al_2O_3	15·23	Na_2O	3·60
Fe_2O_3	8·73	H_2O	1·14
FeO	3.61	CO_2	0·22
CaO	8·46	P_2O_5	0·16
MgO	4·12		
		Total	100·50

I have not had an opportunity of seeing these rocks in the field, but have examined some of Howitt's rock sections from Moore's Crossing. In my opinion the sections show that the rocks have a typical andesitic structure and that several varieties are present.

Those which I have seen include biotite-andesites, hornblende-andesites, enstatite, and augite-andesites, and some of the less basic members have characters which ally them to the trachyandesites.

UPPER PALÆOZOIC.

Upper Devonian or Lower Carboniferous.

Geographical and Geological Relations. (*See* Map, Plate 4).

Two areas of volcanic rocks referable to this age occur, the one in Eastern the other in Western Victoria. The eastern area comprises a mixed series of acid and basic rocks developed near Mount Wellington, with a subsidiary area further east. The western area consists of acid rocks developed near Hamilton and Cavendish, and another area near Balmoral.

The Mount Wellington area. (See Section, Plate II., Fig. 2).—The volcanic rocks of this district as shown on the map consist of a narrow band of rocks stretching northwards from Ben Cruachan in the county of Tangil past Mount Wellington to the Snowy Bluff. North of Mount Wellington a western tongue of similar rocks runs southwards for some miles parallel to and a little to the east of the valley of the Macallister River. The rocks consist mainly of a considerable thickness (up to 2,000 ft.) of acid lavas, rhyolites and quartz-porphyries with minor interbedded flows of a basic rock described by Howitt as melaphyre or basalt (43, 48, 59). The whole series is interbedded with the Upper Palæozoic sediments which stretch from this district north-westwards to Mansfield. The field relations are described by Murray (46) and Thiele (89, 90). The bifurcation of the area of volcanic rocks north of Mount Wellington appears to be due to the fact that all the rocks are bent into a shallow anticline, the axis of which to the south has been denuded, exposing older rocks beneath. In consequence of this folding the volcanic rocks show steep scarps on the inner sides of the fold where the crown of the anticline has been dissected (89, 90). The country is a rugged and mountainous one, and Mount Wellington rises to a height of 5,360 ft. About 10 miles east of Mount Wellington is the northern part of the outcrop of a similar series of acid volcanic rocks which stretches southwards for about 12 miles to the headwaters of Iguana Creek.

The age of these rocks is determined by the fossil contents of the sandstones and mudstones with which they are interbedded. Lepidodendron australe is found near the Avon River and Cordaites occurs at Iguana Creek, while northwards near Mansfield fish remains occur which have been referred to the Lower Carboniferous. Cordaites is generally regarded as U. Devonian in age, while the Lepidodendron is known both from this horizon and the L. Carboniferous. The age of the rhyolites and melaphyres is thus either U. Devonian or Lower Carboniferous.

The Western District areas.—The volcanic or intrusive rocks of these areas have been partially described and their areas delimited by Dennant (63), and later work in the area of the Grampians has been done by Herman (82). The larger area outcrops near Hamilton and stretches northwards to near Cavendish (See Map), while a second area of apparently similar rocks occurs in the neighbourhood of Balmoral.

The district is one of comparatively low relief, and the volcanic or intrusive rocks are exposed at the surface owing to the denudation of the Lower and Upper Kainozoic sediments which formerly covered them. The rocks consist mainly of quartz-porphyries, and their stratigraphical relations are by no means clear. They are certainly older than any of the Kainozoic rocks of the district. East of Cavendish they appear to come into close juxtaposition with the Grampian sandstones of the Victoria Range, while east of Balmoral the other mass probably has similar relations to the sandstones of the Black Range. It would appear as if the quartz-porphyries underlie these sandstones. No fossils have been found in the sandstones, and their age is to some extent a matter of conjecture. They are usually regarded as probably L. Carboniferous. If so, it would appear that the quartz-porphyries of Cavendish and Balmoral may have the same relations to the Grampian sandstones as the rhyolites and quartz-porphyries of Mount Wellington have to the Upper Palæozoic sediments of that area. While the field evidence, scanty as it is, suggests that the igneous rocks underlie or are interbedded with the sandstones in one or two places, as at Hall's Gap in the Grampians, dykes of an acid character penetrate the sandstones. They are mineralogically similar to the quartz-porphyries and make it possible that some at least of the quartz-porphyries may represent intrusive rocks rather than lava flows. I have only examined these rocks at Grange Burn near Hamilton, where they appear rather massive in character. Dennant states, however, that near these the porphyry shows good prismatic structure, and that on the east side of the Dundas Ranges they are seen in a small creek and present a laminated appearance as if they had been poured out in sheets.

Petrological and Chemical Characters.

The Mount Wellington area. The acid series of volcanic rocks.—The only description of these rocks is by Howitt, included in Murray's description of the area (46). The rocks are described as felsites, and quartz-felsites. In some notes on L. Karng, on Mount Wellington, Howitt (59) refers to the acid series as quartz-porphyries with possibly varieties of ceratophyre. I have examined some of Howitt's sections and others which I have had cut from specimens collected by Thiele. Two types appear to be represented.

The one type well represented on the southern plateau of Mount Wellington is a beautifully banded rhyolite. The accompanying analysis by Thiele (92) shows its very acid character. The very high silica percentage is partly due to secondary silicification. Under the microscope corroded and cracked phenocrysts of quartz and orthoclase are present; a small amount of radiating crystals of biotite of a drab-brown colour also occur. The ground mass is cryptocrystalline to microcrystalline, shows fluidal structure particularly well and in places a tendency to perlitic cracks. The rock is in part fragmental along certain flow lines; recrystallization, probably due to secondary silicification, has resulted in the formation of more coarsely crystalline aggregates of quartz and chalcedony with secondary felspar sometimes showing. Another rhyolite from L. Karng shows no banding but a striking perlitic structure. The ground mass was originally glassy, but is now cryptocrystalline to microcrystalline. No fluidal structure can be seen, but the phenocrysts are corroded and partly replaced by calcite. The other type which I have not seen Thiele refers to the typical quartz-porphyries, although he says that the ground mass in some sections resembles that of a pyroclastic rock.

ANALYSES BY E. O. THIELE, B.Sc.

	I.	II.
SiO_2	78·64	78·47
Al_2O_3	9·85	10·68
Fe_2O_3	0·54	0·18
FeO	2·00	2·23
MgO	0·10	tr.
CaO	0·80	0·66
Na_2O	2·03	3·29
K_2O	5·16	4·15
T_1O_2	0·67	0·59
P_2O_5	tr.	tr.
H_2O (comb.)	0·40	0·20
H_2O (Hygrosc.)	0·14	0·09
Total	100·33	100·54

I. Banded Rhyolite, southern plateau of Mount Wellington.
II. Quartz-porphyry, southern shore of L. Karng, Mount Wellington.

THE BASIC SERIES (MELAPHYRES OR BASALTS).

Interbedded with the rhyolites and the Palæozoic sediments of the Mount Wellington area are a series of basic rocks described by Howitt (46) as melaphyres or ancient basalts. Using the former term in the sense of an altered basalt it will be convenient to retain this name for the series, as it will serve to distinguish them from the older basalts of Kainozoic age.

In the field they occur as thin flows, quite subordinate in importance to the rhyolites, and are dense, black, and frequently much altered. A section of a rock collected by Thiele from the Moroka Snow Plain consists of a basic plagioclase, light-brown augite ophitically enclosing the felspar, abundant opaque minerals mainly ilmenite, and a considerable amount of chlorite possibly secondary after olivine. The rock is considerably altered. Thiele states (92) that epidote and calcite are common alteration products, and that amygdaloidal varieties have the cavities filled with chalcedony. The accompanying analysis is by G. Ampt from the above rock.

SiO_2	49·35	TiO_2	2·83
Al_2O_3	17·61	P_2O_5	tr.
Fe_2O_3	1·50	H_2O (comb.)...	2·56
FeO	9·72	H_2O (hygrosc.)	0·65
MgO	7·71	MnO	0·07
CaO	3·17	FeS_2	0·34
Na_2O	3·10		
K_2O	1·56		100·17

The Western District area.—No analysis of the acid rocks of this district are available, but Dennant (63) in his paper states that the silica percentage of a quartz-porphyry from this district is 74·7.

A section from the handsome red quartz-porphyry of Grange Burn near Hamilton shows that the rock is porphyritic in structure. The phenocrysts consist of cloudy orthoclase and of quartz, both of which are typically corroded. Ferro-magnesian minerals appear to be absent. The ground mass varies from cryptocrystalline to microcrystalline and is drusy in places. Lining the walls of the druses, quartz and orthoclose crystals are intergrown in an approach to the granophyric habit. Minute opaque areas of iron oxide occur in the ground mass, which is reddish in colour owing to iron staining.

A section from an acid dyke penetrating the Grampian sandstones, at the junction of Stony and Fyan's Creek, at Hall's Gap in the Grampians, shows considerable resemblance to the rock described above. The phenocrysts consist mainly of cloudy orthoclase with a little chlorite secondary after biotite. The ground mass is micrographic to granophyric in texture and consists of an intergrowth of quartz and orthoclase. The orthoclase, both the phenocrysts and that in the ground mass, is iron-stained, and the rock may be described as a micrographic or granophyric orthoclase-quartz-porphyry.

Jurassic.

No volcanic rocks of Jurassic age are known in Victoria. The bulk of the Jurassic freestones, mudstones, or sandstones from the Otway Ranges and from S. Gippsland, however, are rocks composed largely of the detritus of igneous and probably volcanic rocks. Whether they derive their material from contemporaneous or from older igneous rocks is a matter of conjecture. Prof. Gregory has suggested (9) that they may have derived their material by denudation of a former northward extension of the Tasmanian diabases. The age of these is generally stated to be Mesozoic, but various authorities have referred them to the Permo-Carboniferous on the one hand and to the Kainozoic on the other. If the latter view of their age should be correct another source for the volcanic materials of the Victorian Jurassic sediments would have to be sought. It is not impossible that the denudation of the dacite series may have provided the material for these rocks.

LOWER KAINOZOIC.

The Older Basalts. (See Map, Plate 4).

Geographical and Geological Relations. (*See* Section, Plate III., Fig. 2).—Any attempt to distinguish precisely the age and stratigraphical relations of all the Victorian basaltic rocks is attended with very great difficulties. In a general way the early Geological Survey of Victoria recognised two main geological horizons in the Kainozoic rocks among which basic lavas and pyroclastic rocks occur. Stratigraphical evidence sufficient to fix their age is wanting in the case of many of the occurrences, and attempts made to distinguish between older and newer basalts by the petrological characters of the rocks or by the degree of alteration they have suffered have met with indifferent success. So much is this the case that even now, except in the comparatively few cases where the relations of the lavas to the Kainozoic sediments serve to define their stratigraphical horizon, the reference of a basalt to the older or newer series is frequently based only on conjecture or analogy. The Geological Survey has experienced and had to face this difficulty in colouring the Geological Map of Victoria. In the map of 1902, on the scale of 8 in. to the mile, a few areas of newer basalt are shown in North and East Gippsland, and three areas of older basalt are shown near Bacchus Marsh, the Moorabool River and the Bellarine Peninsula. With these exceptions a line drawn north and south through Melbourne separates the areas coloured newer basalt to the west from areas coloured older basalt to the east of this assumed line. In the small geological map published in the Settler's Guide in 1905, the only alteration in the mapping of the Kainozoic volcanic areas is the alteration of those areas in North and East Gippsland formerly coloured as newer basalt and the reference of them to the older series.

In this paper the distribution as shown by the Geological Survey in the 1905 map, the latest available, is followed, but I should be unable to give any satisfactory reason for referring many of the areas to one rather than the other series.

Adopting, however, this method of grouping, a reference to the map accompanying this paper will show that a number of areas near Melbourne are referred to the older basalts. At Royal Park, Essendon, and Keilor, basaltic rocks occur beneath the Lower Kainozoic fossiliferous sediments (134). Much the same relations obtain near Mornington and Flinders. In the valley of the Moorabool River, near Maude, the lower basalt is interbedded between two distinct marine limestones, both of which are of L. Kainozoic age.

At Curlewis, near Geelong, and at Airy's Inlet, older volcanic vents occur (169), and flanking them are agglomerates and tuffs. At Curlewis a Lower Kainozoic marine polyzoal limestone overlies the older volcanic rock. Near Bacchus Marsh, leaf beds, regarded as of L. Kainozoic age, overlie the older basalt. In all these cases cited the evidence of age is fairly satisfactory since the rocks are overlain by fossiliferous sediments. At Berwick, 27 miles south-east of Melbourne, a basalt referred to the older series immediately overlies and seals up clays containing leaf remains referred by Deane (161) to the L. Kainozoic.

At an altitude of about 5,000 ft. on the Dargo and Bogong high plains basalts occur which seal up deep lead gravels containing fossil leaves and fruit which have been referred to the Lower Kainozoic. In these three cases the evidence of age of the basalts is less satisfactory. It is probable but not certain that the basalts were poured out almost contemporaneously with the deposition of the subjacent leaf-bearing deposits. Again, fossil leaves and fruit, even when well preserved, are at the best unsatisfactory remains on which to arrive at the age of a deposit, and a good deal of uncertainty must still attach to the age of the basalts just mentioned. A number of other areas remain, such as the volcanic necks of Anderson's Inlet (165), other areas in South Gippsland from Leongatha to Warragul, Philip and French Islands, and numerous areas in North and East Gippsland, where no upper limit to the age of the occurrences can be assigned with any certainty. In each case the basalts pierce or overlie rocks of various age, but all older than the Kainozoic, and no rocks rest upon them. In some cases, such as those of French and Philip Islands, the proximity of proved Lower Kainozoic basalt at Flinders, together with the general field relations, suffice to make it probable that the age of the basalt in all three areas is the same. Many of the occurrences are separated by considerable distances from basalts whose age can be demonstrated, and in these cases considerable doubt remains as to whether they are correctly referred to the older basalt, and if so, as to whether they are contemporaneous or part of a series of eruptions extending over a long period of time.

Petrological and Chemical Characters.

It is frequently stated that the older basalts can be distinguished from the newer basalts by two characters—*i.e.*, their fine-grained dense texture and the greater alteration they have suffered. This is sometimes the case, but the more I have seen of the Victorian basalts in the field and under the microscope the less reliance I feel inclined to place on these generalisations. I know of all gradations from a coarse dolerite to a glassy tachylyte among the newer basalts and also from among those areas classed as older basalt. Fresh and decomposed basalts occur among each series. Neither in hand specimens nor in section do the Victorian basalts present petrological characters sufficiently distinctive to enable me to say whether a given specimen comes from the Older or the Newer series.

Short descriptions of a few sections from different localities will serve to indicate the variety of types included within the older basalts.

Howitt has described (102) a considerable number of the basalts in North and East Gippsland.

A Tachylyte (or Basalt vitrophyre) is described by Howitt from the Tangil Deep Leads Mine (112). The rock is a mixture of volcanic glass and fragments of crystalline rock. The glass is black in hand specimen and yellow and isotropic under the microscope, with small lath-shaped labradorite, colourless olivine, magnetite and chlorite and carbonates as alteration products. The sp. gr. of the rock is 2·61, and the analysis given below shows that the rock is a tachylyte.

Another *Tachylyte* collected by Howitt from Butcher's Creek, Gelantipy, shows in section numerous minute perfectly formed crystals of plagioclase and colourless olivine crystals. The bulk of the rock consists of a light-brown isotropic glass in which the crystals are embedded.

A dense older basalt from Grice's Creek, between Frankston and Mornington, has a small amount of a glassy base, granular augite and magnetite, porphyritic crystals of olivine and abundant small elongated lath-shaped plagioclase with some indications of flow structure. Another dense rock from Leongatha differs from the above in the very fine granular texture of the rock. Lath-shaped plagioclase is only sparingly represented, minute granular augites and magnetite with some olivine making up the bulk of the rock.

A basalt from Flinders somewhat resembles the last but is coarser in grain and has larger phenocrysts of olivine.

The highly decomposed basalt in the Royal Park cutting contains unweathered nodules (134), which when sliced present considerable resemblance to the newer basalts of the Melbourne district. It is a medium-grained ophitic-olivine basalt with large olivine phenocrysts, brown, irregular augites, magnetite, lath-shaped plagioclase and a little residual interstitial felspar of a more acid character, and which may be in part orthoclase.

The basalt from the Berwick quarry is a very coarse grained rock. Olivine phenocrysts are large and abundant, the augite is purplish-brown and probably titaniferous, ilmenite and magnetite are common and two types of felspar occur, a lath-shaped plagioclase and a residuum of a more acid felspar. It is really an ophitic olivine-dolerite. A rock from Korumburra is even coarser in grain, and more felspathic. Olivine is not present. Pale augite and a brown hornblende occur sparingly as phenocrysts. Magnetite is present, but the dominant minerals are the felspars, of which the phenocrysts occur as broad plagioclase crystals showing zoning, and a more acid type as a colourless ground mass in which prisms of apatite are embedded.

A rock from the Bacchus Marsh district occurs on the horizon of the older basalts, but the section is seen to have the fine-grained almost felted ground mass and zoned plagioclase phenocrysts characteristic of the andesites. A pale augite and magnetite are also present, and the rock is best described *as a basic augite-andesite.*

As far as I know no recent analyses have been made of the older basalts, and the only two I can find are Howitt's analysis of the tachylyte from Tangil and one of an older basalt from Phillip Island, quoted in Selwyn's Catalogue of Rock Specimens and Minerals in the National Museum, Melbourne, 1868.

These two analyses are quoted below.

—	Tachylyte Tangil.	Older Basalt. Phillip Island.
SiO_2	51·31	45·28
Al_2O_3	18·03	15·57
Fe_2O_3	1·50	5·92
FeO	7·32	8·32
MnO	tr.	0·23
CaO	8·74	6·26
MgO	5·60	15·62
Na_2O	3·30	2·59
K_2O	2·26	1·52
P_2O_5	0·45	...
TiO_2	tr.	0·02
CO_2	0·88	...
H_2O	0·79	1·06
Total ...	100·18	102·39

MIDDLE KAINOZOIC (?)

ALKALI SERIES OF CENTRAL AND WESTERN VICTORIA.

Geographical development. (*See* Map, Plate 4.)

Central Victoria.—In Central Victoria alkaline rocks are fairly widespread in the Mount Macedon district. Solvsbergite plugs occur at Camel's Hump, the Hanging Rock, and Brock's Monument. Lava flows of anorthoclase-trachyte and various more basic rocks gradually merging into the newer basalts occupy many square miles to the north of the divide at Mount Macedon, extending up towards the southern flanks of the Cobaw Ranges, between Carlsruhe on W. and Lancefield on E. At Upper Macedon and the Barringo Creek the flows are south of the divide.

Physiography.—The solvsbergite plugs form projecting masses: Camel's Hump, 3,300 ft., rising about 300 ft. above the surrounding dacite of Mount Macedon; Hanging Rock, 2,360 ft., rising 350 ft. above the anorthoclase-trachyte flows at its base; and Brock's Monument rising above the Ordovician sediments. Some of the trachyte lava flows issued from parts near the summit of Mount Macedon, two flows have a southerly trend—one down the valley of Barringo Creek, and another better defined one, on which U. Macedon is built, forming now a ridge between Turritable and Willimigongong Creeks. Other flows started on the northern slope of Mount Macedon, one from near Braemar House, another from above Hesket, while others appear to have originated from vents like the Jim Jim and Macalister's Rock, or fissures on the plains to the north.

Geological Relations.—Prof. Gregory describes the alkali series of rocks as starting with geburite-dacite, followed by solvsbergites, trachyphonolites, and soda-andesites (176). He regards the dacite as resting on a denuded surface of granodiorite. Mr. Summers and the author, as the result of more extended work, the detailed results of which will shortly be published, have come to different conclusions concerning several of the geological and petrological problems in the Macedon district. We regard the granodiorite and the dacite as consanguineous, the dacite being the earlier extrusion from the magma, and partly eruptive, partly effusive, while the granodiorite represents a rather later more deep-seated intrusion. Analyses show that the two rocks have almost identical chemical composition (see p. 193), and contain only about 5 per cent. of alkalies. The Alkali series is a much younger one of probably Mid-Kainozoic age, since the later rocks merge into the newer basalts. Numerous analyses made by Messrs. Bailey, Lewis, and Hall, of the Mines Department (266), support the field and microscopic evidence. The sequence of the rocks from older to newer appears to be as follows:—Solvsbergite, anorthoclase-trachyte, olivine-anorthoclase-basalt, anorthoclase; olivine-trachyte, macedonite, olivine-anorthoclase-andesite, limburgite, newer basalt.

Western District.

Geographical Distribution.—Alkali rocks occur at Coleraine, a few miles to the North of Coleraine, at Carapook, Phoines, and near Casterton (172, 173, 174, 175).

Physiography and Geological Relations.

The area is one of little relief. The basement of Archæan (?) and Ordovician (?) rocks, with glacial conglomerate and Jurassic sandstones has been planed down, and newer Kainozoic ironstone gravels and other sediments have been deposited in a horizontal belt reaching northwards to the Murray plains. Subsequent uplift and denudation of this plain by rivers has exposed the underlying rocks. The alkali series nowhere rises above the level of this elevated plateau, and is almost certainly older. How much older is uncertain, as no good junctions can be seen with the glacial conglomerate or with the Jurassics. Dennant's find of a block in tuffs containing a Jurassic plant Otozamites suggests the possibility of the tuffs being Jurassic. They cannot be older, but may be younger, as from his wording it is uncertain whether the plant was in a tuff matrix or represented a block of Jurassic sandstone enclosed in the volcanic rock. The latter seems the more probable, and if so the alkali rocks may be of the same age as the Macedon series. Since writing this I have seen Dennant's specimen, and a small piece of the matrix has been sectioned. The rock is a grayish rock, which may represent a Jurassic mudstone altered by contact with a molten magma. It is certainly quite unlike the black basaltic rock of Mount Koroite. It seems safer to regard the Otozamites as occurring in a block of Jurassic mudstone, and to treat the volcanic rock as probably of Kainozoic age. The alkali rocks include trachyte probably anorthoclase bearing, but containing very little of the ferro-magnesian minerals. About 1½ miles N. of Coleraine are two small conical hills, called Adam and Eve, and consisting of a dense basic rock. A trachyte dyke traverses these hills. An olivine-bearing anorthoclase-basalt occurs at Mount Koroite, and in association with this rock the Otozamites was found. The rock sequence is rather obscure.

The main trachyte mass may be older than the basic series, but if so alkali intrusions, represented by a trachyte dyke through Adam and Eve, followed the basic flow. These rocks have been partially described by Hogg (174), and also by Dennant (172, 175). Two analyses by the latter of the trachytes are available, and are quoted in p. 207.

Petrological and Chemical Characters.

Macedon Area.—Professor Gregory has described some of the alkali rocks of the Macedon district (176). The following notes of the chief types are partly based on his determinations, supplemented by observations by Mr. Summers and myself.

Solvsbergites.—The solvsbergite plugs of the Camel's Hump, the Hanging Rock, and Brock's Monument agree very closely in chemical composition, but present some minor points of difference in mineralogical content and texture. The Camel's Hump rock may be taken as a type.

The rock is grayish in colour. The phenocrysts consist of large crystals of anorthoclase, and smaller ones of ægirine, and a few brown pleochroic crystals of cossyrite. The ground mass consists mainly of fluidally-arranged lath-shaped crystals of anorthoclase or soda-sanidine, and between the felspars are mossy aggregates of ægirine and a blue pleochroic soda-hornblende identified by Gregory as riebeckite. Ilmenite, zircon, biotite, and melilite are occasionally noticed.

Anorthoclase-trachyte.—This type is described by Professor Gregory as trachyphonolite. He was probably influenced by the analysis of one of these rocks which is published in his paper, which records over 13 per cent. of total alkalies and over 8 per cent. of soda. More recent analyses by Lewis and Hall (266) show that the alkali percentage is about 10 equally divided between soda and potash. This together with the absence of nepheline and the very sparing occurrence of microscopic nosean has led Mr. Summers and myself to the conclusion that the rock is better described as a soda-trachyte, and as anorthoclase is the dominant felspar we call it an *Anorthoclase-trachyte.* The rock covers a large area as a number of separate flows. The more acid types present close chemical and petrological relationships, and the rock from the Turritable Falls at Upper Macedon may be taken as the type. It is a dark-greenish rock. Large phenocrysts of anorthoclase are numerous. The ground mass has sometimes a fluidal arrangement of laths of anorthoclase, in other cases the crystals are stouter and the structure orthophyric. Small crystals of ægirine are scattered through the rock, a little green glass, a few sections of nosean, ilmenite, and occasionally melilite are also present.

Anorthoclase-olivine-trachyte.—In the field several flows appear to be more basic than the rock just described, and confirmation of this is given by the microscopic evidence, which shows that while in other respects resembling the more acid type it contains, in addition, smaller or larger quantities of olivine. The upper part of Sugarloaf Hill, north of Wood End, consists of this type.

Olivine-anorthoclase-basalt.—A still less acid type occurs at the base of Sugarloaf Hill, and at other localities near it. It differs mainly from the last type in the greater abundance of olivine and less frequent anorthoclase.

Macedonite.—A peculiar and interesting rock occurs at Spring Mound, north-east of Hesket and west of Lancefield, on the plains north of Mount Macedon. It is a dark, dense, rather basaltic looking rock. No perfectly fresh samples have been obtained. It is not porphyritic and consists largely of minute felspars, a colourless to green interstitial mineral, either glass or chlorite, a little nosean, serpentine or chlorite pseudomorphs after olivine, some light-brown biotite and apatite prisms. Melilite is not uncommon, and abundant octahedra of perofskite occur, some of which are opaque, others a dark-grayish green colour. The exact relations of this rock are difficult to determine. Chemically it is in some respects intermediate between the tephrites and the orthoclase basalts but mineralogically it is quite distinct. It appears to be a new rock type for which we suggest the name of *Macedonite.*

Olivine-anorthoclase-andesite.—Several still more basic flows have characters which ally them to some extent to the newer basalts of the plains, but are distinguished by the presence of occasional anorthoclase phenocrysts which are often corroded. Some of the later flows from a hill called the Jim Jim, north of Hanging Rock, are of this type. The general structure of the rock is that of a basic andesite. Lath-shaped plagioclase and granular, or ophitic augite, magnetite and olivine are the normal constituents, but corroded phenocrysts of anorthoclase which are present serve to link this type with the alkali series.

Limburgite.—Very basic rocks occur in a few localities which show no anorthoclase, and yet are distinct from the normal basalts. Chemically they are related to the orthoclase basalts, but structurally they are limburgites. Such a rock is represented in a few small plugs of dense, black prismatic basalt just south of Wood End. A section of one of these rocks shows phenocrysts of fresh olivine set in a dark, dense, fine-grained ground mass, consisting of lath-shaped minute augites, magnetite, and small felspars with a residuum of dark glass.

Newer Basalt.—The last eruptions appear to be those of the newer basalt series occurring on the plains surrounding the Macedon district. They include a number of types ranging from a basic andesite to normal basalt.

The following analyses of a few of the Macedon rocks made by Bailey, Lewis and Hall, will serve to indicate the composition of a few of the types (266).

	1.	2.	3.	4.	5.
SiO_2	65·46	59.52	51·48	52·38	43·58
Al_2O_3	17·40	18·06	16·34	14·06	11·46
Fe_2O_3	3·00	3·76	4·86	6·86	3·40
FeO	1·60	2·27	5·14	4·82	9·13
MgO	0·09	0·78	2·82	8·02	10·80
CaO	0·76	1·98	4·70	7·12	9 ·88
Na_2O	6·51	5·38	3·57	1·78	2·18
K_2O	4·74	5·03	3·43	1·26	2·13
H_2O+	0·35	0·96	1·62	0·52	2·40
H_2O-	0·52	0·88	1·90	0·62	·47
CO_2	...	...	tr.	...	...
TiO_2	0·24	0·67	2·62	1·95	3·32
P_2O_5	nil	0·27	1·28	0·36	·95
MnO...	...	...	0·35	0·04	...
Cl_2	tr.	tr.	tr.	tr.	tr
Total	100·67	99·56	100·11	99·79	99·70

1. Solvsbergite, Camel's Hump.
2. Anorthoclase-trachyte, Turritable Falls.
3. Macedonite, Spring Mound.
4. Anorthoclase-olivine-andesite, the Jim Jim.
5. Limburgite, Quarry S. of Wood End.

One noticeable peculiarity of the alkali rocks of Mount Macedon is the occurrence of melilite in rocks containing abundant felspar. This is especially noticeable in the Spring Mound Rock where it is associated with much perofskite.

The relative ages of the solvsbergite and anorthoclase-trachyte are difficult to determine. Probably the former is the older. The sequence of the rocks is rather peculiar, and perhaps may be explained on the assumption that a magma differentiated into two parts, one calcic, the other alkalic, and that eruptions of the differentiated parts and of lavas formed by mixing these in different proportions then took place. Consistent with this view is the corrosion of the anorthoclase in the more basic types.

The Western District Area.—The alkali rocks of Coleraine, Carapook, &c., in the western district have been partially described by Dennant (172, 175), and by Hogg (174).

Trachytic and basaltic rocks occur. Their relative ages in most places remains uncertain from lack of field evidence. The hill called Adam, North of Coleraine, however, is composed of a basic rock described by Hogg as an olivine-basalt, and penetrating it is a dyke of the trachytic type suggesting the possibility that here the order of eruption is from basic to acid. This cannot yet be regarded as proved to be the general order for the district. A section of the dense black rock from Adam shows that its general characters are those of an olivine-basalt.

Olivine and augite phenocrysts are set in a ground mass consisting of lath-shaped plagioclase, granular augite, and magnetite. Its relation to the alkali series is suggested by the presence of a few large corroded crystals of anorthoclase. Other basic rocks occur at Mount Koroite, &c.

The trachytic rocks are more widely spread and show considerable uniformity of petrographic characters. The rock from the Quarry at Coleraine may be taken as a type. It is a greenish, dense rock, weathering to a very light colour. It consists mainly of anorthoclase in orthophyric prisms with few phenocrysts. The rock is not quite fresh, and scattered crystals of ægirine have been partially or wholly changed to chlorite. Some magnetite is also present. It is best described as an anorthoclase-trachyte. In some varieties of the trachytes from this district little or no ferro-magnesian minerals are present, and the rock consists then almost entirely of felspar. The two analyses quoted below are by Dennant, and show that these are rather more acid than the anorthoclase-trachytes of Macedon.

	1.	2.
SiO_2	68·22	63·37
Al_2O_3	16·89	16·47
Fe_2O_3	2·75	4·45
FeO	...	1·21
MgO	tr.	0·51
CaO	tr.	1·27
Na_2O	5·30	5·88
K_2O	4·47	5·57
H_2O+	0·95	...
H_2O-	...	0·76
CO_2	...	...
Total	98·58	99·49

1. Trachyte, Little Rock North of Coleraine.
2. Trachyte, Carapook.

NEWER KAINOZOIC TO RECENT.

Newer Basalts.

Geographical Distribution. (*See* Map, Plate 4).

The youngest volcanic rocks of Victoria consist of a series of basic lavas and fragmental rocks having a considerable geological range and a wide geographical distribution. They form the Melbourne and Keilor Plains, they occur in the Ballarat and Smythesdale areas, over large areas of the Lodden Valley, and some thousands of square miles in the Western District passing over into South Australia, and connecting with the recent volcanic rocks of the Mount Gambier district.

Physiographical and Geological Relations. (*See* Section, Plate III., Fig. 2.)

The outpourings of lava and eruptions of fragmental rocks have largely obliterated former inequalities in surface relief over the areas in which they occur. The readjustment of drainage led to swampy conditions, and the filling of swamps in low-lying depressions has over extensive districts given the area the character of a monotonous plain (6). It is diversified by few features. Brecciation of the lava flows by flow during final stages of consolidation has produced the "Stony Rises." A sharp scarp-like line runs N.W. from west of Station Peak, and another occurs near Bacchus Marsh. This may represent a feature formed by denudation and not obliterated by the lava flows, or it may represent a fault scarf formed during the eruptive period. It separates an elevated plain from a low-lying one of 50-100 ft. less altitude. The more impressive relief features are of two kinds. In the one case, the basalt flows occur in areas of considerable relief and only fill up the low ground, so that the older rocks in places rise as islands above the general basalt level. Sometimes these islands are of the lower Palæozoic sediments, in other cases, as in the You Yangs, between Melbourne and Geelong, they consist of bold granitic hills.

The other eminences in the basaltic plains are the volcanic hills which are scattered in profusion over the area, and which present examples of volcanoes in all stages of dissection and disintegration. Some apparently undenuded hills show no signs of a crater, and their appearance suggests a simple heaping up of lava above some orifice, or above the point of intersection of fissures. Hills like Mount Franklin, near Daylesford, and Mount Noorat, are examples of recent volcanoes with well-preserved craters. Mount Franklin is breached on the eastern side.

Tower Hill, west of Warrnambool, is an illustration of one of the most recent of Victorian volcanoes. It is a good example of a caldera with a lake in the enlarged older crater, and more recent craters built up within the enlarged crater ring. Almost horizontal tuffs build up the mass of the hill. Near Camperdown lavas and tuffs are interbedded, but more generally the last materials forming the cones consists of pyroclastic material—*i.e.*, agglomerates, scoria, and tuffs.

The basalts vary considerably in thickness from a few feet up to about 200 ft. Fresh and altered scoriaceous and dense types, fine and coarse grained varieties are all represented. Platy, spheroidal, and columnar structures are well shown; hexagonal pavements at Coburg, near Melbourne, and the organ-pipe columns near Digger's Rest are excellent examples of the last-mentioned structure. The geological ages of the newer basalts vary considerably, probably from the Pliocene to the recent, if not historic, periods. Professor Gregory has discussed (255) the question as to whether man witnessed the last eruptions of the Victorian volcanoes. The basalt covering, in places hundreds of feet in thickness, which seals up the buried alluvial gravels or deep leads, was poured out while the gravels were being formed. Fossil leaves and fruits in these gravels have been referred to the Pliocene, and although these substances are not of high zonal value, and the reference to a Pliocene age is not certain, yet the fruits, &c., are all of extinct forms and indicate considerable antiquity for the gravels, and presumably for the lavas, which sealed up the old valleys. Near Ballarat four flows of basalt are met with in sinking shafts through the leads, and intercalated between each are alluvial gravels. In many areas the exact age of the basalts cannot be determined, since they form the superficial rock. In these cases physiographic relations afford some help. In some cases since the pouring out of the basalt-sheets, and the consequent obliteration of former stream-courses, the new rejuvenated streams have trenched the basalt plains with river valleys of considerable depth and breadth. In some cases the valleys are nearly 200 ft. deep, and many are V-shaped in cross-section, indicating a still youthful stage of dissection. In other cases they are as much as a mile in breadth and fairly mature. These latter must be of considerable antiquity. The youngest volcanic rocks probably occur at and near Tower Hill, west of Warrnambool. Road cuttings on the Warrnambool road show, in places, that the tuffs overlie the geologically recent dune limestone of that district.

Petrological and Chemical Characters.—Very little systematic petrological work, and still less of chemical work, have been done on the newer basalts of Victoria. Howitt has described some of the Gippsland rocks, and Gregory has examined some, chiefly from the mining centres.

The great bulk of the rocks of this period probably belong to the basic series, and are correctly referred to the basalts. So few analyses have been made of these rocks that our knowledge of their range in chemical composition is very scanty. The few reliable analyses which have been made, and more particularly the microscopic examination of sections from different areas, suggest that a fairly considerable range in composition exists from very basic limburgites through olivine-basalts and dolerites, augite-basalts to rocks which are highly felspathic, and probably some types should be referred to the andesites.

A special occurrence of a felspathoid from the ejected blocks of Lake Bullenmerri, near Camperdown, has been identified by Mr. Mahony. His description is now in the press, and will appear in a memoir of the Geological Survey of Victoria. He identifies the felspathoid as hauyn, and it occurs interstitially as a residuum between plagioclase crystals in a very coarse type of olivine-augite-dolerite occurring as boulders in the tuffs at the base of the series at L. Bullenmerri. The occurrence of this felspathoid-bearing dolerite among the rocks of the newer basalt is interesting. It is the first record for Victoria for this series, and it raises the interesting question of the possibility of the earliest eruptions in the western district being contemporaneous with some of those from the alkali series of Macedon and Coleraine.

From the normal calcic basaltic rocks, microscopic description of a few types will suffice to indicate the range in texture and composition in this series. The pyroclastic rocks may be represented by a tuff from Lake Burrumbeet, near Ballarat. In section the fragmental character is clear. The fragments consist of ophitic basalt, of a very amygdaloidal glassy basalt, and of a yellowish-green glass resembling palagonite, while secondary calcite fills some of the cavities in the rock.

Rocks approaching tachylytes occur in places as a thin selvage to flows where they have been quickly cooled. A specimen from the Lal Lal Falls between Geelong and Ballarat consists of lath-shaped plagioclase crystals, a little olivine, and some secondary calcite in a dense brown isotropic matrix of glass.

A rock from Hepburn Recreation Reserve, near Daylesford, may be taken as an example of a basic and fine-grained basalt. A fair amount of brown glass remains, and this, with minute lath-shaped augites and plagioclase, with magnetite grains, constitutes the ground mass, in which phenocrysts of augite and olivine are embedded.

The basalt of Mount Franklin, near Daylesford, may be taken as a type of a fine grained but porphyritic basalt. The ground mass consists of lath-shaped plagiolase, granular augite and magnetite grains. The phenocrysts consist of moderate-sized crystals of pale augite and olivine and very large crystals, up to 3 in. in length, of a clear glassy variety of oligoclase.

At the Melbourne Corporation Quarries at Clifton Hill several flows of basalt occur and are quarried extensively for road metal. They show considerable textural differences. The rock from the lowest flow, about 120 ft. below the top of the quarry, is a medium-grained olivine-basalt with pale augite, ilmenite and magnetite and plagioclase laths included ophitically in augite. There is in places a sheaf-like and in others a fluidal arrangement of the felspar laths. Contrasted with this is the rock of the top flow, which is distinctly columnar and coarse grained. It is best described as an ophitic olivine-dolerite. Olivine and large brown augites and iron oxide occur as phenocrysts. The felspar is of two types, lath-shaped crystals enclosed in augite and big broad plates of a fairly acid plagioclase, but showing marked zoning. A little interstitial felspar may be orthoclase.

The following analysis was taken from a sample of Melbourne basalt:—

SiO_2	49·95
Al_2O_3	18·51
Fe_2O_3	6·42
FeO	5·18
MgO	6·36
CaO	8·80
Na_2O	3·25
K_2O	0·68
H_2O + ...	0·70
H_2O –	...
CO_2	0·15
TiO_2	...
P_2O_5	...
MnO	...
Cl_2	...
NiO.Co.O.	...
SrO	...
Total	100·00

CONCLUSION.

In this account of the Volcanic Rocks of Victoria it will be noted that I have not discussed the general question of the origin of the magmas from which the volcanic rocks were derived, nor the possible causes which led to their reaching the surface. This might well form matter for a later paper. Prof. David (62) has already made an interesting contribution to this vexed question. The above account indicates that our present knowledge of the distribution, composition, and varieties of the Victorian volcanic rocks is far from complete, and in particular the Snowy River porphyries and the basaltic rocks present abundant opportunities for further and extended petrological and chemical investigations.

BIBLIOGRAPHY.

The following list of references comprises most of the papers dealing wholly or in part with the Volcanic Rocks of Victoria, and it is hoped that all the important and original contributions are included.

The references are arranged chronologically under each geological period.

GENERAL REFERENCES.

The geological boundaries of the volcanic rocks are shown in many of the Quarter Sheets of the Geological Survey of Victoria, and in a more general way on the Geological Map of Victoria on the scale of 8 miles to an inch.

Other publications of a general character are as follows:—

Reference No. Year.

1 1866—Selwyn, A. R. C., and Ulrich, J. H. F. Notes on the Physical Geography, Geology, and Mineralogy of Victoria. (Intercolonial Exhibition Essay, 1866.)

2 Brough-Smyth, R. Catalogue of Minerals, Rocks, and Fossils, collected in the colony by the Mining Department, Melbourne.

3 1868—Selwyn, A. R. C., and others. A Descriptive Catalogue of the Rock Specimens and Minerals in the National Museum, collected by the Geological Survey of Victoria.

4 1875—Ulrich, J. H. F. Descriptive Catalogue of the Specimens of Rocks of Victoria in the Industrial and Technological Museum, Melbourne, 1875. (Second edition of above in 1894, by J. Cosmo Newbery.)

5 1895—Murray, R. A. F. Geology and Physical Geography of Victoria, 1895.

6 1903—Gregory, J. W. The Geography of Victoria, 1903. (Whitcombe and Tombs.)

7 Dunn, E. J. Victorian Rocks and their resulting soils, with map. (Victorian Settler's Guide, 1905, pp. 58-62.)

8 Kitson, A. E. The Economic Minerals and Rocks of Victoria. (Mines Dept., Melbourne.)

9 1907—Gregory, J. W. Stanford's Compendium of Geography, Vol. I., Australasia, 1907.

10 1908—Dunn, E. J. Geology of Victoria, in Commonwealth Year Book, 1908.

Special references arranged stratigraphically:—

1. Heathcotian or Basal Ordovician.

11 1866—Selwyn, A. R. C. Sketch Map of Victoria, 1866.

12 Selwyn, A. R. C. Descriptive Catalogue of the Rock Specimens and Minerals in the National Museum, Melbourne, 1868.

13 1888—Dunn, E. J. Notes on the Geological Features of Heathcote and Neighbouring Parishes. (Quarterly Rep. Min. Dept., Vict., Dec., 1888, pp., 76-77. *See also* Records Geol. Sur., Vict., Vol. II., Part I., 1907.)

14 Stirling, J. Report on the Examination of Reefs at Howqua Valley. (Quarterly Rep. Min. Reg., Vict., June, 1888, p. 70.)

15 1888—STIRLING, J. Preliminary Report on the Geology of Dookie District. 1 Map and 2 Sections. (*Ibid.*, pp., 76-77.)

16 1894—LIDGEY, E. Notes on Quarter Sheet No. 80, N.W. Parishes of Dargile, Heathcote, Costerfield, and Knowsley. (Prog. Rep. Geol. Surv. Vict., No. VIII., 1894, pp., 44-46.)

17 FERGUSON, W. H. Notes on the Rocks at Dookie. (Prog. Rep. Geol. Surv., Vict., No. VIII., 1894, pp. 59-60.)

18 CHAPMAN, F. On some Brachiopods and a Bivalve from Heathcote. (Rec. Geol. Sur., Vict., Vol. I., Pt. 3, 1904, p. 222.)

19 HOWITT, A. W. Notes on Diabase and Adjacent Formations of the Heathcote District. (Special Rep. Dept. Mines Vict., 1896, 3 plans and maps; Appendix by E. Lidgey.)

20 ETHERIDGE, R., junr. Evidence of the existence of a Cambrian Fauna in Victoria. (Proc. Roy. Soc., Vict., New Series, Vol. VIII., 1896, pp. 52-56, 1 Plate.)

21 1899—FERGUSON, W. H. Report on an area of Cambrian Rocks at Heathcote. (Monthly Prog. Rep. Geol. Surv., Vict., No. 2, 1899, pp. 23-25, 1 Plate.)

22 FERGUSON, W. H. Report on Sketch Survey of Eastern Portion of County of Moira. (Monthly Prog. Rep., Geol. Sur. Vict., No. 10, 1900, p. 10.)

23 HALL, T. S. Supposed Graptolites from Heathcote. (Monthly Prog. Rept., Geol. Sur. Vict., No. 11, 1900, p. 26.)

24 1903—GREGORY, J. W. The Heathcotian, a Pre-Ordovician Series, and its Distribution in Victoria. (Proc. Roy. Soc., Vict., Vol. XV. (New Series), Pt. II., 1903, Pl. 4.)

25 HOWITT, A. M. Report on the Edi-Myrrhee Turquoise Belt, and the Chert and Jasper Beds near Tatong, County of Delatite. With Plan. (Rec. Geol. Sur. Vict., Vol. I., Pt. 4, 1906, p. 239.)

26 HOWITT, A. M. Report on the Phosphate of Alumina Beds, near Mansfield, County of Delatite, with plan. (Plate XXVII.) (*Ibid.*, pp. 245-247.)

27 1907—DUNN, E. J. The Iron Mask Ferro-Manganese Mine near Buchan, E. Gippsland. (Rec. Geol. Sur. Vict., Vol. II., Part 2, 1907, p. 49.)

28 DUNN, E. J. The Mt. Tara Goldfield, E. Gippsland. (*Ibid*, p. 46.)

29 DUNN, E. J. "Red Jasper" in the Heathcotian Rocks of Tooleen. (*Ibid*, p. 81.)

30 DUNN, E. J. General Geological Notes on the Country between Omeo and Limestone Creek, County of Benambra. (*Ibid*, p. 131.)

31 1907—DUNN, E. J. Some Gold Mines at Egerton. (Rec. Geol. Sur. Vict., Vol. II., Pt. I., 1907, p. 24.)

32 DUNN, E. J. On Mt. Wellington Corundum. ("Mining Standard," 16th October, 1907.)

33 1908—SUMMERS, H. S. The Cherts and Diabase Rocks of Tatong. (Proc. Roy. Soc. Vict., Vol. XXI., 1908, p.

34 THIELE, E. O. Notes on the Dolodrook Serpentine Area and the Mt. Wellington Rhyolites, North Gippsland. (Proc. R. Soc. Vict., Vol. XXI., 1908, p. 249.)

35 HALL, T. S. Excursion to Mt. William, Lancefield. ("Victorian Naturalist," Vol. XXV., No. 1, May, 1908, pp. 9-11.)

36 SKEATS, E. W. On the Evidence of the Origin, Age, and Alteration of the Rocks near Heathcote, Victoria. (Proc. Roy. Soc. Vict., Vol. XXI., 1908, pp. 302-348. Plates and Maps, XIV.-XVIII.)

37 DUNN, E. J. The Copper Lode at Mt. Camel near Heathcote. (Rec. Geol. Surv., Vict., Vol. II., Pt. 4, 1908, p. 160.)

SILURIAN (YERINGIAN.)

38 1907—CHAPMAN, F. Newer Silurian Fossils of Eastern Victoria. (Rec. Geol. Surv., Vict., Vol. II., Part. I., p. 69.)

DEVONIAN.

The papers indicated by the following reference numbers deal with the volcanic rocks of the different formations as under:—

Snowy River Porphyries (L. Devonian).—41, 42, 43, 44, 45, 47, 48, 50, 51, 56, 62, 64, 74, 75, 77, 78, 79, 80, 84.

Alkali Rocks of Eastern Victoria (L. Devonian?).—47, 52, 56, 57, 58.

Dacite, Quartz-Porphyrite Series (L. Devonian ?).—39, 47, 61, 73, 74, 81, 83, 86, 87, 88, 91.

Buchan Series (M. Devonian).—45, 46, 47, 48, 49, 50, 51, 53, 56, 68, 70, 71, 75, 76, 78.

Mount Wellington Rhyolites and Melaphyres and Quartz-Porphyries of W. District (U. Devonian or L. Carb?).—46, 47, 48, 49, 50, 54, 56, 59, 60, 62, 63, 64, 68, 69, 72, 74, 78, 82, 85, 89, 90, 92.

DEVONIAN.

39 1854—SELWYN, A. R. C. On the Geology, Palæontology, and Mineralogy of the country situated between Melbourne, Western Port Bay, Cape Schanck, and Point Nepean. (Rept. Geol. Sur., Vict., Nov., 1854, pp. 3-10.)

40 1872—SMYTH, R. B. Coalfields of Western Port. (Victorian Parliamentary Papers, 1872, Report of the Board, pp. 1-18.)

41 1875—HOWITT, A. W. Notes on the Geology of part of the Mitchell River Division of the Gippsland Mining District. (Geol. Surv., Vict., Prog. Rep. II., 1875, pp. 59-73.)

42 SMYTH, R. B. General Rep. on the Geol. Surv., Vict. (Prog. Rep. III., 1876, pp. 3-23.)

43 HOWITT, A. W. Notes on the Devonian Rocks of North Gippsland. (Geol. Sur., Vict., Prog. Rep. III., 1876, pp. 181-249, Maps and Sections.)

44 NEWBERY, J. C. List of Rocks and Minerals. (Geol. Surv., Vict., Prog. Rept. III., 1876, pp. 291-298.)

45 HOWITT, A. W. Notes on the Geology of part of the Mitchell River Division of the Mining District of Gippsland. (Geol. Surv., Vict., Prog., Rep. IV., 1877, pp. 118-126.)

46 MURRAY, R. A. F. Progress Report on Geology of Portion of Country between the Thomson and Wonnangatta Rivers, North Gippsland. (Geol. Surv., Vict., Prog. Rep. IV., 1877, pp. 52-57.)

47 HOWITT, A. W. Notes on the Geological Structure of North Gippsland. (Geol. Surv., Vict., Prog. Rep. IV., 1877, pp. 75-117.)

48 1878—HOWITT, A. W. Notes on the Devonian Rocks of North Gippsland. (Geol. Surv., Vict., Prog. Rep. V., 1878, pp. 117-147.)

49 MURRAY, R. A. F. Geological Sketch Map, Sheet No. 2, South-East Gippsland.—Report. (Geol. Surv., Vict., Prog. Rep. V., 1878, pp. 44-70.)

50 HOWITT, A. W. Notes on the Physical Geography and Geology of North Gippsland, Victoria. (Q.J.G.S., Vol. XXXV., 1879, pp. 1-41.)

51 HOWITT, A. W. Notes on the Diabase Rocks of the Buchan District. (Trans. R. Soc., Vict., Vol. XVIII., 1882, pp. 7-39, 1 Plate.)

52 HOWITT, A. W. The Rocks of Noyang. (Trans. R. Soc., Vict., Vol. XX., 1884, pp. 18-70.)

53 HOWITT, A. W. Supplementary Notes on the Diabase Rocks of the Buchan District. (Trans. R. Soc., Vict., Vol. XXI., 1885, pp. 101-105.)

54 1886—DENNANT, J. Geological Sketch of South-Western Victoria. (The "Victorian Naturalist," Vol. II., No. 6, 1885, p. 70. No. 8, 1885, p. 102. No. 9, 1886, p. 114.)

55 HOWITT, A. W. The Sedimentary, Metamorphic, and Igneous Rocks of Ensay. (Trans. R. Soc., Vict., Vol. XXII., 1886, pp. 65-127. Plates I.-IV.)

56 HOWITT, A. W. Notes on the Metamorphic Rocks of the Omeo District, Gippsland. (Aust. Ass. Adv. Science, Vol. I., 1887, p. 206.)

57 1890—HOWITT, A. W. On certain Plutonic and Metamorphic Rocks at Omeo. (Rep. Min. Dept., Vict., March, 1890, pp. 32-40. Plates and Maps.)

58 HOWITT, A. W. Notes on the Rocks occurring between Limestone River and Mount Leinster. (Rep. Min. Dept., Vict., Sept., 1890, pp. 30-33. 2 Plates.)

59 1891—HOWITT, A. W. Notes on Lake Karng. (Rep. Min. Dept., Vict., Sept., 1891, pp. 26-30. Plates and Diagrams.)

60 HOWITT, A. W., LUCAS, A. H. S., and DENDY, A. A Visit to Lake Nigothoruk and the Mount Wellington District, Gippsland. ("Vict. Nat.," Vol. VIII., Nos. 2-3, 1891, pp. 17-40.)

61 POWER, F. DANVERS. Notes on the Late Landslip in the Dandenong Ranges, Vict. (Aust. Ass. Adv. Sc., 1892, p. 337.)

62 DAVID, T. W. E. Volcanic Action in Eastern Australia and Tasmania. (Presidential Address to Section C, Aust. Ass. Adv. Sc., Vol. IV., 1892.

63 DENNANT, J. Notes on the Igneous Rocks of South-Western Victoria. (Aust. Ass. Adv. Sc., Vol. V., 1893, p. 389.)

64 DAVID, T. W. E. Contribution to the Study of Volcanic Action in Eastern Australia. (Aust. Ass. Adv. Sc., Vol. V., 1893, p. 397.)

65 FERGUSON, W. H. Notes on certain Geological Features of the Parishes of Gembrook North and Nangara. (Geol. Surv., Vict., Prog. Rept. No. VIII., 1904, p. 58.)

66 1895—MURRAY, R. A. F. Victoria, Geology and Physical Geography, 1895 Ed.

67 HOWITT, A. M. Report on Lignite Deposits near Mahaikah, County of Delatite. (Rec. Geol. Surv., Vic., Vol. I., Pt. 4, 1906, p. 241.)

68 WHITELAW, O. A. L. Report on the Geological Survey of the Parish of Bindi. (Geol. Surv., Vict., Prog. Rep. No. IX., 1898, p. 99.)

69 STIRLING, J. Report on the Geological and Mining Features of Portion of the Western District. (Geol. Surv., Vict., Prog. Rep. No. IX., 1898, pp. 85-91, with Sections.)

70 1898—FERGUSON, W. H. Report on the Argentiferous Lead Ore Deposits at Buchan. (Geol. Surv., Vict., Prog. Rep. No. IX., 1898, p. 99.)

71 ROSALES, H. Report on Silver-Lead Mines, Buchan District. (Geol. Sur., Vict., Prog. Rep. No. IX., 1898, pp. 104-106.)

72 HOGG, E. G. On the Glacial Beds, Toolleen, Coleraine, and Wanda Vale. (Aust. Ass. Adv. Sc., Vol. VII., 1898, p. 356.)

73 1898—STIRLING, J. Report on Mining Operations, Little Fern Creek, E. of Dandenong Ranges. (Geol. Surv., Vict., Prog. Rep. Nos. 8 and 9, 1899, pp. 28-29.)

74 KITSON, A. E. Report on the Rapid Geological Survey of Portion of the Basins of the Upper King and Broken Rivers, County of Delatite. (Geol. Surv., Vict., Month. Prog. Rep. No. 11, 1899-0, pp. 9-18, Map and Sections.)

75 1899—FERGUSON, W. H. Report on Geological Survey of Snowy River Valley. (Geol. Surv., Vict., Prog. Rep. No. XI., 1899, pp. 20-22.)

76 FERGUSON, W. H. Notes on some Galena Deposits, Buchan District. (Geol. Surv., Vict., Prog. Rep. No. XI., 1899, pp. 26-27, with Sections.)

77 FERGUSON, W. H. Report on Country Adjacent to Mining Track from Mount St. Bernard to Mount Howitt. Geol. Surv., Vict., Month. Prog. Rep. (New Ser.) No. 2, 1899, pp. 3-4.)

78 WHITELAW, O. A. L. Notes on the Devonian Rocks of Gippsland. (Geol. Surv., Vict,. Month. Prog. Rep. (New Ser.) No. 2, 1899, pp. 16-22, with Sections.)

79 FERGUSON, W. H. The Geological Survey of Mount Deddick District. (Geol. Surv., Vict., Month. Prog. Rep. Nos. 4 and 5 (New Ser.), 1899, pp. 9-14.)

80 FERGUSON, W. H. Report on the Geology of portion of the County of Benambra. (Geol. Surv. of Vict., Month. Prog. Rep. No. 11 (New Series), pp. 18-22.)

81 STIRLING, V. R. Geological Report on Lilydale District (Geol. Surv., Vict., Month. Prog. Rep. No. 1 (New Series), 1899, pp. 10-11, with Map.)

82 HERMAN, H. Report on the Mount William Goldfield. (Spec. Rep., Vict. Mines Dep., 1900.)

83 1901—GREGORY, J. W. The Geology of Mount Macedon. (Proc. R. Soc., Vict., Vol. XIV. (New Ser.), Pt. II., 1902, pp. 185-217. Plates XI.-XVII.)

84 FERGUSON, W. H. Notes on Common Opal Deposits in East Gippsland. (Rec. Geol. Surv., Vict., Vol. I., Pt. I., 1902, p. 85.)

85 KITSON, A. E. Glacial Deposits at Taminick, Glenrowan, and Greta, N.E. Gippsland. (Proc. R. Soc., Vict., Vol. XVI., 1903, p. 148.)

86 SUTHERLAND, IAN M. The Relations of the Granitic and Lower Palæozoic Rocks near Dandenong. (Proc. R. Soc., Vict., Vol. XVII., 1904, p. 112.)

87 1904—CHAPMAN, F. Excursion to Launching Place. ("Vict. Naturalist," Vol. XX., No. 9, 1904, p. 127.)

88 KITSON, A. E. Excursion to Warburton. ("Vict. Naturalist," Vol. XXII., No. 8, 1905, p. 128.)

89 1905—THIELE, E. O. A Trip to Lake Karng and Mount Wellington. ("Vict. Naturalist," Vol. XXII., No. 2, 1905, p. 22.)

90 1905—THIELE, E. O. Physiographical and Geological Notes on the Mount Wellington District, North Gippsland. ("Vict. Naturalist," Vol. XXIV., No. 2, 1907, p. 23.)

91 1908—SUMMERS, H. S. The Cherts and Diabase Rocks of Tatong. (Proc. R. Soc., Vict., Vol. XXI., 1908, p. 240.)

92 THIELE, E. O. Notes on the Dolodrook Serpentine Area and the Mount Wellington Rhyolites, North Gippsland. (Proc. R. Soc., Vict., Vol. XXI., 1908, p. 249.)

93 SUMMERS, H. S. Geology of the Proposed Nillahcootie Water Conservation Area. (Proc. R. Soc., Vict., Vol. XXI., 1908, pp. 285-301.)

94 RICHARDS, H. C. On the Separation and Analysis of Minerals in the Dacite of Mount Dandenong, Victoria. (Proc. Roy. Soc. ,Vict., Vol. XXI., 1908, pp. 528-539.)

LOWER KAINOZOIC.

Older Basalts.

(Papers marked thus * refer also to Newer Basalts.)

95 1857—BLANDOWSKI, W. Report II.—Frankston, Balcomb's Creek, Mount Martha, Port Phillip Heads, and Cape Schank. (Trans. Phil. Inst., Vict., Vol. I., 1857, p. 24.)

96 1861—DAINTREE, R. Report on the Geology of Bellarine and Paywit, with special reference to the probable existence of workable Coal in those Parishes. (Geol. Surv., Vict., Reports, 1861-2, p. 17.)

97 1869—*SMYTH, R. B. The Goldfields of Victoria, &c., 1869, p. 50.

98 *DUNCAN, M. P. The Fossil Corals of the Australian Tertiary Deposits. (Q.J.G.S., Vol. XXVI., 1870, p. 284.)

99 SMYTH, R. B. General Report. (Geol. Surv., Vict., Prog. Rep. II., 1875, p. 23.)

100 1876—SMYTH, R. B. General Report. (Geol. Surv., Vict., Prog. Rep. III., 1876. *See* Index.)

101 MURRAY, R. A. F. Report on the Geology and Mineral Resources of South-Western Gippsland. (Geol. Surv., Vict., Prog. Rep. III., 1876, p. 134.)

102 HOWITT, A. W. Notes on the Microscopic Examination of Igneous Rock Specimens from S.W. Gippsland. (Geol. Surv., Vict., Prog. Rep. III., 1876, p. 175.)

103 MURRAY, R. A. F. Report on the Forests of Western Gippsland. (Geol. Surv., Vict., Prog. Rep. III., 1876, p. 177.)

104 HOWITT, A. W. Notes on the Devonian Rocks of North Gippsland. (Geol. Surv., Vict., Prog. Rep. III., 1876, p. 181.)

105 *NEWBERY, J. C. Laboratory Report and List of Specimens. (Geol. Surv., Vict., Prog. Rept. III., 1876, 291.)

106 1876—Howitt, A. W. Notes on the Geological Structure of North Gippsland. (Geol. Surv., Vict., Prog. Rep. IV., 1876, p. 75.)

107 Murray, R. A. F. Geol. Surv., Vict., Prog. Rep. V., 1878, p. 15; also Report on Geological Sketch-Map, Sheet No. 2, South-East Gippsland, *ibid.*, p. 44.

108 Murray, R. A. F. Report on the Geological Survey of portions of Dargo and Bogong. (Geol. Surv., Vict., Prog. Rep. V., 1878, p. 96.)

109 Howitt, A. W. Notes on the Devonian Rocks of North Gippsland. (Geol. Surv., Vict., Prog. Rept. V., 1878, p. 117.)

110 1880—Murray, R. A. F. Geological Surv. of Gippsland, Russell's Creek Goldfield. (Geol. Surv., Vict., Prog. Rept. VI., 1880, p. 39; also reference in Gen. Rep., *ibid.*, p. 3.)

111 Murray, R. A. F. Remarks on Sites near Smeaton and Clunes suitable for Bores for testing the relative depths of the Basaltic rocks and ascertaining the Direction of deep Auriferous Leads. (Geol. Surv., Vict., Prog. Rep. VI., 1880, p. 48.)

112 Howitt, A. W. Notes on a Basaltic Vitrophyre at Tangil. (The "Victorian Naturalist," Vol. II., No. 6, 1885, p. 67.)

113 1887—Howitt, A. W. Notes on the Metamorphic Rocks of the Omeo District, Gippsland. (Aus. Ass. Adv. Sc., Vol. I., 1887, p. 206.)

114 Stirling, J. Preliminary Report on the Bonang Mining District. (Rep. Min. Reg., March, 1889, p. 70.)

115 1890—Hall, T. S. Notes on the Geology of Moonee Ponds District. ("Vict. Naturalist," Vol. VII., No. 4, 1890, p. 59.)

116 Howitt, A. W. Notes on Certain Plutonic and Metamorphic Rocks at Omeo. (Victoria, Rep. Min. Dept., March, 1890, p. 32.)

117 Howitt, A. W., Lucas, A. H. S., and Dendy, A. A Visit to Lake Nigothoruk and the Mount Wellington District, Gippsland. ("Victorian Naturalist," Vol. VIII., No. 2-3, 1891, p. 17.)

118 *Ferguson, W. H. Report on the Rocks and Fossils at Bacchus Marsh. (Victoria, Rep. Min. Dept., June, 1891, p. 31.)

119 Stirling, J. Notes on Character of Country between Leongatha and North Mirboo, and between North and South Mirboo. (Victoria, Rept. Min. Dept., September, 1891, p. 21.)

120 *David, T. W. E. Volcanic Action in Eastern Australia and Tasmania. Pres. Address, Sec. C. (Aust. Ass. Adv. Sc., Vol. IV., 1892.)

121 1893—OFFICER, G. Excursion to Keilor. ("Vict. Naturalist," Vol. X., No. 2, 1893, p. 21.)

122 STIRLING, J. Report on the Victorian Coal Fields, No. 2, San Remo and Kilcunda, &c. (Vict. Min. Dept., Spec. Rep., 1893, pp. 9-11, *et seq.*)

123 HALL, T. S., and PRITCHARD, G. B. On the Age of Certain Plant-bearing Beds in Victoria. (Aust. Ass. Adv. Sc., Vol. V., 1893, p. 338.)

124 *DAVID, T. W. E. Contribution to the Study of Volcanic Action in Eastern Australia. (Aust. Ass. Adv. Sc., Vol. V., 1893.)

125 HALL, T. S., and PRITCHARD, G. B. Notes on the Eocene Strata of the Bellarine Peninsula, with brief references to the other Deposits. (Proc. R. Soc., Vict., Vol. VI. (New Series), 1893, p. 2-3.)

126 WRIGHT, J. H. Notes on the Geological Features of an Area in South Gippsland. (Geol. Surv., Victoria, Prog. Rep. VIII., 1894, p. 28.)

127 FERGUSON, W. H. Notes on Certain Geological Features of the Parishes of Gembrook North and Nangana. (Geol. Surv., Vict., Prog. Rep. VIII., 1894, p. 58.)

128 FERGUSON, W. H. Geological Notes on the County of Dundas. (Geol. Surv., Vict., Prog. Rep. VIII., 1894, p. 58.)

129 STIRLING, J. Notes on the Site of Alleged Gold Discoveries at Gembrook. (Geol. Surv., Vict., Prog. Rep. VIII., 1894, p. 60.)

130 *HART, T. S. The Volcanic Rocks of the Melbourne District. ("Vict. Naturalist," Vol. XI., No. 5, 1894, p. 74.)

131 *HALL, T. S., PRITCHARD, G. B. The Older Tertiaries of Maude, with an Indication of the Sequence of the Eocene Rocks of Victoria. (Proc. R. Soc., Vict., Vol. VII. (New Series), 1894, p. 181.)

132 HALL, T. S., PRITCHARD, G. B. Remarks on the Proposed Subdivisions of the Eocene Rocks of Victoria. (Proc. R. Soc., Vict., Vol. VIII., 1895, p. 151.)

133 SWEET, G. Excursion to the Moonee Valley. ("Vict. Naturalist," Vol. XI., No. 12, 1895, p. 160.)

134 *HALL, T. S., PRITCHARD, G. B. A Contribution to our Knowledge of the Tertiaries in the Neighbourhood of Melbourne. (Proc. R. Soc., Vict., Vol. IX., 1896, pp. 187-229.)

135 1897—*HALL, T. S., PRITCHARD, G. B. Geology of the Lower Moorabool. (Proc. R. Soc., Vict., Vol. X., 1897, p. 43.)

136 STIRLING, J. Topographical and Geological Notes on Quar. Sheet, No. 34, S.E. (Vict. Dept. Min., Spec. Rep., No. 6, on the Vict. Coal Fields, 1897, p. 4.)

137 1898—DENNANT, J., and MULDER, J. F. The Geology of the Lower Leigh Valley. (Proc. R. Soc., Vict., Vol. XI., 1898, p. 54.)

138 HUNTER, S. Dargo High Plains. (Geol. Surv., Vict., Prog. Rep. No. IX., 1898, p. 50.)

139 WHITELAW, O. A. L. Report on Basaltic Area, Benson River Valley. (Geol. Surv., Vict., Prog. Rep. IX., 1898, p. 65.)

140 WHITELAW, O. A. L. Report on the Geological Survey of the Parish of Bindi. (Geol. Surv., Vict., Prog. Rep. IX., 1898, p. 78.)

141 FERGUSON, W. H. Report on Geological Survey of an Area in the Buchan District. (Geol. Surv., Vict., Prog. Rep. IX., 1898, p. 100.)

142 ALLAN, E. W. Geological Report on Parish of Jinderboine, County of Benambra. (Geol. Surv., Vict., Prog. Rep. X., 1899, p. 38.)

143 STIRLING, J. Report on the Brown Coals and Lignites of Victoria. Geol. Surv., Vict., Prog. Rep. X., 1899, p. 73.)

144 FERGUSON, W. H. Report on Geological Survey of Snowy River Valley. (Geol. Surv., Vict., Prog. Rept. XI., 1899, p. 20.)

145 STIRLING, V. R. Geological Report on Lilydale District. (Geol. Surv., Vict. (New Series), Month. Prog. Rep., No. 1, April, 1899, p. 10.)

146 FERGUSON, W. H. Report on Country adjacent to Mining Track from Mount St. Bernard to Mount Howitt. (Geol. Surv., Vict. (New Ser.), No. 2, Month. Prog. Rept., May, 1899, p. 3.)

147 WHITELAW, O. A. L. Rept. on Geol. Surv.—Portions of Neerim, Jindivick, Noogee, Nayook, and North Neerim (Geol. Surv., Vict. (New Ser.), Mth. Prog. Rep. No. 3, June, 1899, p. 20.)

148 STIRLING, J. Further Report on Gembrook District, Cockatoo Creek. (Geol. Surv., Vict. (New Ser.), Mth. Prog. Rep., Nos. 8 and 9, 1899, p. 6.)

149 STIRLING, J. Notes on Bird's Line of Reef, Bendigo. (Geol. Surv., Vict. (New Ser.), Mth., Prog. Rept., Nos. 8 and 9, 1899, p. 26.)

150 WHITELAW, O. A. L. Notes on the Geological Survey of Parishes of Boola Boola and Toongabbie. (Geol. Surv., Vict. (New Ser.), Month. Prog. Rep., Nos. 8 and 9, 1899, p. 29.)

151 FERGUSON, W. H. Report on Sketch Survey of Eastern Portion of County of Moira. (Geol. Surv., Vict. (New Ser.), Month. Prog. Rep., No. 11, 1900, p. 9.)

152 1900—KITSON, A. E. Report on the Rapid Geological Survey of portion of the basins of the Upper King and Broken Rivers, County of Delatite. (Geol. Surv., Vict. (New Ser.), Month. Prog. Rep., No. X., 1900, p. 10.)

153 KITSON, A.E. Report on the Coast Line and Adjacent Country between Frankston, Mornington, and Dromana. (Geol. Surv., Vict. (New Series), Month. Prog. Rep., No. 12, 1900, p. 3.)

154 HERMAN, H. Report on the Walhalla Goldfield. (Vict. Dept. of Min., Spec. Repts., 1901, p. 23.)

155 HUNTER, S. B. Report on the Pitfield Plains Goldfield. (Vict. Dept. of Mines, Spec. Repts., 1901, p. 8.) ?

156 HALL, T. S., and PRITCHARD, G. B. Some Sections illustrating the Geological Structure of the Country about Mornington. (Proc. R. Soc., Vict., Vol. XIV., 1901, p. 32.)

157 PRITCHARD, G. B. On a new Zeolite (Mooraboolite). ("Vict. Naturalist," Vol. XVIII., No. 4, 1901, p. 63.)

158 1902—HALL, T. S. The Shoreham Camp Out. ("Vict. Naturalist," Vol. XIX., No. 1, 1902, p. 7.)

159 KITSON, A. E. Report on Lignite at Wonwoon. (Rec. Geol. Surv., Vol. I., P. 1; 1902, p. 45.)

160 KITSON, A. E. Report on the Bryozoan Limestone at Flinders. (Rec. Geol. Surv., Vict., Vol. I., P. 1, p. 49.)

161 KITSON, A. E. Report on the rapid Survey of an Area in the Berwick-Cranbourne District. (Rec. Geol. Surv., Vict., Vol. I., P. 1, 1902, p. 52.)

162 KITSON, A. E. Report on the probable occurrence of Coal in the Welshpool District. (Rec. Geol. Surv., Vict., Vol. I., P. 1, 1902, p. 61.)

163 FERGUSON, W. H. Notes on Common Opal Deposits in East Gippsland. (Rec. Geol. Surv., Vict., Vol. I., P. 1, 1902, p. 85.)

164 1903—PRITCHARD, G. B. The Geology of Flinders. ("Vict. Naturalist," Vol. XIX., No. 10, 1903, p. 142.)

165 KITSON, A. E. Volcanic Necks at Anderson's Inlet, S. Gippsland, Victoria. (Proc. R. Soc., Vict., Vol. XVI., 1903, p. 154.)

166 WHITELAW, O. A. L. The Woods Point Goldfield (Mems. Geol. Surv., Vict., No. 3, 1905, p. 9.)

167 HOWITT, A. M. Report on Wilkinson and Phelan's Alluvial Gold Mine, Whitfield South, County of Delatite. (Rec. Geol. Surv., Vict., Vol. I., P. 4, 1906, p. 243.)

168 1907—DUNN, E. J. Mining and Geological Notes on the Walhalla and Wood's Point Districts. (Bull. Geol. Surv., Vict., No. 21, 1907, p. 2.)

169 HALL, T. S. Note on the Deposition of Bedded Tuffs. (Proc. R. Soc., Vict., Vol. XX., 1907, p. 21.)

170 MURRAY, R. A. F. Basalt along the Gibbo River. (Rec. Geol. Surv., Vict., Vol. II., P. 4, 1908, p. 195.)

MIDDLE KAINOZOIC ?

The Alkali Rocks.

171 1862—TAYLOR, N. Notes Explanatory of the Geology of the District Comprised in Quarter Sheets No. 5, S.E. and S.W., and No. 6, N.E. and N.W. (Geol. Surv., Vict., Repts. 1862-3, pp. 7-8.)

172 DENNANT, J. Notes on the Igneous Rocks of South-Western Victoria. (Aust. Ass. Adv. Sc., Vol. V., 1903, p. 389.)

173 1898—HOGG, E. G. On the Glacial Beds of Tooleen, Coleraine, and Wanda Vale. (Aust. Ass. Adv. Sc., Vol. VII., 1898, p. 356.)

174 HOGG, E. G. On the Occurrence of Trachyte in Victoria. (Proc. R. Soc., Vict., Vol. XII., 1899, p. 91.)

175 DENNANT, J. Further Notes on the Igneous Rocks of South-Western Victoria. (Proc. R. Soc., Vict., Vol. XIV., 1901, p. 10.)

176 1901—GREGORY, J. W. The Geology of Mount Macedon. (Proc. R. Soc., Vict., Vol. XIV., 1901, p. 185.)

Newer Basalt.

(Papers marked thus * refer also to the Older Basalts.)

177 1853—SELWYN, A. R. C. On the Geology and Mineralogy of Mount Alexander and the Adjacent Country lying between the Rivers Loddon and Campaspie. (Geol. Surv., Vict., 1st Mineralogical Rept., Sept., 1853.)

178 WATKIN, G. H. On the Goldfields of Victoria or Port Phillip. (Q.J.G.S., Vol. IX., 1853, p. 74.)

179 *SELWYN, A. R. C. Rept. on the Geological Structure of the Colony of Victoria, the basin of the River Yarra and part of the Northern, North-eastern, and Eastern Drainage of Western Port Bay. (Geol. Surv. of Vict., Rept. as above, 1855-6, pp. 5-20.)

180 1858—*SMYTH, R. B. On the Extinct Volcanoes of Victoria, Australia. (Q.J.G.S., Vol. XIV., 1858, p. 227.)

181 SELWYN, A. R. C. On the Geology of the Goldfields of Victoria. (Q.J.G.S., 1858, p. 533.)

182 PHILLIPS, J. On the Goldfields of Ballarat. (Q.J.G.S., Vol. XIX., 1858, p. 538.)

183 1858—ROSALES, H. On the Goldfields of Ballarat and Creswick Creek. (Q.J.G.S., Vol. XV., 1859.)

184 1860—SELWYN, A. R. C. Notes on the Geology of Victoria. (Q.J.G.S., Vol. XVII., 1860, p. 145.)

185 TAYLOR, N. Notes Explanatory of the Geology of the District comprised in Quarter Sheets 5, S.E. and S.W., and 6, N.E. and N.W. (Min. and Geol. Surv. of Vict., Repts. and papers, 1863, No. 3, p. 6.)

186 *DAINTREE, R. Report on the Geology of the District from Bacchus Marsh to Bass Straits. (Geol. Surv., Vict., Issued 1863, Repub. 1897, pp. 1-7.)

187 1865—WOODS, J. E. T. On Some Tertiary Deposits in the Colony of Victoria, Aust. (Q.J.G.S., Vol. XXI., 1865, p. 389.)

188 SMYTH, R. B. On the Unexplored Districts of Victoria. (Trans. R. Soc., Vict., Vol. VI., 1864, p. 62.)

189 HARRISON, T. Victoria as a Field for Geologists. (Trans. R.S., Vict., Vol. VII., 1866, p. 27.)

190 BONWICK, J. The Volcanic Rocks of Rome and Victoria compared. (Trans. R. Soc., Vict., Vol. VII., 1866, p. 149.)

191 DAINTREE, R. Report on the Geology of the Ballan District, includ. Quarter Sheets. (Geol. Surv., Vict. (Rep. 15), 1866, pp. 5-11.)

192 *SMYTH, R. B. The Goldfields of Victoria, 1869, pp. 147-9. (*Ibid.* 163-225, &c.)

193 1874—*MURRAY, R. A. F. Geology and Mineral Resources of Ballarat. (Geol. Surv., Vict., Prog. Rep. I., 1874, pp. 63-88.)

194 KRAUSE, F. M. Notes on the Geological Survey of Ararat. (Geol. Surv., Vict., Prog. Rep. II., 1874, p. 93.)

195 MURRAY, R. A. F. Report on the Geology of the Country Intersected by the Durham Lead. (Geol. Surv., Vict., Prog. Rep. II., 1874, p. 101.)

196 NICHOLAS, W. Report on the Country between Tallarook and Longwood. (Geol. Surv., Vict., Prog. Rep. II., 1874, p. 118.)

197 NICHOLAS, W. Report on the Geological Features of the Country near Mount Piper. (Geol. Surv., Vict., Prog. Rep. II., 1874, p. 121.)

198 TAYLOR, N. Geological Survey of Stawell. (Geol. Surv., Vict., Prog. Rep. III., 1876, p. 250.)

199 1876—NICHOLAS, W. Reported Discovery of Coal at Sunbury. (Geol. Surv., Vict., Prog. Rep. III., 1876, p. 288.)

200 COUCHMAN, T. Annual Report. (Geol. Surv., Vict., Prog. Rep. IV., 1877, p. 31.)

201 1876—MURRAY, R. A. F. Progress Report on Geology of portion of Country between the Thomson and Wonnangatta Rivers, North Gippsland. (Geol. Surv., Vict., Prog. Rep. IV., 1877, p. 52.)

202 KRAUSE, F. M. Notes on the Geological Survey of Creswick. (Geol. Surv., Vict., Prog. Rep. IV., 1877, p. 57.)

203 TAYLOR, N. Geological Survey of Learmouth. (Geol. Surv., Vict., Prog. Rep. IV., 1877, p. 68.)

204 MURRAY, R. A. F. Report on the Geology of portion of the Cape Otway District. (Geol. Surv., Vict., Prog. Rep. IV., 1877, p. 127.)

205 KRAUSE, F. M. Notes on the Auriferous Leads of Middle Pliocene age on the Creswick Goldfield. (Geol. Surv., Vict., Prog. Rep. V., 1878, p. 71.)

206 TAYLOR, N. Geological Survey of Learmouth. (Supplementary Geol. Surv., Vict., Prog. Rep. V., 1878, p. 78.)

207 TAYLOR, N. Report on an Outcrop of Granite East of Buninyong. (Geol. Surv., Vict., Prog. Rep. V., 1878, p. 82.)

208 KRAUSE, F. M. Notes on the Geological Survey of Daylesford. Geol. Surv., Vict., Prog. Rep. V., 1878, p. 87.)

209 1880—MURRAY, R. A. F. Remarks on Sites near Smeaton and Clunes suitable for bores for testing the Relative Depths of the Basaltic Rocks and ascertaining the direction of deep Auriferous Leads. (Geol. Surv., Vict., Prog. Rep. VI., 1880, p. 48.)

210 NEWBERY, J. C. Laboratory Report. (Geol. Surv., Vict., Prog. Rept. VI., 1880, p. 72.)

211 MURRAY, R. A. F. Geological Surveyor's Report on the Deep Leads of the Loddon Valley. (Geol. Surv., Vict., Prog. Rep. VII., 1884, p. 21.)

212 MURRAY, R. A. F. Report on the Geological Survey of the Area containing the Clunes, Mount Greenock, and part of the Talbot and Amhurst Goldfields. (Geol. Surv., Vict., Prog. Rept. VII., 1884, p. 30.)

213 MURRAY, R. A. F. Rodborough Geological Survey. (Geol. Surv., Vict., Prog. Rep. VII., 1884, p. 48.)

214 *MURRAY, R. A. F. Report on Bacchus Marsh District. (Geol. Surv., Vict., Prog. Rep. VII., 1884, p. 51.)

215 1885—DENNANT, J. Geological Sketch of South-Western Victoria. Intro. ("Victorian Naturalist," Vol. II., No. 6, 1885, p. 70.)

216 WINTLE, S. H. The Geology of the You Yangs. ("Vict. Naturalist," Vol. III., No. 10, 1887, p. 144.)

217 1887—GRIFFITHS, G. S. The Geology of the Portland Promontory. (Trans. R. Soc., Vict., Vol. XXIV., 1887, pp. 64-71.)

218 DUNN, E. J. Geological Progress Report No. 2.—Parish of Meredith. (Min. Reg., March Qr., 1888, Appen. B, p. 79.)

219 DUNN, E. J. Report on the Ballarat and Ballarat East Water Reserves. (Rept. Min. Reg., June Qr., 1888, Appen. C, p. 68.)

220 DUNN, E. J. Geological Progress Report.—Parish of Beremboke. (Rept. Min. Reg., June Qr., 1888, Appen. G, p. 73.)

221 DUNN, E. J. Geological Prog. Rept.—Parish of Bungeeltap. (Rept. Min. Reg., June Qr., 1888, Appen. H, p. 74.)

222 TAYLOR, N. Report on part of the Parishes of Strangways, Tarrengower and Sandon. (Rept. Min. Reg., Decr. Qr., 1888, Append. B, p. 69.)

223 1890—DENNANT, J. Observations on the Tertiary and Post-Tertiary Geology of South-Western Victoria. (Aust. Ass. Adv. Sc., Vol. II., 1890, p. 441.)

224 STEEL, T. On a Mineral occurring in Igneous Rock at Yarraville. ("Vict. Naturalist," Vol. VIII., Nos. 2-3, 1890, p. 95.)

225 HALL, T. S., and PRITCHARD, G. B. Notes on the Lower Tertiaries of the Southern Portion of the Moorabool Valley. (Proc R. Soc., Vict. (N.S.), 1891, p. 11.)

226 SWEET, G. Excursion to Merri Creek. ("Vict. Naturalist," Vol. IX., No. 1, 1892, p. 5.)

227 HALL, T. S. The Geology of Castlemaine with a subdivision of part of the lower Silurian rocks of Victoria. (Proc. R. Soc., Vict., Vol. VII., 1894, p. 80.)

228 TAYLOR, N. Report on the Geological Survey of Daylesford Gold Field. (Geol. Surv., Vict., Prog. Rep. VIII., 1894, p. 6.)

229 LIDGEY, E. Report on the Malmsbury and Lauriston Gold Field. (Geol. Surv., Vict., Prog. Rep. VIII., 1894, p. 20.)

230 1895—HALL, T. S., and PRITCHARD, G. B. Remarks on the proposed subdivisions of the Eocene Rocks of Victoria. (Proc. R. Soc., Vict., Vol. VIII., 1895, p. 151.)

231 DENNANT, J., and MULDER, J. F. Probable Miocene Age of a Conglomerate at Shelford. (Proc. R. Soc., Vict., Vol. IX., 1896, p. 174.)

232 OFFICER, G., and HOGG, E. G. The Geology of Cormaida, Pt. 1. (Proc. R. Soc., Vict., Vol. X., 1897, p. 60.)

233 1897—HALL, T. S. Excursion to Collingwood Quarries. ("Vict. Naturalist," Vol. XIV., No. 5, 1897, p. 67.)

234 *DENNANT, J., and MULDER, J. F. The Geology of the Lower Leigh Valley. (Proc. R. Soc., Vict., Vol. XI., 1898, p. 54.)

235 Hogg, E. G. On the Glacial Beds, Tooleen, Coleraine, and Wanda Vale. (Aust. Ass. Adv. Sc., Vol. VII., 1898, p. 356.)

236 HOWITT, A. W. On Oligoclase Felspar from Mt. Anakies in Victoria. (Aust. Ass. Adv. Sc., Vol. VII., 1898, p. 375.)

237 HART, T. S. The Bone Clay and Associated Basalts at the Great Buninyong Estate Mine. (Proc. R. Soc., Vict., Vol. XII., 1899, p. 74.)

238 WALCOTT, R. H. Note on a Basalt Tree Cast. (Proc. R. Soc., Vict., Vol. XII., 1899, p. 139.)

239 1899—HUNTER, S. B. Report on Parish of Wareek. (Geol. Surv., Vict., Prog. Rep. X., 1899, p. 7.)

240 LIDGEY, E. Report on the Parish of Livingstone, Counties of Ripon and Talbot. (Geol. Surv., Vict., Prog. Rep. X., 1899, p. 32.)

241 STIRLING, H. R. Geological Rept. on Lilydale District. Geol. Surv., Vict., Month. Prog. Rept., No. 1, April, 1899, p. 10.)

242 STIRLING, J. Geological Sketch Plan and Section of the Werribee Gorge, near Bacchus Marsh. (Geol. Surv., Vict., Month. Prog. Rep., No. 2, May, 1899, p. 25.)

243 HOWITT, A. M. Report on the Parish of Wallinduc. (Geol. Surv., Vict., Month. Prog. Rep., No. 10, 1900, p. 12.)

244 HOWITT, A. M. Report on the Parish Kuruc-a-ruc. (Geol. Surv., Vict., Month. Prog. Rep., No. 10, 1900, p. 13.)

245 KITSON, A. E. Geological Notes on the Yarra Improvement Sections at the Botanical Gardens and Vicinity, Melbourne. (Proc. Roy. Soc., Vol. XVII., 1900, p. 243.)

246 HALL, T. S. Excursion to Sydenham. ("Vict. Naturalist," Vol. XVII., No. 7, 1900, p. 120.)

247 MULDER, J. F. Newer Pliocene Strata of the Moorabool River. (Proc. R. Soc., Vict., Vol. XIV., 1901, p. 82.)

248 HUNTER, S. B. The Pitfield Plains Gold Field. (Vict. Dept. of Min., Spec. Rept., 1901, p. 8.)

249 KITSON, A. E. Observations on the Geology of Mount Mary and the Lower Werribee Valley. (Proc. R. Soc., Vict., Vol. XIV. 1901, p. 153.)

250 1901—Hart, T. S. Notes on a Visit to Tower Hill, Koroit. ("Vict. Naturalist," Vol. XVII., No. 9, 1901, p. 157.)

251 Hart, T. S. The Tuffs of Burrumbeet. ("Vict. Naturalist," Vol. XVII., No. 9, 1901, p. 160.)

252 Kitson, A. E. Further Notes on the River Yarra Improvement Sections at the Botanical Gardens, Melbourne. (Proc. R. Soc., Vict., Vol. XV., 1902, p. 41.)

253 Hall, T. S., and Pritchard, G. B. The Geology of the Barwon about Inverleigh. (Proc. R. Soc., Vict., Vol. XVII., 1903, p. 292.)

254 Gregory, J. W. The Geology of the Berry Lead at Spring Hill and Central Leads. (Bull. Geol. Surv., Vict., No. 1, 1903.)

255 Gregory, J. W. The Antiquity of Man in Victoria. (Proc. R. Soc., Vict., Vol. XVII., 1904, p. 120.)

256 Hart, T. S. Note on Stony Creek Basin, Daylesford. (Proc. R. Soc., Vict., Vol. XVIII., 1904, p. 366.)

257 1905—Chapman, F. Excursion to Burnley. ("Vict. Naturalist," Vol. XXI., No. 12, 1905, p. 173.)

258 Jutson, J. T. Notes on the Volcanic History of Mt. Shadwell. ("Vict. Naturalist," Vol. XXII., No. 1, 1905, p. 8.)

259 Ferguson, W. H. The Blackwood-Trentham Gold Field. (Bull. Geol. Surv., Vict., No. 18, 1906, p. 41.)

260 Kitson, A. E. Report on the Diatomite Deposits and General Geology of the Portland District. (Records Geol. Surv., Vict., Vol. I., Pt. 4, 1906, p. 251.)

261 1907—Hart, T. S. The Highlands of the Main Divide of Western Victoria. (Proc. R. Soc., Vict., Vol. XX., 1907, p. 250.)

262 Hall, T. S. Notes on the Deposition of Bedded Tuffs. (Proc. R. Soc., Vict., Vol. XX, 1907, p. 21.)

263 Chapman, F. Excursion to Clifton Hill Quarry. ("Vict. Naturalist," Vol. XXIII., No. 12, 1907, p. 244.)

264 Barnard, F. G. A. Over the Dividing Range. ("Vict. Naturalist," Vol. XXIV., No. 7, 1907, p. 111.)

265 Dunn, E. J. Some Gold Mines at Egerton. (Rec. Geol. Surv., Vict., Vol. II., Pt. 1, 1907, p. 23.)

266 Dunn, E. J. Rock and Mineral Analyses. (Ann. Rep. of Sec. for Mines, Victoria, for 1907, p. 63.)

267 1908—Dunn, E. J. Obsidian Buttons. (Rec. Geol. Surv., Vict., Vol. II., Pt. 4, 1908, p. 202.)

268 Wilkinson, H. L. Deep Leads of Victoria. (Trans. Inst. of Min. and Me., London, 1907-1908, pp. 210-262.)

EXPLANATION OF PLATES.

Plate I.

Fig. 1.—Geological Sketch Section from W. to E. through Knowsley East, North of Heathcote, to show the relation of the diabases and chert to the Lower Ordovician sediments and of the Silurian and Glacial beds to the Ordovician series.

Fig. 2.—Geological Sketch Section from W. to E. through Western Victoria to show the relations of the diabases and cherts, the quartz porphyries, and the trachytic rocks to the sedimentary rocks associated with them.

Plate II.

Fig. 1.—Geological Sketch Section from N.W. to S.E. from Bindi to Buchan, East Gippsland, to show the relations of the Snowy River porphyries, the Buchan pyroclastic rocks, and the older basalts to the sedimentary rocks associated with them.

Fig. 2.—Geological Sketch Section from W. to E. through North Gippsland to show the relations of the serpentines, Mount Wellington rhyolites, and melaphyres, and the older basalt to the sedimentary rocks associated with them.

Plate III.

Fig. 1.—Geological Sketch Section from S. to N. through Mount Macedon to show the relations of the dacites, alkali rocks, and newer basalts to one another and to the sedimentary and granitic rocks associated with them.

Fig. 2.—Geological Sketch Section from W. to E. from Albion to Royal Park, near Melbourne, to show the relations of the older and newer basalts to the Silurian and to the Kainozoic sediments.

Plate I.

GEOLOGICAL SKETCH-SECTION FROM W. TO E. THROUGH KNOWSLEY EAST, N. OF HEATHCOTE.

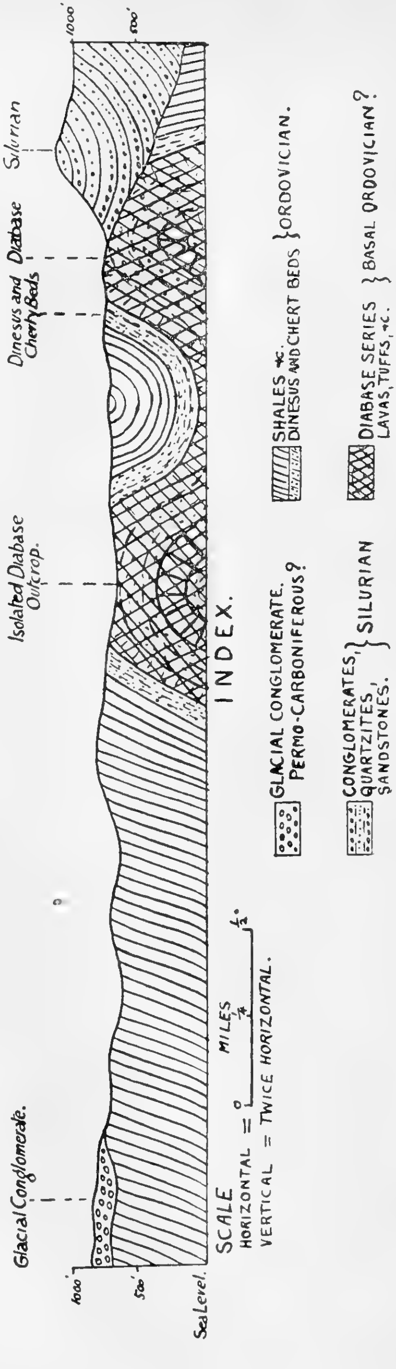


Fig. 1.

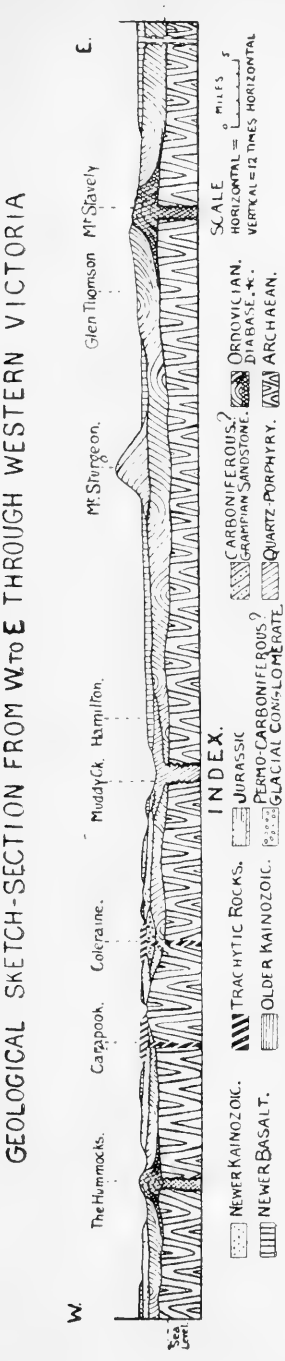

GEOLOGICAL SKETCH-SECTION FROM W. TO E THROUGH WESTERN VICTORIA
W.
E.
The Hummocks.
Carapook.
Coleraine.
Muddy Ck.
Hamilton.
Mt. Sturgeon.
Glen Thomson
Mt. Stavely
Sea Level.
INDEX.
NEWER KAINOZOIC.
NEWER BASALT.
TRACHYTIC ROCKS.
OLDER KAINOZOIC.
JURASSIC
PERMO-CARBONIFEROUS?
GLACIAL CONGLOMERATE
CARBONIFEROUS?
GRAMPIAN SANDSTONE.
QUARTZ-PORPHYRY.
ORDOVICIAN.
DIABASE. &c.
ARCHAEAN.
SCALE
HORIZONTAL = 0 MILES 5
VERTICAL = 12 TIMES HORIZONTAL

FIG. 2.

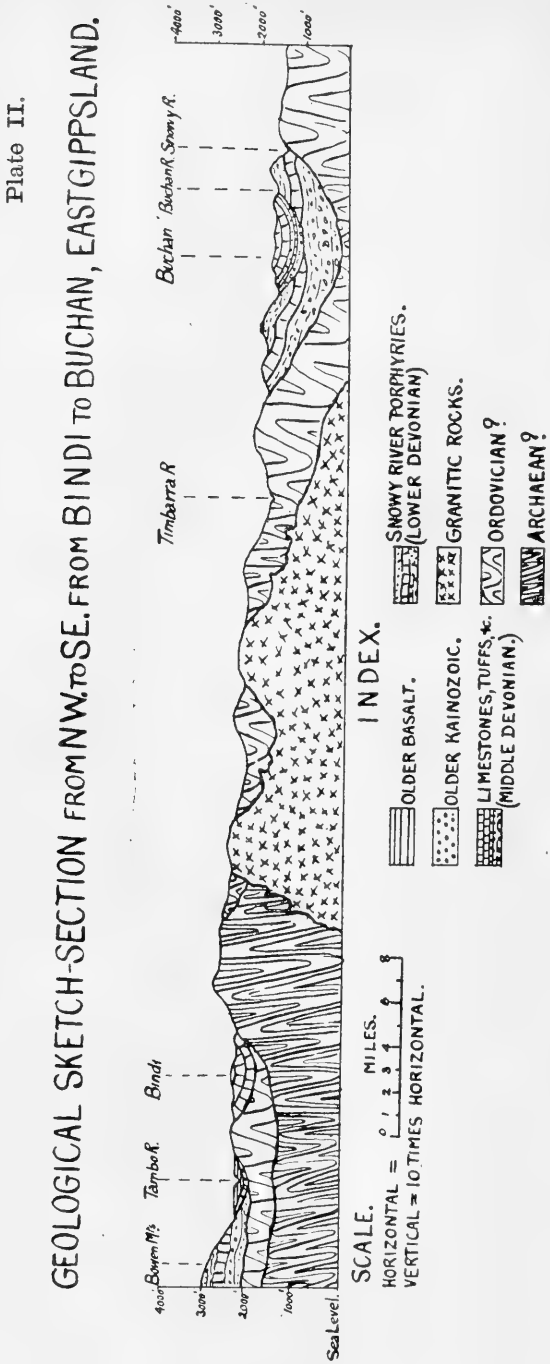


Plate II.
GEOLOGICAL SKETCH-SECTION FROM NW. TO SE. FROM BINDI TO BUCHAN, EASTGIPPSLAND.
Bowen Mts
Tambo R.
Bindi
Timbarra R
Buchan
Buchan R.
Snowy R.
4000'
3000'
2000'
1000'
Sea Level.
SCALE.
HORIZONTAL = 0 1 2 3 4 6 8 MILES.
VERTICAL = 10 TIMES HORIZONTAL.
INDEX.
OLDER BASALT.
OLDER KAINOZOIC.
LIMESTONES, TUFFS, &c. (MIDDLE DEVONIAN.)
SNOWY RIVER PORPHYRIES. (LOWER DEVONIAN)
GRANITIC ROCKS.
ORDOVICIAN?
ARCHAEAN?

Fig. 1.

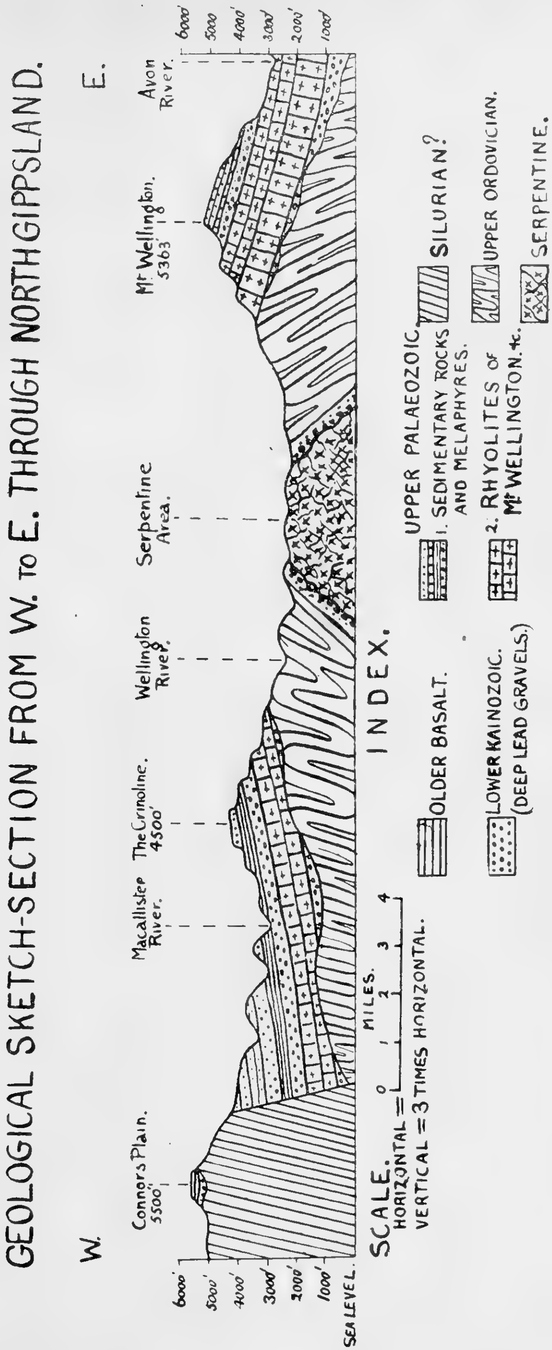

GEOLOGICAL SKETCH-SECTION FROM W. TO E. THROUGH NORTH GIPPSLAND.
W.
E.
Connors Plain. 5500'
Macallister River.
The Crinoline. 4500'
Wellington River.
Serpentine Area.
Mt. Wellington. 5363'
Avon River.
6000'
5000'
4000'
3000'
2000'
1000'
SEA LEVEL.
SCALE.
HORIZONTAL = 0 1 2 3 4 MILES.
VERTICAL = 3 TIMES HORIZONTAL.
INDEX.
OLDER BASALT.
LOWER KAINOZOIC. (DEEP LEAD GRAVELS.)
UPPER PALAEOZOIC.
1. SEDIMENTARY ROCKS AND MELAPHYRES.
2. RHYOLITES OF Mt. WELLINGTON, &c.
SILURIAN?
UPPER ORDOVICIAN.
SERPENTINE.

Fig. 2.

Plate III.

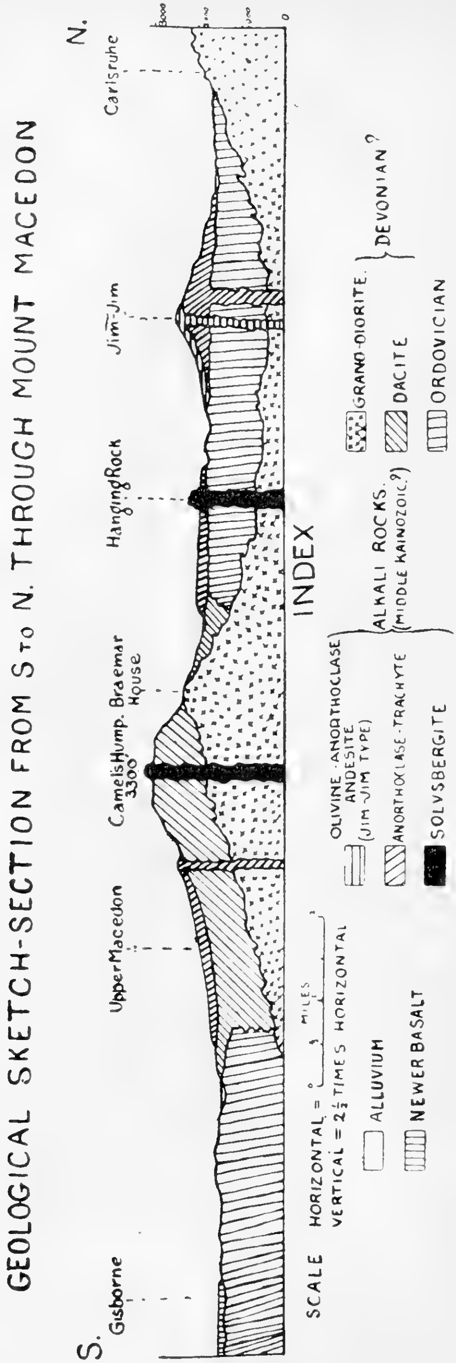


Fig. 1.

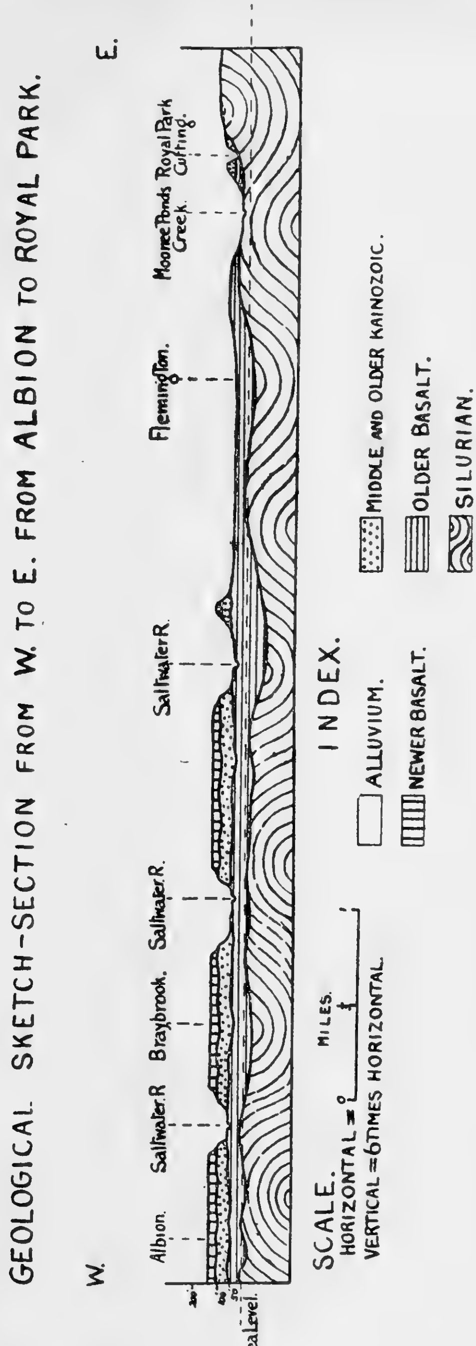
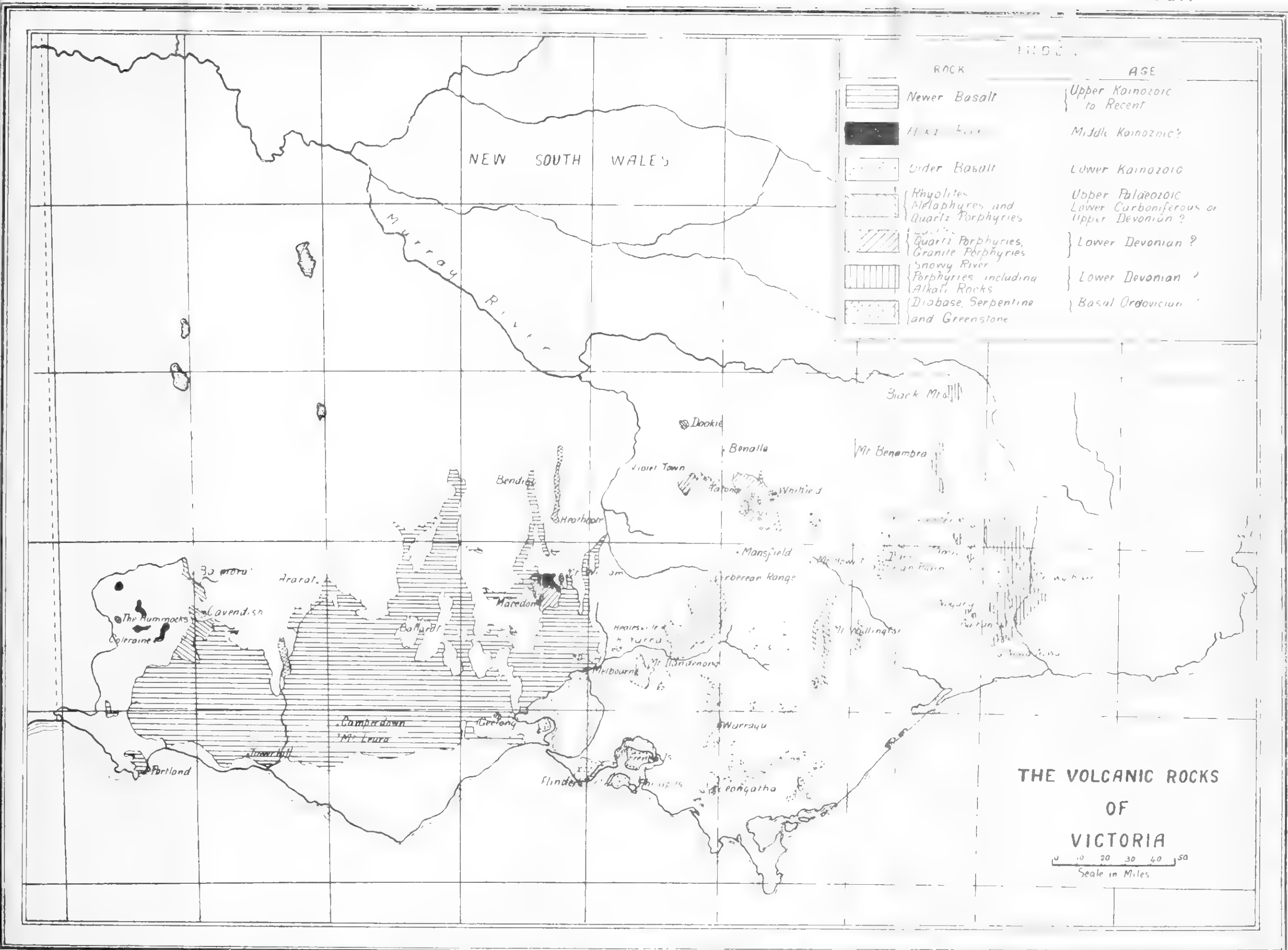

GEOLOGICAL SKETCH-SECTION FROM W. TO E. FROM ALBION TO ROYAL PARK.
W.
E.
Albion.
Saltwater R.
Braybrook.
Saltwater R.
Saltwater R.
Flemington.
Moonee Ponds Creek.
Royal Park Cutting.
Sea Level.
SCALE.
HORIZONTAL =
VERTICAL = 6 TIMES HORIZONTAL.
MILES.
INDEX.
ALLUVIUM.
NEWER BASALT.
MIDDLE AND OLDER KAINOZOIC.
OLDER BASALT.
SILURIAN.

FIG. 2.

Plate IV.



ROCK
AGE
Newer Basalt
Upper Kainozoic to Recent
Middle Kainozoic?
Older Basalt
Lower Kainozoic
Rhyolites Melaphyres and Quartz Porphyries
Upper Palaeozoic Lower Carboniferous or Upper Devonian ?
Quartz Porphyries, Granite Porphyries
Lower Devonian ?
Snowy River Porphyries including Alkali Rocks
Lower Devonian ?
Diabase, Serpentine and Greenstone
Basal Ordovician
NEW SOUTH WALES
Murray River
Black Mtn
Dookie
Benalla
Mt Benambra
Violet Town
Heathcote
Mansfield
Ararat
Cavendish
The Hummocks
Coleraine
Macedon
Ballarat
Melbourne
Mt Dandenong
Camperdown
Mt Leura
Geelong
Tower Hill
Portland
Flinders
Warragul
THE VOLCANIC ROCKS OF VICTORIA
0 10 20 30 40 50
Scale in Miles

PAPERS READ IN SECTION C.

1.—REPORTS OF THE RESEARCH COMMITTEES ON STRUCTURAL FEATURES AND GLACIATION.

Communicated by Professor P. MARSHALL, D.Sc., Otago University.

A.—Structural Features, New Zealand.

Recent work of the reorganised geological survey under Dr. J. M. Bell has added greatly to our knowledge of some of the important structural features of both islands. The reports deal with isolated districts in various portions of the island. The areas have been selected because of their economic importance, but the work that has been done has taken a wide view of the scientific problems that have been encountered.

Bulletin 1, by Dr. Bell and C. Fraser, shows that there is an apparent conformity of rock series across the central portion of the Southern Alps in the section from the Wilberforce River to the Arahura. The structure is that of a complex synclinorium. The metamorphism gradually increases from east to west until intrusive granite is encountered. On the west of this again in the foot hills unaltered rocks of perhaps the same series are found. It is suggested that their occurrence in this position is due to faulting. In Bulletin 6, Mr. P. Morgan has found much the same structure in the district extending fifty miles further south. Here, however, a fault of great importance is described along the line of magnesian intrusives (Pounamu series), and the western sedimentaries are slightly folded with an east and west strike.

In Bulletin 3, the north-west of the South Island is described. This region includes graptolite beds of Ordovician age. The strike is north-north-west, and the structure so complicated that it is impossible to describe it in small space. The metamorphism increases to the east. An unconformity separates the Ordovician from older rocks, and there are huge thrust planes and gravity faults, with several intrusions of various plutonics.

In Otago, Park (Bulletins 2, 5, and 7) has described a series of faults striking nearly north and south across the area of schists in Central Otago. Owing to these faults the several ranges of mountains are left as block mountains. It will be noticed that the direction of the faults is at right angles to the strike of the schist folds.

In Coromandel, C. Fraser and J. H. Adams have found the strike line nearly due north and south as described in Bulletin 4. It is said with some hesitation that there are three unconformable series of rocks, the youngest of which is Jurassic. The Jurassic rocks alone are fossiliferous.

In the extreme north the direction of folding is found by E. Clarke to be north-north-west and south-south-east, but the structure is extremely difficult to decipher.

Professor Gregory has in several publications† referred to two periods of folding in the main structure of New Zealand. The major period has resulted in the formation of the south-west north-east mountain axis. The older period was held to account for the north-west axes in Otago and North Auckland. It is now shown in the bulletins referred to that the south-east north-west axis is not older than the other. The same is true in Otago, where the Triassic rocks are wholly involved in the folding.

At the Auckland Islands the structure is that of nearly horizontal basaltic lavas resting nearly horizontally on gabbro and granite probably of much greater age.

Campbell Island has a mass of gabbro on which rest nearly horizontally conglomerates, shales, and limestones of Miocene age. These have been covered by a great mass of tuffs, over which were afterwards poured lavas ranging from trachytes to melilite basalt.

The Snares are formed entirely of granite.

B.—Glaciation, New Zealand.

In Bulletin 3, New Zealand Geological Survey, full details are given of the effects of glaciation in the north-west of Nelson. Boulder Lake, a rock basin previously mentioned by Park, is here fully described. Its elevation is 4,018 feet above sea level. A reconnaisance with Dr. Bell along these mountains in 1908 convinced the writer that the heads of all the valleys at the head waters of the Aorere, and of the northern tributaries of the Karamea, owe their features to glaciation. The opinion was based on the U-shaped valleys, the frequent presence of rock basins, the uniform occurrence of cirques at the heads of them, and the usual glaciated rock surfaces.

A visit to Ruapehu by the writer in 1907 showed that there is no indication of heavier glaciation on that volcano than is found there at the present time.

In the Southern Islands no glacial features were found by Mr. Speight and the writer on the Snares.

In the Auckland group all the main features are ascribed by us to glaciation. Mr. Speight observed examples of lateral moraines at Carnley Harbour. At Norman's Inlet and other places there are typical hanging valleys. The valley heads are cirques. The valleys are U-shaped. Lateral streamlets flow over rock faces in which no erosion has taken place.

The same features were found in Campbell Island. Lateral moraines are found near the head of North-East Harbour, otherwise the remarks made in regard to Auckland Island apply with equal force here.

In Stewart Island the only recorded instance of glaciation is on the slopes near the summit of Mount Anglem, 3,000 feet high, but the topography of the island requires more detailed examination, for many facts in regard to the form of valleys near Port Pegasus suggest glaciation.

C.—Glaciation—New South Wales.

A specimen of Cambrian glacial till, obtained at Cartwright's Creek, twenty-seven miles north-north-west of Broken Hill, was exhibited by Mr. W. N. Benson, B. Sc. In 1894, Mr. J. B. Jaquet, F.G.S., noted the occurrence here of large waterworn boulders of granite, and fragments of schist in a schistose matrix. Recent examination showed the formation to be quite analogous to South Australian occurrences of Lower Cambrian till, though much more highly metamorphosed than it in most instances. Underlying knotted mica schist is a considerable thickness of micaceous schist containing fragments of schist quartz and quartzite, and small boulders of granite. The inclusions are largest in the lower portion of the bed, being sometimes 4 feet in diameter. Intercalated in the series are lenticular beds of limestone up to 20 feet in thickness. The lowest portions of the series observed are alternating schist and quartzite, probably representing not the basal bed of the series, but the phyllites—quartzites that occupy the middle portion of the Glacial series as observed elsewhere. This occurrence is of interest as proving the identity of the crystalline schist of the Barrier Ranges with the slates and conglomerates of that area, among which, as at Tarrowangie, Mr. Mawson, B. Sc., has discovered Cambrian glacial till, and also affords confirmation of the assumption by that author of a Lower Cambrian age for much of the Barrier Ranges slates and schists.

2.—NOTES ON THE ROCK PHOSPHATE DEPOSITS OF SOUTH AUSTRALIA.

By H. Y. L. BROWN, F.G.S., Government Geologist of South Australia.

Clinton Rock Phosphates.—Situated on the north end of Yorke Peninsula, near the head of St. Vincent's Gulf.

The existence of phosphate beneath the soil is indicated by scattered fragments and blocks which have been upturned and brought to the surface when the land was under cultivation. Some of these fragments are white in colour, whilst others are brown, yellow, and iron-stained: they are often associated with iron ore and manganese, fragments of which are also scattered on the surface; they are embedded with black earth, clay, loam, marl, &c., and occur in patches. The soil generally contains nodules and lumps of phosphate rock, beneath which lies the phosphate deposit *in situ*. This consists of soft yellow and grey clay, calcareous marl and sandy clay, embedded in which are segregated, rounded, and bedded-like masses of phosphate rock.

The rock presents considerable variety in appearance, being sometimes grey, white, and chalk-like, reticulated with thin veins of denser composition, and at others a compact yellow, grey, and reddish-coloured rock, with cellular spaces of various sizes, causing the whole to have a brecciated appearance, and again compact and nodular. In places earthy manganese fills the cellular spaces, particularly in the case of the soft chalk-like rock, which is also stained with iron oxide.

The deposit as a whole has no regular stratification, although here and there appear traces of stratification, which, however, are not persistent. The strata in which the deposits occur are Cambrian limestones, eroded walls of which are to be seen in some of the excavations, in some places vertical, and in others inclined, but they dip generally at a much higher angle than the limestone strata. From this and other facts relating to the exposed portion of the limestone rock, it would appear that at one time caves and fissures, varying in extent, were formed, and that at a later period these became filled with the phosphate deposit. With regard to the size of these caves and depressions, the evidence obtainable from the position of the outcrops of limestone points to them being large.

Samples analysed contained up to 75·44% tricalcic phosphate.

The phosphate rock is found, intermittently, over seven sections of land in the Hundred of Clinton, and a large quantity has been marketed.

Fairview, Hundred of Bright.—About eighteen miles south-south-east of the Township of Kooringa (Burra Burra).

The phosphate in the north workings is in irregular-shaped bodies and bands, associated with claystone and clay, with which it is interstratified, and segregated. It contains small veins of quartz, such as are found in lode formations in some places, and varies from a compact chalk-like rock to a soft friable one. On the east side dolomitic limestone, of presumably Cambrian age, bounds the deposit; and west, at a distance of several chains, in which direction the ground rises steeply, the bed rock exposed is quartzite. These rocks strike north-north-west, and dip west: the surface space between the outcrops is covered with soil and detritus. At the south workings a quarry has been opened up along and into the side of the hill for a length of 130 ft. and a width varying from 30 ft. to 70 ft. The workings are in massive phosphate rock, which is quarried out in large blocks from a face 66 ft. long and from 6 ft. to 12 ft. high: it shows underfoot, and the depth to which it extends has not yet been ascertained. Immediately east the deposit is bounded by the dolomitic limestone, and west, at a distance of several chains, quartzite outcrops on and along the hill; these are a continuation south of the rock exposures mentioned in connection with the north workings.

Outcrops of phosphate rock occur at several points west of and between the north and south workings, a distance of 11½ chains, and it is probable that the deposit is continuous for this distance. Phosphate has also been found north and south of the main workings.

In this case, as at Clinton, the deposit appears to fill large cavernous openings or caves in the dolomitic limestone. These openings may have been ravines at the outlet of an ancient creek or river, in which silt might be deposited and form an estuary. The deposit at Clinton is close to the sea coast: that at Bright, although now at a distance from the sea, was, in the late Tertiary times, in close proximity to it.

Samples of the rock gave on analysis from 51·02 to 76·23% tricalcic phosphate.

Three other finds have been made in this locality.

St. John's.—Situated four miles south-east of Kapunda.

The principal outcrop of phosphate rock is approximately 10 chains long by 2½ chains wide, and it is in the vicinity of this exposure that the shafts and quarry workings made in prospecting for and opening up the deposit are situated. The outcrop can be traced south-east for some 30 chains, and, where not actually outcropping, scattered lumps of phosphate rock strewn over the surface and embedded in the soil indicate its presence beneath.

The outcrops to the south-east, which are in the vicinity of a quartzite and slate hill, contain quartz and ferruginous matter, and

Occurrence of Phosphate Rock, East of the Burra.

samples on analysis were found to contain hydrous phosphate of alumina instead of phosphate of lime; this mineral is also associated with the phosphate rock at Clinton.

The deposit occurs in limestone, quartzite, sandstones, and slate formations of the same geological age as those of Clinton and Bright. The limestone bounds it at a distance on the east-north-east and north sides at a low elevation, while the quartzite and slate occur as isolated hills of small extent on higher ground. The ground between the outcrops is more or less thickly covered with an over-burden of soil and detritus. The workings consist of quarries, shafts, and tunnels.

This deposit, besides containing massive rock and segregated masses and nodules, consists largely of a softer friable formation, which is worked by means of galleries or drives about 50 ft. below the surface: it apparently fills a wide interval between the soft argillaceous and arenaceous beds on the one side and the limestone on the other; it is being extensively worked, and its limits, both laterally and in depth, have not yet been determined.

Analyses of samples showed from 58·9 to 77·9% tricalcic phosphate.

In this district, *i.e.*, Kapunda and Belvidere, five other large deposits have been opened out and worked upon--viz., St. Kitt's, Allandale, Koonunga, Green's Freehold, and Moculta; they are all somewhat similar in character to St. John's.

Bendeeby.—About 8 miles east of Carrieton Railway Station, or about 180 miles north of Adelaide.

Phosphate has been found here in two localities two miles apart; it outcrops in irregular-shaped veins and masses in claystone and clay. The country rock consists of dolomitic limestone, of the same geological age as that of Clinton, argillaceous limestone and clay slate striking north-north-east and dipping west-north-west at a high inclination. The phosphate rock, as usual, is found chiefly in conjunction with the limestone, and appears to occupy places in the bed rock, which were originally open cavities.

Analyses gave from 12·4 to 73·1% tricalcic phosphate.

Hundred of Cunningham.—Near Ardrossan, Yorke Peninsula.

Phosphate rock occurs here, associated with argillaceous, arenaceous, and calcareous beds in Cambrian limestone. Analyses gave up to 82% tricalcic phosphate, the deposit also containing a large quantity of lower grade rock. Phosphate of alumina also occurs in this locality.

The character of the above deposits is that of large masses occupying what were apparently at one time either caves and hollows in the Cambrian limestone, or segregated and diffused through the accompanying argillaceous and arenaceous beds; which have near the surface been redeposited as a secondary formation through the clay and sandy detritus resulting from denudation.

Development in depth has not gone far enough to show definitely whether the phosphate rock will in depth exist as interstratified beds or lode-like formations. Indications of this are, however, afforded by more recent discoveries, where deposits which have a similar character at and near the surface to those mentioned above, on being followed down appear to be interstratified with the argillaceous and arenaceous beds, and, in some cases, to resemble lode formations filling fissures and chasms in the rock.

The following deposits are described as examples of this:—

Hundred of Willunga.—About 20 miles south of Adelaide.

Phosphate is being rather extensively worked here. The country rock is Cambrian limestone with interstratified argillaceous, arenaceous, and calcareous beds. The workings extend north and south, the lowest quarry being the most northern: here two bodies of phosphate, separated by a wedge or "horse" of dolomitic limestone, have been quarried out from the surface downward to a depth of about 40 ft. These bodies approach one another in going down as the limestone wedge becomes narrower, and appear to unite in the bottom of the quarry, being bounded on each side by argillaceous and arenaceous beds having a vertical and sometimes contorted dip. The appearance presented is that of an irregular shattered fissure, caused by upheaval and faulting, in which argillaceous material, broken bed rock, and phosphate had been deposited; blocks and boulders, chiefly of limestone, are also contained, and manganese and iron oxides occur as veins and coatings. At the bottom the phosphate rock is still under foot.

Going southward, towards rising ground, shallow quarries have been made in clay and decomposed argillaceous and arenaceous rock, limestone and slate mixed with phosphate, which is more widely distributed, and apparently occupies hollows in the bed rock, being disseminated in nodules, veins, and segregations for a considerable width through them and the superincumbent clay and calcareous material derived from their disintegration.

Hundred of Noarlunga.—About 18 miles south of Adelaide.

Phosphate rock occurs in clay and jointed broken argillaceous strata in segregated nodular masses and lode-like bedded formations in the dolomitic limestone. The deposit conforms to the north and south strike of the containing rocks; it has been worked by quarries, and in one place by a shaft which has been sunk to a depth of 40 ft., and a drive made on a lode-like formation, which may be, however, a stratified bed, the phosphate rock being confined between walls several feet apart; manganese and iron oxide as small irregular veins and stains are associated. At the bottom of this shaft and drive the phosphate still continues under foot, and further sinking should afford valuable information as to the persistence in depth and true character respecting this and phosphate localities where the occurrence is under similar conditions.

Orroroo.—About 170 miles north of Adelaide.

Phosphate rock has been quarried here, and also disclosed by shallow pits at several points for a distance of about 1 mile along the eastern boundary of the dolomitic limestone; it occurs along the limestone boundary in irregular-shaped intermittent bands of varying thickness and segregated masses in soft earthy argillaceous and arenaceous and calcareous rock dipping at high angles westward beneath

Cambrian limestone, which occupies the higher ground, and forms the hilly country extending from this place to Pekina Creek. The strike of the rocks is north-north-easterly, and the dip generally more or less vertical owing to extensive denudation acting on anticlinal and synclinal folds.

The phosphate rock deposits, so far as they have been traced downward, some 20 ft. or so, appear to be roughly interstratified with the rocks in which they occur, and also partake of the nature of lode formations, particularly near the outcrops.

Numerous other deposits exist, and the occurrence of rock phosphate, at intervals, has been demonstrated for about 200 miles along the Main Range; but the chief characteristics of the most important deposits have now been given, and it is not necessary to go into further descriptive detail.

These deposits are already of economic value, about 24,000 tons of crude rock having been marketed during the six years which have elapsed since the first discovery; they are not yet able, however, to successfully compete with the imported rock from Christmas and Ocean Islands, but I feel assured that we may with every confidence look forward to the time when they will be of the greatest importance and value, not only to the State of South Australia, but to the Commonwealth generally.

Suggested Origin.

A special feature in connection with some of these rock phosphate occurrences is their (apparent) bedded character and interstratification with soft earthy argillaceous and arenaceous and calcareous beds, which are interstratified with the Cambrian limestones, quartzites, sandstones, and other rocks belonging to that series. This is accompanied by evidences of segregations of phosphate as bands and nodular masses in clay and argillaceous material derived from the disintegration of the soft rocks above mentioned. Quartz as small veins, oxides of iron and manganese, are associated in all localities hitherto discovered, indicating to my mind deposition by solution from phosphate-bearing rocks in a similar manner to what is supposed to occur in the formation of lodes.

A theory that may be put forward to account for the bedded character of the deposits is that during the time the Cambrian rocks were deposited, the mud and other argillaceous and arenaceous beds of the then existing sea-bottom were inhabited to a greater or less extent by forms of life which secreted phosphate matter and phosphate of lime, as carbonate of lime was secreted by the coral animalcules which are responsible for the deposition of the limestone: that in the argillaceous deposits these phosphatic animalcules were developed in larger proportion than in the limestone, in which latter animalcules secreting carbonate of lime were in the majority, probably because such material was more favourable to their existence. Phosphate of lime may also have been derived from the coverings of a few of the Brachiopoda, such as Lingula and its allies, and from some of the Trilobites.

The result would be that certain strata would be charged with phosphate of lime, and others with carbonate of lime, while the intervening strata would contain a small proportion of both varieties. As evidence in favour of this theory, the Cambrian limestone, calcareous slates and claystones, sandstones, &c., almost invariably contain small percentages of phosphate of lime, as also do the chert and flinty boulders, those found in the limestone generally containing most.

In conjunction with these occurrences there is generally a large amount of clay and other argillaceous material also containing segregated phosphate, partly due to the erosion of the rocks, sometimes occupying caves and depressions, particularly in the limestone. This formation is of still later date, and the deposit may have been enriched by the deposition of guano and other animal remains.

3.—A GEOLOGIST'S SLIDE RULE, AND SUNDRY PROBLEMS IN PREPARATION OF GEOLOGICAL MAPS AND SECTIONS.

By W. G. WOOLNOUGH, D.Sc., F.G.S., Acting-Professor in Geology and Mineralogy, University of Sydney.

In geological survey work, both in the field and in the office, the geologist is called upon to make a number of calculations; and the instrument described in the present communication has been devised to assist in making or checking these calculations.

The instrument is easily constructed as follows:—Cut out strips of smooth cardboard—

22 inches	by	$3\frac{1}{2}$ inches	... ...	(one piece).
22	,,	$1\frac{1}{2}$,,	... ...	(one piece).
22	,,	$1\frac{1}{4}$,,	... ...	(two pieces).
22	,,	1 ,,	... ...	(three pieces).

Cut a semi-circular hole about 1 in. diameter out of the middle of each end of the $3\frac{1}{2}$-in. strip.

Now carefully paste one of the 1-in strips flat along each edge of the $3\frac{1}{2}$-in. strip. (It is well to "bank up" these strips with pieces of thick paper to allow sufficient "play" for the slide.)

On top of each of the 1-in. strips paste one of the $1\frac{1}{4}$-in. strips overlapping the narrower underlying one on the inside. By this method a "slide way" is formed (Figs. 1 and 3).

Take the remaining 1-in. strip and paste it centrally along the $1\frac{1}{2}$-in. piece, so that a strip of the latter $\frac{1}{4}$-in. wide projects on each side. This forms the "slide" (Figs. 2 and 4).

Each piece pasted on should be allowed to dry thoroughly under pressure before being covered by another strip.

The graduation is the next step. Four scales are necessary; these may with advantage be increased to eight, but that is not essential.

Two are simple logarithmic scales. On the experimental rule 10 in. was taken as the unit; a foot rule with inches divided to tenths then permits a reading to two places and estimation to the third place of decimals.

From a table of logarithms mark off on one edge of the narrow strip of the slide the lengths corresponding to the logarithms of the numbers. Beginning from one end of the slide, the lengths corresponding to the numbers 10, 20, 37, 122 are 10·00, 13·01, 15·68, 20·86; and so on for the other numbers. The points so obtained should be marked with the values of the *natural numbers* corresponding to them. A slide of the length described gives a range from 1 to about 150.

Run the slide into the slide way till the ends of the two are flush, and engrave on the slide way a scale identical with the one on the slide.

Now proceed to engrave on the other side of the slide a logarithmic cosine scale. Take the end of the slide corresponding to 1 on the logarithmic scale as the value 10 on the cosine scale (that is, corresponding to an angle 0°), and engrave it exactly as above described, making use of the table of logarithmic cosines given in the mathematical tables. Opposite each graduation put the number in *degrees* of the corresponding angle.

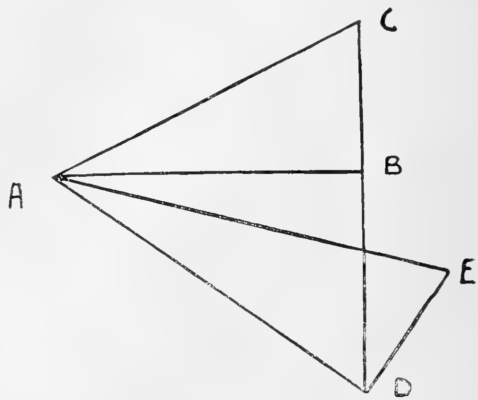
The fourth scale, engraved on the other edge of the slide way, is one of logarithmic tangents. Take the centre point of the edge as 10, (corresponding to the angle 45°), and graduate it by means of a logarithmic tangent table, the numbers *rising* in the direction in which those of the cosine scale *fall*.

This completes the essential part of the rule. A printed description makes the manipulation appear complicated; it is, however, quite simple in practice.

One of the commonest mathematical operations involved in geological field work is the multiplication or division of numbers. This can be done by means of the two logarithmic scales. If the numbers are large shift the decimal point to the left in both. For multiplication place the 1 graduation of one scale against the value of the multiplier on the other scale; then read off on this latter scale the value of the product, which comes opposite the number corresponding to the multiplicand on the first scale. In division, the graduations corresponding to divisor and dividend are brought together, when the value of the quotient can be read off opposite the 1 graduation of the scale taken for the divisor.

This method is useful in converting paces, (of a known number to the chain), into chains; chains into yards; yards into metres, &c., the points on the slide scale corresponding to the factors required for such reductions can be marked in red ink to save time in manipulation.

It is for the evaluation of dip problems, however, that the rule is specially designed. In drawing a geological section from the information furnished by a map, the line of section is often oblique to the direction of dip of geological structures (beds, dykes, fault planes, &c.). The apparent angle of dip in the direction of the section is always less than the true dip measured in the field. It is this apparent dip which has to be determined and plotted. The geometrical construction by means of which it is determined is as follows:—



Let the angle between the directions of true and apparent dip be called the direction angle. Draw a straight line AB of any convenient length. Make an angle BAC equal to the angle of true dip. Draw BC at right angles to AB. Make an angle BAD equal to the direction angle. Produce CB to meet AD in D. Draw DE at right angles to AD. Make DE equal to BC. Join AE, then the angle DAE is the apparent angle of dip required.

If P is the angle of true dip, Q the angle of apparent dip, and R the direction angle, it is easily shown that—

$$\tan.Q = \cos.R. \tan.P.$$

The slide rule enables this value to be read off at once.

RULE.—Place the zero of the cosine scale opposite the graduation on the tangent scale corresponding to the angle of true dip. Read the value on the tangent scale opposite the graduation on the cosine scale corresponding to the direction angle. The reading is the amount of apparent dip required.

Table 1 gives the values to the nearest half-degree of apparent dip for every 5 degrees difference of true dip and direction angle. Intermediate values may easily be interpolated. As a rule, the probable error in observation of angle of dip is rather large, and there is little certainty of absolute uniformity of dip over considerable areas. Therefore a high degree of accuracy in determination of apparent dip is unnecessary.

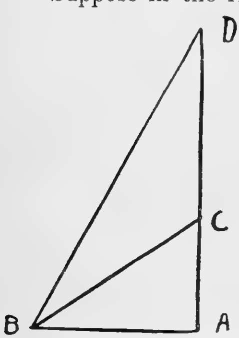
The diagram (plate 2) affords another means of reading off the apparent dip. True dips are plotted along the horizontal axis, and direction angles along the vertical axis. The corresponding lines for apparent dip angles form a series of hyperboloid curves. These have been drawn for every 5 degrees of apparent dip. In order to use the diagram, follow the horizontal line corresponding with the given direction angle to its intersection with the vertical line corresponding with the given true dip. The apparent dip required will lie between the values represented by the curves between which the point lies, and its value may easily be estimated to within a degree.

Another frequently recurring problem is one which, unfortunately, is too often neglected by geological draughtsmen. In drawing a geological section, the profile of the land surface is first drawn from the data supplied by contour lines, determined heights, &c. In a long section, if the same scale be used for horizontal and vertical distances, the width of the section becomes inconveniently small, and the surface irregularities become insignificant. It is, therefore, customary to *exaggerate the vertical scale.* For instance, we often find a horizontal scale of 1 mile to the inch, and a vertical scale of 1,000 ft. to the inch. In this case the vertical scale has been exaggerated 5·28 times. This number 5·28 may for convenience be called the *factor of exaggeration.*

In order to determine the factor of exaggeration in any given case, determine the number of feet (or yards) on vertical and horizontal scales corresponding to 1 in. (or any other convenient unit) in the diagram. Divide the number for the horizontal scale by that for the vertical scale, and the result is the factor of exaggeration. This is readily obtained by means of the logarithm scales of the rule.

The result of exaggeration of vertical scale is to increase the slopes of all surface features (hills and valleys). It should be obvious to everyone that, in order to obtain a correct section, geological dips should be increased proportionately. This is very frequently omitted, with the result that sections are either "faked"* (an immoral proceeding on the part of a scientist), or else they convey an entirely incorrect impression.

Suppose in the right-angled triangle ABC the apparent dip of a geological structure in the direction of section is equal to the angle ABC, and the factor of exaggeration is, say, 3; it is obvious that to obtain the angle which must be plotted in order to correctly represent the structure on our enlarged section we must produce AC to D, making AD equal to three times AC. Join DB, then the angle ABD is the angle required.



If the apparent angle of dip be P, and the angle to be plotted be Q, and the factor of exaggeration be—

$$\tan.Q = n \ \tan.P.$$

This value can at once be obtained from the slide rule.

Draw out the slide and reverse it end for end in the slide way. This brings a logarithmic scale against the tangent scale. Place 1 on the logarithm scale against the value of apparent dip on the tangent scale, and read off on the latter the graduation against

* Readers, please excuse the use of this slang term.

the number on the logarithm scale, expressing the factor of exaggeration. The value so found is the magnitude of the angle which has to be plotted on the exaggerated section.

It is an advantage to mount the slide way on a strip of board, which prevents warping, and gives "body" to the instrument.

PLATE I.

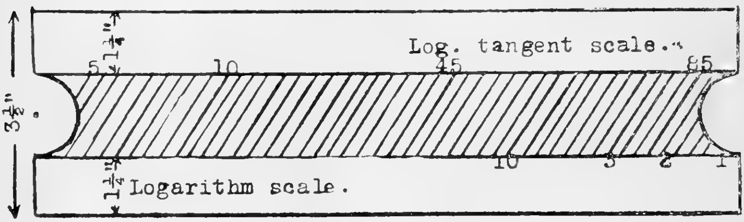


Fig. 1

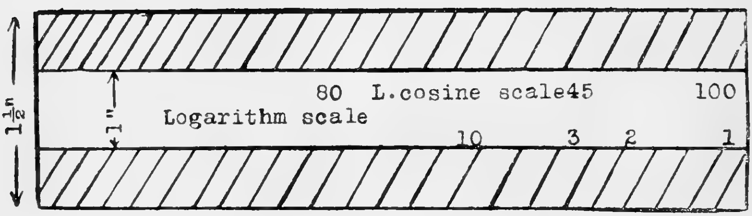


Fig. 2.

Fig. 3

Fig. 4.

Fig. 1.—Slide Way (plan) showing arrangement of logarithmic tangent and logarithm scales. The graduations are diagrammatic only. Shaded area is depressed portion.

Fig. 2.—Plan of slide showing diagrammatically arrangement of logarithmic cosine and logarithm scales.

Fig. 3.—Section of slide way. Thickness of strips is exaggerated.

Fig. 4.—Section of slide.

APPARENT DIP TABLE.

Compiled by W. G. WOOLNOUGH, D.Sc., University of Sydney.

True Dip.

Direction Angle.

	5		10		15		20		25		30		35		40		45		50		55		60		65		70		75		80		85	
5	5	1·0	10	1·0	15	1·0	20	1·0	25	1·0	30	1·0	35	1·0	40	1·0	45	1·0	50	1·0	55	1·0	60	1·0	65	1·0	70	1·0	75	1·0	80	1·0	85	5
	0		0		0		·1		·1		·1		·1		·1		·1		·1		·1		·1		·1		·1		0		0		0	
10	5	1·0	10	1·0	15	·9	19½	1·0	24½	1·0	29½	1·0	34½	1·0	39½	1·0	44½	1·0	49½	1·0	54½	1·0	59½	1·0	64½	1·0	69½	1·1	75	1·0	80	1·0	85	10
	0		·1		·1		0		·1		·1		·1		·1		·1		·1		·1		·1		·0		·0		·1		·1		0	
15	5	·9	9½	1·0	14½	1·0	19½	·9	24	1·0	29	1·0	34	1·0	39	1·0	44	1·0	49	1·0	54	1·0	59	·9	64½	1·0	69½	1·0	74½	1·0	79½	1·1	85	15
	·1		0		·1		·1		·1		·1		·1		·1		·2		·2		·2		·1		·2		·1		1		0		·1	
20	4½	1·0	9½	·9	14	1·0	19	·9	23½	1·0	28½	1·0	33½	1·0	38½	·9	43	1·0	48	1·0	53	1·1	58½	1·0	63½	1·1	69	1·0	74	1·1	79½	1·0	84½	20
	0		·1		·1		·2		·1		·2		·2		·2		·2		·2		·2		·1		·2		·2		·1		·1		0	
25	4½	·9	9	·9	13½	·9	18	1·0	23	·9	27½	1·0	32½	1·0	37½	·9	42	1·0	47	1·0	52	1·1	57½	1·0	62½	1·1	68	1·1	73½	1·1	79	1·1	84½	25
	0		·1		·1		·1		·2		·2		·3		·3		·2		·2		·2		·1		·2		·2		·1		1		·1	
30	4½	·8	8½	·9	13	·9	17½	·9	22	·9	26½	·9	31	1·0	36	1·0	41	1·0	46	1·0	51	1·1	56½	1·0	61½	1·1	67	1·2	73	1·1	78½	1·1	84	30
	·1		·1		·1		·2		·2		·2		·2		·3		·3		·3		·3		·3		·2		·2		·2		·1		0	
35	4	·8	8	·9	12½	·8	16½	·9	21	·9	25½	·9	30	·9	34½	1·0	39½	1·0	44½	1·0	49½	1·1	55	1·1	60½	1·1	66	1·2	72	1·2	78	1·2	84	35
	0		·1		·2		·2		·3		·3		·4		·4		4		·4		·4		·4		·4		·3		·3		·2		·1	
40	4	·7	7½	·8	11½	·8	15½	·8	19½	·9	24	·8	28	·9	32½	1·0	37½	1·0	42½	1·0	47½	1·1	53	1·1	58½	1·2	64½	1·2	70½	1·3	77	1·3	83½	40
	·1		·1		·2		·2		·3		·4		·3		·4		·5		·5		·5		·5		·4		·4		·4		·2		·1	
45	3½	·7	7	·7	10½	·8	14½	·7	18	·8	22	·9	26½	·8	30½	·9	35	1·0	40	1·0	45	1·1	50½	1·2	56½	1·2	62½	1·4	69½	1·3	76	1·4	83	45
	·1		·1		·1		·3		·3		·5		·5		·4		·5		5		·5		·5		·5		·4		·4		·3		0	
50	3	·7	6½	·7	10	·6	13	·7	16½	·8	20½	·7	24	·9	28½	·8	32½	1·0	37½	1·0	42½	1·1	48	1·2	54	1·3	60½	1·4	67½	1·4	74½	1·7	83	50
	0		·1		·3		·2		·3		·5		·4		·6		·5		·6		·7		·7		·6		·6		·5		·3		·3	
55	3	·6	6	·5	8½	·7	12	·6	15	·6	18	·8	22	·7	25½	·9	30	·9	34½	·9	39	1·1	44½	1·3	51	1·3	57½	1·5	65	1·6	73	1·7	81½	55
	·1		·2		·2		·3		·4		4		·5		·6		·7		·8		·7		·8		·8		·7		·6		·5		·3	
60	2½	·5	5	·5	7½	·6	10½	·5	13	·6	16	·7	19½	·6	22½	·8	26½	·8	30½	1·0	35½	1·0	40½	1·3	47	1·4	54	1·6	62	1·7	70½	1·9	80	60
	·1		·1		·2		·3		·4		·5		·6		·6		·7		·8		·9		·9		1·0		1·0		·9		·6		·3	
65	2	·5	4½	·4	6½	·5	9	·4	11	·5	13½	·6	16½	·6	19½	·9	23	·9	26½	·9	31	1·0	36	1·2	42	1·4	49	1·7	57½	2·0	67½	2·2	78½	65
	·1		·2		·3		·4		·4		·5		·6		·7		·8		·9		1·0		1·1		1·1		1·2		1·1		1·0		·6	
70	1½	·4	3½	·3	5	·4	7	·4	9	·4	11	·5	13½	·5	16	·6	19	·6	22	·8	26	·9	30½	1·2	36½	1·3	43	1·8	52	2·1	62½	2·6	75½	70
	0		·2		·2		·3		·4		·5		·6		·7		·9		1·0		1·2		1·3		1·5		1·5		1·6		1·4		·8	
75	1½	·2	2½	·3	4	·3	5½	·3	7	·3	8½	·4	10½	·4	12½	·4	14½	·5	17	·6	20	·8	24	1·0	29	1·3	35½	1·5	44	2·3	55½	3·2	71½	75
	·1		·2		·3		·4		·5		·6		·7		·8		·9		1·1		1·2		1·5		1·7		2·0		2·2		2·2		1·7	
80	1	·1	1½	·2	2½	·2	3½	·2	4½	·2	5½	·3	7	·3	8½	·3	10	·3	11½	·5	14	·9	16½	·8	20½	1·0	25½	1·5	33	2·3	44½	3·7	63	80
	·1		·1		·2		·3		·4		·5		·7		·8		1·0		1·1		1·4		1·6		2·0		2·5		3·0		3·7		3·6	
85	½	·1	1	·1	1½	·1	2	·1	2½	·1	3	·1	3½	·2	4½	·1	5	·2	6	·2	7	·3	8½	·4	10½	·6	13½	·9	18	1·6	26	3·8	45	85
	5		10		15		20		25		30		35		40		45		50		55		60		65		70		75		80		85	

APPARENT DIP TABLE.

NUMBERS at top and bottom of vertical columns represent *true dip angles* (every 5° being given). Numbers to the right and left of horizontal lines represent *direction angles* (every 5° being given). Each number in heavy faced type is the value of *apparent dip* corresponding to the true dip and direction angle of the column and line, respectively, in which it is situated.

Numbers in lines in fine type give the difference (in decimals of a degree) of apparent dip for each degree of difference in true dip, at the particular direction angle for the line concerned.

Numbers in columns in fine type give the difference (in decimals of a degree) of apparent dip for each degree of difference in direction angle at the particular true dip for the column concerned.

These "difference numbers" permit interpolation of values not directly given by the table.

In performing this interpolation, correct first for difference of true dip (at approximately the correct direction angle), and then correct the result so obtained for difference of direction angle (at approximately the correct true dip).

For example: To find apparent dip when true dip is 63° and direction angle 54°. Taking the 60° and 65° columns and the 50 and 55° lines we get the group of numbers:—

48	1·2	**54**
·7		·6
44½	1·3	**51**

Difference in true dip is 3°. Since 54° is nearer 55° than 50°, take the lower line.

$3 \times 1{\cdot}3 = 3{\cdot}9$ to be added to 44½ gives 48·4.

Since 63° is about midway between 60° and 65° take ·65 the mean of ·7 and ·6 as the correction due to error of direction angle.

$\cdot 65 + 1 = \cdot 65$ to be added to $48{\cdot}4 = 49.05$, *i.e.*, 49° (in round numbers) is the apparent dip required.

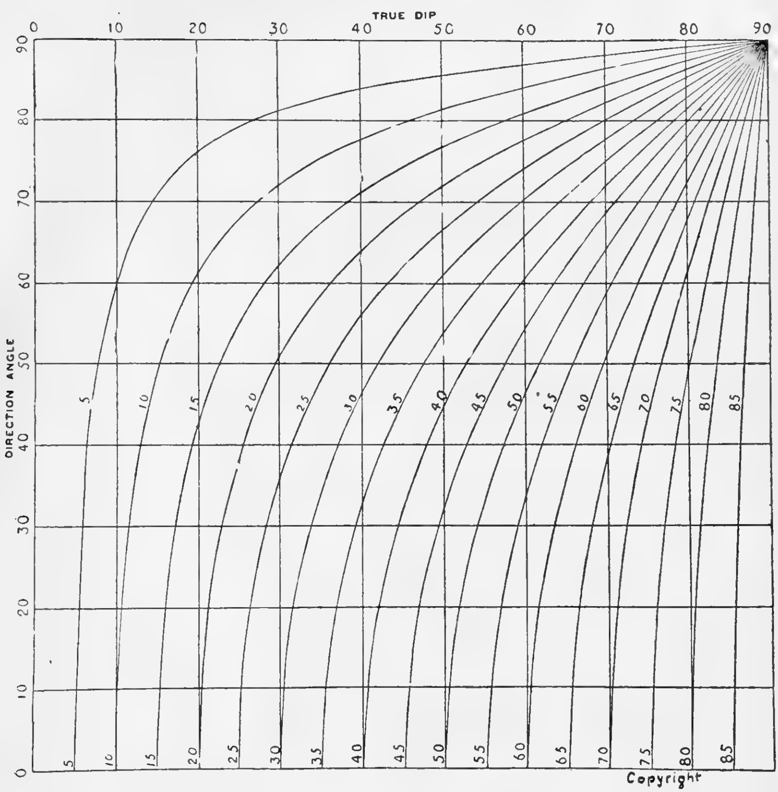
(Calculated by trigonometry the angle is 49°4′).

The values in the table are given to the nearest ½° with a probable error of ±¼°. Hence the slight irregularities in difference numbers.

PLATE II.

APPARENT DIP DIAGRAM.

Designed by W. G. WOOLNOUGH, D.Sc., University of Sydney.



4.—THE ALKALINE ROCKS OF SOUTHERN QUEENSLAND.

By H. I. JENSEN, D.Sc.

Introduction.

Eastern Australia possesses a vast abundance and great variety of alkaline rocks. In Tasmania they occur at Regatta Point, Port Cygnet, &c.; in Victoria at Mount Macedon; in New South Wales at Mount Kosciusko, and in the Kiama-Jamberoo district, the Gib Rock and Mittagong district, the Warrumbungle and Nandewar Mountains, the Canobolas Mountains, the Macpherson Range, and at Barrigan. In Queensland they occur in great abundance in the Glass House Mountains, the Maroochy and Cooran districts (on the North Coast line), at Mount Flinders, and in the Little Liverpool Range. The author has personally investigated these South Queensland occurrences as well as many of the alkaline bodies of New South Wales, and his work is reviewed in a paper entitled "The Distribution, Origin, and Relationships of Alkaline Rocks," in the Proceedings of the Linnean Society of New South Wales, 1908, Vol. XXXIII., Part 3. References to all the author's other papers on alkaline rocks, and to the work of other investigators on the same topic may be found in the same paper.

It is the author's object to outline in the present paper the main features of the alkaline areas of Southern Queensland. Other alkaline areas do exist in the State, such as the alkaline trachytes of the Yeppoon Range, in Central Queensland, and similar masses in the Springsure and Clermont districts, but they have never been thoroughly examined.

The best known group of such rocks is that of the Glass House Mountains, which is situated on the North Coast Railway line, and is a popular tourist resort. Yet so little interest was taken in the geology of the district that, until a few years ago, those wonderful trachyte pinnacles were taken for masses of metamorphic sandstone. To Mr. H. G. Stokes belongs the credit of discovering that they consisted of trachyte.

Our vice-president, Mr. R. A. Wearne, B.A., of Ipswich, has collected extensively in the Mount Flinders area and in the Little Liverpool Range, and to him belongs the credit of having first established that alkaline trachytes are abundantly represented in these areas.

2. Geological Structure of the Coastal Portions of Southern Queensland.—It will be seen on reference to the geological map of Queensland that, from the Brisbane River northwards to the mouth of the Mary River, the coast is bordered by Trias-Jura coal measures. I have in one of my papers* shown that the Ipswich and Burrum beds are not separated by a strip of Gympie formation at Point Arkwright, as shown on the old geological map of Queensland, but they are continuous. There is probably no unconformity between them. The Mesozoic beds, between Brisbane and Gympie, form a comparatively narrow coastal plain, west of which the country rises sharply and Palæozoic rocks displace the Trias-Jura. The line along which this change sets in is also characterised by the appearance of volcanic rocks, which are particularly abundant along and a couple of miles on either side of this line. Thus, close to the junction of the Palæozoic and Mesozoic, we have the basalts of Mount Mee, the trachytes of the Glass Houses, and the andesites and rhyolites of the Tuchekoi Range; whereas the Blackall Range basalts partly cover the line. The coastal plain is partly covered with Tertiary alluvium, and shows indications in many places, especially in the Maroochy district, of recent emergence. Behind the plain lies a low tableland, the coastal range having but a slight fall to the west. This tableland has the character of a Tertiary peneplain.

A similar structure is observed in the Fassifern district south of Ipswich, where, behind the plain of Walloon coal measures, the trachyte peaks of Mount Mitchell, Spicer's Peak, Mount Huntley, and Mount Roberts, &c., form the culminating points of the Little Liverpool Range, which has only a slight fall to the Darling Downs on the west. The Downs constitute a plain or peneplain (probably a Tertiary peneplain) covered with basalts of late Tertiary age.

---

* Geology of the Volcanic Area of the East Moreton and Wide Bay districts. Proc. Linn. Soc. of N.S.W.

The analogy is very close between the situation of Mount Beerwah and Mount Mitchell. Mount Mitchell, on the Little Liverpool Range, has the Darling Downs tableland on the west and the low Fassifern plain on the east bestrewn with trachyte peaks (Mount French, Mount Edwards, &c.). Mount Beerwah, on the D'Aguilar Range, has the Stanley River tableland (Woodford peneplain) on the west, and the low coastal plain of Toorbul on the east with trachyte peaks (Conowrin, Ngun-Ngun, &c.) towering up above it.

The trachytes appear to have been extruded from a line of fracture separating adjacent earth segments undergoing differential uplift or subsidence—that is, while the one segment was uplifted the adjacent one was depressed.

3. The Alkaline Areas of Southern Queensland known to the author may be divided into the following groups:—

(*a*) The Maroochy-Cooran alkaline group, comprising the following heights:—(1) Mount Coolum (620 ft.), consisting of comendite; (2) Mount Peregian (300 ft.), pantellarite; (3) Mount Nindherry (900 ft.), pantellarite and rhyolite; (4) Mount Cooroy (1,340 ft.), monzonite; (5) Mount Eerwah (1,290 ft.), pantellarite and rhyolite; (6) Mount Cooran (950 ft.), and Mount Cooroora (1,290 ft.), comendite and riebeckite trachyte; (7) Mount Tinbeerwah, pantellarite; and (8) the portion of the Blackall Range known locally as The Bottle and Glass. The rhyolites of the Toolburra Range and the porphyrites of Point Arkwright have alkaline affinities.

(*b*) *The Glass House Group*, comprising the following hills:—(1) Coochin Hills; (2) Mount Ngun-Ngun (810 ft.); (3) Beerwah (1,760 ft.); (4) Conowrin (1,170 ft.); (5) Barren Mountain (350 ft.); (6) Tibrogargan (1,160 ft.); (7) Ewin; (8) Beerburrum (920 ft.); (9) Tunbubudla (1,020 ft.); (10) Micketeebumulgrai (750 ft.), &c. All these mountains consist of arfvedsonite, riebeckite, and ægirine comendites, and trachytes.

(*c*) *The Mount Flinders Group*, consisting of Mount Flinders and a number of smaller mountains and hills surrounding the larger heights. Mount Flinders (2,240 ft.) is composed of alkaline felspar porphyry, ægirine trachyte, tuffs, and breccias, and dacitic lava. The smaller hills consist mainly of pantellarite and breccias.

(*d*) *The Little Liverpool Range Group.*—This consists of most of the peaks on the Little Liverpool Range (Mount Mitchell, Mount Huntley (4,153 ft.), Spicer's Peak, Mount Roberts (4,850 ft.), and Wilson's Peak); several parts of the Macpherson Range, and a number of isolated peaks in the Fassifern plain; including Mount Flinders (2,240 ft.), comendite; Mount Edwards, quartz trachyte; Mount Greville, quartz trachyte; and many others. Mount Obelisk and a number of other peaks on the New South Wales side of the border form a continuation of the Little Liverpool Range, and consist of riebeckite comendite.

The members of the Maroochy-Cooran Group are scattered about in an indiscriminate way, and it is impossible to detect any definite arrangement. The country is considerably faulted, but owing to its level nature, the denseness of the vegetation, and the absence of mining shafts, it is impossible at present to map the faults.

The mountains of the Glass House Group lie on two sets of intersecting fractures. The main fracture runs S.S.E.-N.N.W.; and numerous fault lines cross this almost at right angles. Radiating dykes in sets diverging from the principal foci of eruption form a noteworthy feature in this district.

The hills around Mount Flinders are probably situated on fissures radiating from the main focus of activity.

The Little Liverpool Range has the same trend as the D'Aguilar Range, viz.:—N.N.W.-S.S.E., and in the arrangement of the trachytic peaks of this area an indication of sets of intersecting cracks, as in the Glass House Mountains, is noticeable.

One of the most characteristic features of a mountain of alkaline rock is its ruggedness and precipitousness. This is particularly so for those composed of comendite, or other leucocratic types of alkaline rock. Some alkaline masses form rugged steep cones; such sugarloafs are Mount Tunbubudla, Coochin Hills, Micketeebumulgrai, &c., in the Glass House Group; Mount Edwards, Mount Greville, &c., in the Fassifern Group. Trachyte and comendite lavas are of a very viscous character, and would cool with very steep sides if slowly extruded from a small vent. It appears, therefore, that most of the sugarloaf-shaped hills and many of the steeper pinnacles have originated in the same way as the mamelons of Mauritius. In other cases the steep obelisks and pillars may have originated by the extrusion of a solid column of congealed lava like the new lava pillar of Mount Pelée in Martinique, but in most cases the very steep, precipitous, and almost inaccessible trachyte peaks have originated by the intrusion of a lava mass into the pipe of a tuff cone, and the subsequent removal of the tuffs by denudation. This process of destruction of tuff cones, leading to the survival of the volcanic neck only, I have observed in various stages at Mount Flinders, Mount Coolum, Mount Beerwah, and elsewhere.

Columnar structure is another almost invariable feature of the leucocratic trachytes and comendites, and as already pointed out in my previous papers, the arrangement of the columns is such that there can be no doubt that the trachytic peaks are independent foci of eruption. The arrangement shows, too, that the peaks are not "monadnocks," and it favours the theory that they constitute the necks and plugs of tuff cones.

4. PETROGRAPHY.—The rocks of the alkaline areas may be divided as follows:—

A.—Sedimentary.

B.—Metamorphic.

C.—Igneous but not alkaline.

D.—Igneous alkaline.

In the Maroochy-Cooran and the Glass House areas all these rock classes are present; but at Mount Flinders and in those parts of the Little Liverpool and Fassifern areas which I have visited rocks affected by regional metamorphism are absent.

A.—The *sedimentary* rocks in each of the four districts consist essentially of sandstones, shales, and conglomerates of Upper Trias-Jura age.

B.—Most of the rocks west of the line dividing the Palæozoic from the Mesozoic formations are *metamorphic*. The rest are igneous in origin. The metamorphic rocks I am discussing in a separate paper.

C.—The *non-alkaline igneous* rocks comprise granites and syenites (Cooran, Woondum, Obi-Obi, Woodford, Leacey's Creek), rhyolites (Tuchekoi Range, Blackall Range, in part, Toolburra Range, Mount Archer, &c.), quartz porphyry (Upper Mary River), andesites (Blackall Range, in part, Little Liverpool Range, in part), basalts (Woondum, Blackall Range, Mount Mee, Little Liverpool Range, &c.), and dacites (Glass House Mountains, Yandina, and Mount Flinders), gabbro at Milora on the Boonah line.

D.—The *alkaline* rocks with which we are specially concerned here comprise:—

(*a*) *Pantellarite.*—Tinbeerwah, Peregian, Bottle and Glass, Nindherry, Eerwah, Ngun-Ngun, Trachyte Range; also in isolated places on and near Mount Flinders and on the Little Liverpool Range. Some of the pantellarites possess a trachytic fabric with flow structure; others are hyalopilitic; some are pilotaxitic, and a few orthophyric. The pantellarites are darker in colour, and have a higher iron and lime percentage than the following class.

(*b*) *Comendite.*—Cooran, Cooroora, Coolum, Conowrin, Tibrogargan (Tiberowaccam), Beerburrum, Ewin, Mount French, Spicer's Peak, Mount Mitchell, &c. The comendites are all light in colour, greyish, bluish white, or yellowish; their fabric is microgranitic or orthophyric, and the dominating constituents are sanidine or sodasanidine and ægirine, riebeckite or arfvedsonite. Quartz is also present.

(*c*) *Leucocratic Soda-Trachytes.*—Beerwah, Mount Flinders, and the Little Liverpool Range. These rocks are similar in colour to the comendites, but have a trachytic fabric. In composition they differ from the comendites only in being quartz-free or nearly so.

(*d*) *Melanocratic Soda-Trachytes.*—These differ from the above in being much darker in colour—from grey-blue to almost black. They are easily recognised in hand specimen from basalts and andesites by their silky lustre. The dominant minerals are anorthoclase, microcline microperthite, and ægirine, with or without magnetite. Such rocks have been described in my papers from the Round Mountain, near Caboolture, Mount Flinders, and various points on the Little Liverpool Range. Occasionally nosean and pseudo-leucite form important constituents in these rocks.

(*e*) *Monzonite* has been described from Mount Cooroy.

(*f*) *Quartz-keratophyre* has been described from Mount Byron, near Mount Mee.

True nepheline phonolites, tephrites, leucitites, &c., have not been met with so far in these districts. Nor have any true hypabyssal or plutonic equivalents of the alkaline lavas been found. Many of the lavas are, however, so like hypabyssal rocks in fabric and appearance that if described by a petrologist unacquainted with the region they would be given the names distinctive of the hypabyssal group. Many of the *comendites* would be termed *paisanite*.

Rare Minerals.—A number of rare minerals characteristic of alkaline rocks have been detected and described in my papers dealing with special regions.

In addition to riebeckite, arfvedsonite, ægirite, zirconite, microperthite, and anorthoclase, which are common constituents, wöhlerite, eucolite (?), nosean, analcite, meliphanite (?), guarinite (?), cossyrite, and barkevicite have each been detected in some of the rocks which I have described. Because of these rare minerals our alkaline rocks present an interesting and puzzling study to the petrologist.

From the correlation of chemical analyses with microscopic work it is clear that the peculiar structure, composition, and texture of the alkaline rocks are largely due to the action of pneumatolytic vapours carrying HF, HCl, TiO_2, and ZrO_2 in the period of consolidation.

5. PETROLOGY.—In order that the mineralogical composition of the principal of these rocks may be clearly understood, the following abridged petrological descriptions are given:—

(*a*) *Orthophyric Pantellarite.*—Mount Ngun-Ngun, Glass House Mountains.

Texture: Holocrystalline, porphyritic, orthophyric, with microcrystalline to cryptocrystalline base.

Constituents: Sanidine, anorthoclase, arfvedsonite, riebeckite, cossyrite, chalcedony, and quartz.

Analysis:

S_iO_2	...	72·38	CO_2	...	n.d.
Al_2O_3	...	12 21	TiO_2	...	0·25
Fe_2O_3	...	3·36	ZrO_2	...	n.d.
FeO	...	0·69	P_2O_5	...	trace
MgO	...	0·17	Cl	...	0·01
CaO	...	0·18	MnO	...	0·70
Na_2O	...	3·52	NiO	...	0·04
K_2O	...	5·20			——
H_2O (100°)+		0 86	Total	...	100·26
H_2O (100°−)		0·69			

Magmatic Name: Liparose.

(*b*) *Orthophyric Comendite.*—Mount Conowrin, Glass House Mountains.

Texture: Holocrystalline, microcrystalline, orthophyric.

Constituents: Sanidine, anorthoclase, riebeckite, quartz (micrographic intergrowth with felspar).

Analysis:

S_1O_2	...	74·20	CO_2	...	0·01
Al_2O_3	...	11·75	TiO_2	...	0·13
Fe_2O_3	...	1·92	ZrO_2	...	0·38
FeO	...	1·30	Cl	...	0·17
MgO	...	0·30	F	...	0·02
CaO	...	0·19	S (FeS_2)	...	0·10
Na_2O	...	4·25	MnO	...	0·02
K_2O	...	5·00	NiO	...	0·03
H_2O (100°+)		0·27			
H_2O (100°−)		0·06	Total	...	100·10

Magmatic name: Alaskose.

(*c*) *Leucocratic Alkaline Trachyte.*—Mount Beerwah, Glass House Mountains.

Texture: Holocrystalline, aphanitic, trachytic.

Constituents: Sanidine, soda-sanidine, barkevicite, arfvedsonite (cossyrite (?) or katophorite (?), ægirine, magnetite, zircon; and apatite, garnet, and quartz in very minute amount.

Analysis:

S_1O_2	...	64·58	T_1O_2	...	0·13
Al_2O_3	...	17·52	ZrO_2	...	0·21
Fe_2O_3	...	2·56	P_2O_5	...	trace
FeO	...	0·96	SO_3	...	abs.
MgO	...	0·22	Cl	...	0·08
CaO	...	0·39	F	...	n.d.
Na_2O	...	6·41	S (FeS_2)	...	0·08
K_2O	...	6·23	MnO	...	0·08
H_2O(100° +)		0·30	NiO	...	0·03
H_2O(100° −)		0·11			
CO_2	...	0·08			99·97

Magmatic Name: Phlegrose, near Nordmarkose.

(*d*) *Melanocratic* (Phonolitic) *Ægirine Trachyte.*—Mount Flinders.

Texture: Holomicrocrystalline, even grained, pilotaxitic.

Constituents: Soda-microcline, albite, ægirine, magnetite, and a little nepheline.

Analysis:

S_1O_2	...	56·78	H_2O (100°+)		1·70
Al_2O_3	...	14·47	H_2O (100°−)		0·56
Fe_2O_3	...	2·80	TiO_2	...	2·00
FeO	...	6·05	NiO	...	0·05
MgO	...	0·34	MnO	...	trace
CaO	...	2·47			
Na_2O	...	8·67	Total	...	100·40
K_2O	...	4·51			

Magmatic Name: **Umptekose.**

(*e*) *Sölvsbergite.*—Fife's Range, Delaney's Creek road, near Woodford. Dyke rock.

Texture: Holocrystalline, fine grained, even, and microcrystalline, almost panidiomorphic, granular.

Constituents: Orthoclase, anorthoclase, albite, acicular ægirines, magnetite, and interstitial quartz.

(*f*) *Paisanite.*—Dyke near Beerburrum Railway Station. This is a beautiful orthophyric close-grained rock, very like the Conowrin comendite in hand specimen, microscopic structure, and composition. As it occurs as a dyke it may be termed "paisanite," although it is not distinguishable from orthophyric comendite.

(*g*) *Monzonite.*—Mount Cooroy.

Texture: Holocrystalline, medium and uneven grained, allocrysts, ægirines, magnetite, and interstitial quartz.

Constituents: Oligoclase-andesine, albite, orthoclase, pargasite, faint greenish diopside, biotite, magnetite (titaniferous), zircon, and a little quartz and apatite.

Analysis:

S_1O_2	...	62·09	Co_2	...	0·11
Al_2O_3	...	14·45	TiO_2	...	1 30
Fe_2O_3	...	3·46	ZrO_2	...	traces
FeO	...	4·00	P_2O_5	...	0·56
MgO	...	0·94	Cl	...	0·05
CaO	...	3·15	S (FeS_2)	...	0·05
Na_2O	...	4·45	MnO	...	0·38
K_2O	...	4·56	NiO	...	0·09
H_2O (100°=)		0·34			——
H_2O (100°—)		0·24	Total	...	100·22

Magmatic Name: Adamellose.

Magmatic Names.—The alkaline rocks analysed by me from Southern Queensland fall under the headings Alaskose (Conowrin), Kallerudose (Coolum), Liparose (Ngun-Ngun, Trachyte Range), Phlegrose (Beerwah), Nordmarkose (Beerwah), Umptekose (Mount Flinders, Little Liverpool Range, &c.), Pulaskose (Mount Flinders), Adamellose (Mount Cooroy).

Some very closely allied rocks fall under different headings in the American classification.

6. Glaucophane Schists.—In addition to the alkaline volcanic rocks, we have in South Queensland considerable areas of glaucophane schists which are amongst the most beautiful of metamorphic rocks, and consist principally of the soda-amphibole glaucophane. These rocks occur at Mount Mee and on the Mary River slopes of the Conondale Range. I am describing them in more detail in another paper.

7. The Age of the Alkaline Eruptives and the Volcanic Sequence.—No definite evidence as to age has been observed except that the alkaline series has intruded the Upper Trias-Jura. As similar rocks occur in New South Wales (the Warrumbungle Mountains group) of Lower Tertiary, probably Eocene age, it is likely that the Queensland alkaline rocks are of the same age.

The sequence is everywhere the same. The alkaline rocks were first extruded. Andesites and dacites followed close after in some localities; a period of erosion followed; after which basalts were erupted. As the South Queensland basalts are considered Pliocene, and a period intervened between the trachytic and basic eruptions, this fact too tends to show that the eruptions took place in the early Tertiary, Eocene, or Lower Miocene.

8. Soils and Economic Notes.—The alkaline rocks everywhere give but poor soils. Where basaltic eruptions have followed the alkaline good country predominates.

Many of the columnar trachytes would make beautiful and most durable building stones. Particularly fine stone could be obtained from Mount Cooran, Mount Ngun-Ngun, Mount Conowrin, and Mount French.

Alum caves exist near the summit of Mount Flinders. The alum occurs as veins in breccia, and is probably formed by the decomposition of pyrites and felspar.

Coal occurs in the Trias-Jura beds in all the districts noted for alkaline rocks. It is possible that the heat of these slowly cooling igneous rocks may have produced petroleum oil in the coal beds invaded by them. Boring for oil in these districts might meet with a successful termination.

9. References to the author's published papers on the subject—

(*a*) "The Geology of the Glass House Mountains," H. I. Jensen. Proc. Linn. Soc., N.S.W., 1903, Part 4.

(*b*) "The Geology of the Volcanic Area of the East Moreton and Wide Bay districts, Queensland," H. I. Jensen. Proc. Linn. Soc. of N.S.W., 1906, Part. 1.

(*c*) "The Distribution, Origin, and Relationships of Alkaline Rocks," H. I. Jensen. Proc. Linn. Soc. of N.S.W., 1908, Vol. XXXIII., Part 3.

(*d*) "The Alkaline Petrographical Province of Eastern Australia." Proc. Linn. Soc., N.S.W., 1908, Vol. XXXIII., Part 3.

(*e*) "The Geology of Mount Flinders and the Fassifern."

(*f*) "Note on a Glaucophane Schist from the Conondale Range, Queensland." Proc. Linn. Soc., N.S.W., 1907, Vol. XXXII., Part 4.

10. I am indebted to my friend, Mr. Archibald Meston, for the following glossary of aboriginal names of mountains and places in the East Moreton and Wide Bay districts.

Map Name.	Native Name.	Meaning.
Beerwah	Birroa	Sunset
Conowrin	Coonoowarrang	Neck bad or crooked
Ngun Ngun	Gnoon-gnoon	White-headed eagle
Tiberowaccam or Tibrogargan	Geebor-a-gaggalin or Geebor-caccam	Squirrel nibbling
Coochin	Coochin	A swan
Mee	Mee	An eye
Beerburrum	Beear	Blue mountain parrot
	burrum	Noise of wings
Miketeebumul -grai	Mikateeboomàl -garri	Lightning struck the place
Tinbeerwah	Jin-birroa	Dying sunset
Pinbarren	Bin-barren barran	A boomerang
Cooran	Cooran	Tall, lofty
	Cóoranú	A lofty hill
Cooroy	Cooroy	Opossum
Coondoo	Cahndoo	Hungry
Eerwah	...	Same as Beerwah
Wappa	...	Bye and bye
Caboolture	Caboochá	
	Cabool	Carpet snake
	cha	Ground
Maroochy	Mooroo coochy	A black swan
Mooloolah	Moola	A black snake
Cootharaba	Coothar	A nulla
	ba	there
Cooloola	Cooloolooi	Cypress pine
Cooroyba	Cooroy	Opossum
	ba	there
Weyba	Myba	Large
	Mybagong	Big water
Eumundi	...	A blackfellow's name

5.—THE METAMORPHIC ROCKS OF THE EAST MORETON AND GYMPIE DISTRICTS.

By H. I. JENSEN, D.Sc.

1. Introduction.—The purpose of this paper is not to give a complete account of all the metamorphic rocks of the areas mentioned, but rather to record a number of scattered observations which I have made on my journeys, and to describe such rocks as are of particular interest. The area over which my observations extend is bounded by the Kin-Kin Creek, Wolvi Range, and Tinana Creek on the north; the Mary River, Stanley River, and Mount Mee on the west; the Pine River on the south, and Moreton Bay, Bribie Passage, and the ocean on the east. The greater portion of this area is covered by Trias-Jura coal measures and volcanic rocks. The metamorphic rocks occur only in the extreme north-west, west, and south-west portions of the area.

2. Summary of Rock Types Represented in the Area.—

A. *Igneous*—

I. Plutonic.

Rock Family.	Chief Localities.
(a) Granite	... Cooran, Woondum tableland, Beenam Range, Obi-Obi, Woodford, Delaney Creek (Black's Range), Leacy's Creek.
(b) Syenite	... Woondum tableland.
(c) Diorite Porphyry ...	... Noosa Heads, Point Arkwright, Mary River.
(d) Gabbro and Amphibolite	... In some Gympie mines.

II. Volcanic.

(a) Rhyolite	... Mount Archer, Toolburra Range, Nindherry, and railway cuttings near Nambour.
(b) Comendite and Trachyte	... Localities given elsewhere.
(c) Andesite	... Yandina.
(d) Basalt	... Blackall Range, Woondum tableland, Mount Mee.

B. *Sedimentary*—

1. The Gympie beds, which have been so altered that they might well be treated as metamorphic rocks.

2. The Trias-Jura system, consisting of sandstones, conglomerates, clay shales, carbonaceous shales, and coal.

3. Recent alluvium.

C. *Metamorphic Rocks*, comprising—

1. Gympie system, at Gympie, Chinaman Creek, Wararba, &c.

2. Gympie (Carboniferous) or older, much more highly metamorphosed, rocks. These rocks are provisionally considered Gympie by the geological survey, but for reasons which I will give on the following pages I am inclined to regard them as much older.

3. Relationship of the Ipswich and Burrum Beds.—As already emphasised in one of my papers,* there is no stratigraphical break between the Ipswich and Burrum beds. They merge into one another at Point Arkwright without any apparent unconformity. They are probably quite identical in age.

4. The Gympie Beds.—In this paper no attempt will be made to describe the stratigraphy of Gympie, a work with which the geological survey is proceeding at present, but the petrological characters of some of the more well-known Gympie rocks will be described, and their origin will be traced.

(*a*) Gympie General Geology.—The true Gympie rocks at Gympie occupy an area about seven miles long, and perhaps five miles wide, around which appear phyllites with an older facies. The chief rocks represented in the series are known on the field as sandstone, conglomerate, slate, black rock, plumbago, greenstone, diorite, andesite, greywacke, schist, and granite. Of these rocks the granite, diorite,

* Geology of the Volcanic Area of the East Moreton and Wide Bay Districts, Queensland. Proc. Linn. Soc., N.S.W. 1906. Part I.

andesite, and plumbago are generally correctly interpreted by the miners, but utter confusion exists in the miners' nomenclature of rocks not belonging to these classes.

Granite occurs on the western border of the mining field across the Mary River. Diorite and Andesite occurs as dykes and intrusive sheets in many of the mines. Plumbago occurs as beds or "floors" generally overlying, underlying, or interbedded with slate or conglomerates. The reefs are generally very rich where they cut such floors. The plumbago appears to represent either altered coal seams or similar carbonaceous beds.

By "sandstone" is generally understood a tuffy sandstone which has undergone more or less secondary silicification. "Greywacke" is used in the same sense. The constituents of both of these rocks are mostly of volcanic origin, but the volcanic ejacamenta have been redistributed under water. Conglomerate is a term given to reddish, purple, and greenish agglomerates, which constitute volcanic tuffs and breccias subaqueously redistributed. They are more or less crushed and have undergone immense secondary silicification, so that the finer cementing materials have frequently been converted into jasperoid.

The black slate is a characteristic rock which is seldom confused with other rocks, but frequently the white and brick-coloured phyllites and shales are termed slate. These are also sometimes termed "schist." "Greenstone" is a term which is used at Gympie for a great variety of rocks—namely, greenish tuffy sandstone and conglomerate, chloritic decomposed diorite, chloritic tuffs, chloritised andesite, and green rhyolite.

Several sections were made of dyke rocks from various parts of the Gympie field and were examined with the following results:—

(*a*) "Andesite," Great Northern Mine.—This is a very altered diorite porphyry. Secondary calcite and chlorite are important constituents.

(*b*) "Inglewood Dyke" rock, Great Scottish Mine.—This has the same composition as (*a*).

(*c*) "Green Diabase," Columbia Extended Mine.—This rock is identical with (*a*) and (*b*).

(*d*) "Diorite," Columbia Extended.—This rock proved to be an "amphibolite," consisting chiefly of hornblende, some rhombic pyroxene, some plagioclase and subordinate quartz. Several specimens of the stone known as "black-rock" were also sectioned and examined.

(*e*) "Black-rock," Beenam Range.—Apparently a reconstructed tuffy sandstone, consisting of quartz, felspar, magnetite, and some titanium-rich fibrous red mineral.

(*f*) "Speckled Black-rock," Noosa Vale.—This consists mainly of felspar and chlorite, and might be called chloritic clay slate.

(*g*) "Black-rock," Noosa Vale.—A cherty rock, consisting of felspar, hornblende, epidote, magnetite, and kaolin. Probably this too is a silicified tuff.

The Gympie rocks are all characterised by intense secondary silicification, but the remarkable schistosity which the rocks outside the mining area show is not seen within the mining district. This fact is a strong indication that the true Gympie rocks are newer than the others, and have never been dragged down into the zone of schistosity and earth flowage.

East of Gympie beyond the Inglewood dyke the white, yellow, and purple phyllites occur. These are much more schistose than the true Gympie rocks, and much more contorted. They appear to have been at some time or other in the zone of flowage. At Deep Creek they have assumed a facies exactly like that of the Kin-Kin schists on the southern side of the Beenam-Woondum Range. From my latest observations I have come to the conclusion that I was wrong in considering the Kin-Kin phyllites newer than Gympie. I now believe them to be older.

In the Beenam Range, near Noosa Vale, the true Gympie rocks appear again. Here they have been intruded by pyritous hornblende-biotite-tonalite.

The Woondum Tableland (Mother Mountain) consists of very old gneissic granites and red granites, Kin-Kin phyllites, and tonalites of Post-Gympie age, with cappings of tertiary basalt.

The Gympie rocks appear to overlie the Kin-Kin phyllites, and at Gympie they seem to lie in a trough. They consist principally of subaqueous tuffs, breccias, and lavas, which have been metasomatised by silicifying ascending waters. The estuarine situation of the area at the time of deposition is shown by the fossils and the plumbago. The Gympie fossils consist of a mixture of the Carboniferous and Permo-Carboniferous types of New South Wales, with a particularly strong leaning towards the Permo-Carboniferous. The plumbago probably represents metamorphosed plant beds.

For the following reasons it seems likely that the true Gympie is equivalent to the Permo-Carboniferous of New South Wales:—

(1) The Late Carboniferous and Permo-Carboniferous being noted for a cooling of terrestrial climate, it is likely that animal and plant species migrated towards the tropics, and many New South Wales Carboniferous species might in Queensland have existed until well into Permo-Carboniferous times.

(2) Boulders of glacial deposition are reported to have been found in the Gympie mining field, and these occur in a bed probably equivalent to the Branxton horizon of New South Wales.

(3) The fossils consist mainly of Permo-Carboniferous types.

True Gympie rocks occur, in addition to the type locality, at Chinaman Creek and Walli Creek west of the Blackall Range, occupying there a circular area about seven or eight miles in diameter. Here the same fossil beds, the same kind of slates and black-rock, the same types of purple and green conglomerate (agglomerate) occur in apparently the same order. This locality differs only from Gympie in the absence of the great abundance of andesitic and porphyritic (greenstone) dykes and in the rarity of quartz reefs. On the other hand numerous dykes of well-preserved granite and diorite traverse the Gympie beds here. Amphibolite dykes must also occur, as I have found specimens of this rock in the creek beds. True Gympie slates also seem to occur at Wararba and the foothills of Mount Mee. The slates here are, however, more fissile and may be older.

The Chinaman Creek "Gympie" area is surrounded like the type district by a zone of highly foliated phyllites and schists, and appears also to be a basin in which Gympie rocks have escaped erosion.

From petrological considerations it would, therefore, appear that the succession in each of these districts was—

(1) Carboniferous or Permo-Carboniferous:— A basin in which submarine tuffs accumulated, interbedded with clays, sands, and lavas, and a period of deeper water was interpolated in the type district during which limestones formed. Uplift follows.

(2) Later in the same or subsequent period—Intrusions of andesite and diorite porphyry. Erosion simultaneously progresses.

(3) Permo-Carboniferous or Mesozoic (according as we look upon the Gympie as Carboniferous or Permo-Carboniferous) —Granitic intrusions, folding, very severe faulting and formation of quartz reefs.

Note.—This period was possibly as late as Cretaceous.

(4) Between Trias and Tertiary—Intrusion of Amphibolites.

Whatever age the Gympie beds may be it is certain that the andesitic and andesite porphyry intrusions followed very closely upon their deposition. The granite intrusions were much later (hornblende-biotite-tonalites), and may all belong to the Post-Triassic, the same as the quartz-diorite-porphyrites of Noosa Heads and Point Arkwright.

The igneous succession is therefore not unlike that observed by E. C. Andrews in the New England district.

The causes of the metamorphism of the true Gympie rocks were circulating heated siliceous vapours which undoubtedly in the Chinaman Creek area, and probably also in the type area arose from granitic (tonalitic) magmas. All the rocks except the amphibolites and the granites have had their composition altered by this pneumatolytic action. The amphibolites are, therefore, probably post-granitic.

5. Rocks Older than True Gympie.—Most of the country mapped Gympie by the geological survey in the areas which I have examined is composed of formations which are far more metamorphosed than the true Gympie. The metamorphic rocks present the appearance of having undergone regional metamorphism by having at one time been encompassed in the middle and deepest zones of schist formation (according to Grubenmann's classification of the crystalline schists), whereas the Gympie rocks belong to the upper zone.

No doubt many of the quartz—sericite—and talc phyllites of the area also belong to the upper zone, but they are more highly foliated than the true Gympie rocks, and, therefore, belong to a lower zone. Such is the case with the Kin-Kin schists, the Kenilworth (Upper Mary River) white phyllites and similar rocks east of the slates of Wararba and Mount Mee. No age can at present be assigned to these schists and phyllites.

The Brisbane schists also provisionally marked Gympie by our Geological Department are so crushed, folded, foliated, and faulted that they must be assigned to the middle zone, and consequently they are likely to be older than the true Gympie. What age we cannot say, but possibly Pre-Devonian.

The problems connected with these schists of uncertain age and uncertain composition I have not gone into yet, and their discussion must be left over until more work has been done upon them, but I propose in this paper to deal more critically with the Mount Mee metamorphic rocks which I have studied more closely.

In a previous paper to the Linnean Society of New South Wales *(loc. cit.)* I have given petrological descriptions of many of the Mount Mee rocks, which it will be unnecessary to recapitulate. The following table is constructed to assign these rocks to their right positions under Grubenmann's classification.

Name under which Rock was Described.	Structure.	Chief Minerals.	Zone.	New Name in Grubenmann's System.
1. Cyanite-rutile-granulite (Delaney's Creek)	Coarse, uneven, lepidoblastic layer structure	Quartz, orthoclase, topaz, muscovite, cyanite, rutile	Lowest or middle	Kata } Meso } Alkali-felspar-gneiss (probably sedimentogene)
2. Granulitic Mica-schist (Mount Delaney)	Medium grained lepidoblastic (homöoblastic)	Orthoclase, muscovite, sericite, chlorite	Lowest or middle	Meso (or kata) aluminous silicate gneiss (probably sedimentogene)
3. Muscovite-granulite (Mount Delaney)	Heteroblastic and lepidoblastic in in layers	Orthoclase, muscovite, quartz, sericite, chlorite, topaz, biotite, zoisite, rutile	Lowest or middle	Kata (or meso) aluminous silicate gneiss (sedimentogene)
4. Greenstone (Fife's Range). (Epidiorite?)	Homöoblastic and granoblastic	Orthoclase, actinolite, titaniferous magnetite, epidote, chlontoid	Upper ...	Epi-orthoclase amphibolite, igneous
5. Hornblende-schist (Mount Mee)	Nematoblastic ...	Anthophyllite, actinolite, chlorite, tremolite, uralite, sillimanite	Lowest or middle	Chlorite-meso-amphibolite, igneous
6. Epidote-actinolite-topaz-schist (Leacy's Creek)	Nematoblastic ...	Epidote, felspar, actinolite, topaz, quartz, sericite, sillimanite	Middle or lowest	Epidote-meso-amphibolite, igneous
7. Epidote-cordierite-chlorite-schist (Leacy's Creek)	Nematoblastic ...	...	Middle or lowest	Epidote-chlorite-schist
8. Albite-chlorite-schist (Leacy's Creek)	Mainly nematoblastic var. diablastic	Orthoclase, albite, calcite, sillimanite, epidote, chlorite	Middle ...	Meso-albite-chlorite-sillimanite-schist
9. Glaucophane rocks (several localities)	Nematoblastic ...	Glaucophane and epidote	Middle or upper	Glaucophane-schist (meso or epi)

The here presented arrangement of Mount Mee and other metamorphic rocks under Grubenmann's system is only tentative, inasmuch as when I did my field work several years ago this system was unknown to me, and I neglected to make many observations which I would have made if the system had then been known to me. Nevertheless the utility of the classification shows clearly. By its means we are able to approximate much more closely to the age of the Mount Mee schists and granulites than we ever could before. We see clearly that they are older than Gympie, for even many igneous rocks have been completely metamorphosed in the middle and deepest zones, not merely metasomatised by circulating waters in the upper zone, as is the case with the Gympie rocks. We realise that some of the metamorphosed dykes like the greenstones (No. 4 in the list) were intruded during re-emergence from the zone of flowage as they show only the metamorphosis characteristic of the lower levels of the upper zone; while dykes of igneous gneisses exist which were intruded before the depression of the region into the zone of flowage.

We see that numerous rocks are represented which must be either of extremely old age or must have been depressed to extremely deep horizons during great earth-folding processes; these earth-folding processes must have been of such intensity and magnitude that we know with certainty, from the feeble wrinkling of the true Gympie beds in type areas, that they antedate the Gympie period.

Personally I hope that I may have an opportunity to carry through an investigation of these interesting rocks, but if no opportunity occur to me, it is a work which I should like to see taken up by anybody with the determination and capacity to execute it well. It is a badly-wanted piece of research, and one which will amply repay one for the trouble. It would solve many problems in Queensland geology which the geologists of the past have only played with.

6. Glaucophane Schists.—These interesting rocks occur at Mount Mee, Leacy's Creek, and on the Mary River slopes of the Conondale Range. As I have already described their occurrence, chemical, and mineralogical composition in two papers, "The Geology of the East Moreton, &c." (Proc. Linn., N.S.W., 1906, Part 1), and "Chemical Note on a Glaucophane Schist from the Conondale Range" (Proc. Linn., N.S.W.), I will not repeat myself in this respect. However, there is this fact to emphasise—namely, that these rocks are altered tuffs and lavas which have been metamorphosed in the middle zone or the lowest portion of the upper zone. They occur in other parts of the world only in the oldest metamorphic (chiefly Archæan) formations, and thus lend further support to the idea that many of the so called Gympie rocks antedate that age by many periods.

7. Economics.—*Gold:* Payable reef gold in the area which I have traversed occurs only at Gympie. The best prospects of finding undiscovered gold reefs are in the region of the Upper Mary River, particularly in the wedge of country between the Obi-Obi River, the Mary River, and the Blackall Range. Also in the Jimna Ranges west of the Mary River. This country is very little explored and covered with dense scrub, which proves a serious obstacle to prospectors. *Copper:* This metal occurs in its various forms scattered far and wide through the metamorphic formations, but has not yet been met with in payable quantities. Usually one finds it in quartz reefs and leaders in the form of copper pyrites carrying a gossan cap of green and blue carbonates. It is generally more or less auriferous. Such veins occur at Wararba, Kilcoy, Walli Creek, and many other places. Copper in traces is also obtained in some of the basaltic lavas of the Blackall Range. It has probably been assimilated at a depth. *Manganese* (cobalt and nickel): Good deposits of cobaltiferous wad are known both in the D'Aguilar Range and in the Gympie district at Pie Creek. Carriage cost is to-day the stumbling block in the way of profitable mining. Nickel occurs as a rock-forming constituent far and wide. In the metamorphic glaucophane schist and serpentine areas of the D'Aguilar and Mount Crosby Ranges, so similar petrologically to New Caledonia, nickel may yet be found. The dense scrubs may have hidden many valuable ore deposits. *Iron:* Considerable ironstone beds occur in the Trias-Jura formations near Mooloolah Heads; also in other places. *Coal and clay:* Coal and good brick, pottery, and fireclays occur abundantly in the Trias-Jura, and are

worked in many places. *Building stones:* These comprise freestone (sandstone), trachyte, granite (Enoggera), porphyrites, and serpentines. *Beach sands:* All along the coast, the muddy strips excepted, the beach sands contain layers of black sand, which at certain seasons and in certain weathers can be profitably mined for gold, platinum, osmiridium, tin, and rare earths.

6.—THE STUDY OF IGNEOUS ROCKS.

By JOSEPH P. IDDINGS, University of Chicago.

No branch of petrology presents so attractive a field for investigation and study as that concerned with the origin and formation of igneous rocks. The great problems of metamorphism, that traverse so much of the earth's dynamic history and involve so many factors common to the problems of igneous rocks, are less alluring because of their greater complexity and less definite character. While much is being done in each of these fields of rock study it is to the former that I wish to call attention at this time. It is interesting to note how the atttiude of the petrographer toward the subject of igneous rocks has changed with increasing knowledge of their composition, and with advancing experience with the fundamental laws of physics and chemistry.

Rocks that were considered igneous a century ago were almost wholly those known to have poured forth from volcanic craters, and were for the most part compact, aphanitic lavas, often containing porphyritic crystals—distinctly volcanic rocks. The great number of phanerocrystalline massive rocks were not generally considered as having the same character and origin as volcanic rocks—as being igneous. Their formation was explained in different ways by various geologists. And when treated as "plutonic" were still thought of as different from "volcanic" rocks. Some of the commonest were considered as extreme forms of metamorphism, and have been so treated until quite recent times by eminent geologists.

Not only the geological mode of occurrence of many of these rocks was unknown, or only partially known, but the inherent material characters were often matters of conjecture. Before the introduction of the microscope by Sorby, in 1850, the mineralogical study was confined to the larger, megascopic crystals, except for the microscopical investigation of rock fragments and powder by Cordier in the first decade of the last century. And the early chemical analysis of rocks, while adding considerably to a knowledge of their composition as a whole, lacked the completeness and accuracy of modern analytical methods, and failed to explain the composition of the rocks because of the absence of satisfactory knowledge of the mineral components.

With improved methods of investigation, geological, mineralogical, and chemical, knowledge of the character and composition of rocks advanced. The supposed distinction between "volcanic" and "plutonic" broke down, or assumed new definition, through the observations and writings of Judd and others. The term "igneous rocks" came into more general use, and embraced all "volcanic" and "plutonic" masses. The mineral composition of all crystallised igneous rocks became known in more and more exact terms, though much remains at present to be learned of the definite chemical composition of some of the common mineral components of most rocks. Chemical analyses of rocks are becoming more complete, and more frequent in petrographical publications, and the store of chemical data is steadily increasing, and has been made more available by the collection of rock analyses published by Roth, and more recently by Washington.

The description of igneous rocks has been largely fortuitous. As rocks happen to have been encountered in geological field work, they were collected, and not always with due regard to their geological relations to other rock bodies, and subsequently they were investigated in the laboratory more or less thoroughly, and described, often very imperfectly. Up to recent times the terms "petrography" and "petrographer" applied satisfactorily to the subject and to the worker in it, for the work was chiefly descriptive.

Generalisations regarding the nature of igneous rocks, or the formulation of laws controlling their crystallisation were largely empirical dicta not infrequently based on incomplete knowledge or inadequate experience. As a natural consequence of the haphazard manner of growth of the science, there has been an unsystematic nomenclature, derived from many sources at widely remote times, expressing markedly different degrees of information regarding the thing described; rock, texture, or relationship. And in many instances representing in a single term a series of definitions varying with shifting opinion or advancing knowledge. Such, for example, as syenite, granite, and trachyte.

At the present time attempts are being made to apply to the study of igneous rocks the results of laboratory experience in physical chemistry and, not only to investigate directly the physical behaviour of molten rock minerals singly and in combinations, or mixtures, but to apply the more advanced laws of physicochemical reactions to the elucidation of the problems of crystallisation, differentiation, and mineral composition. The researches of Day and his colleagues in the geophysical laboratory of the Carnegie Institution of Washington, D.C., upon temperatures of fusion, crystallisation, and transformation points of silicate compounds corresponding to rock minerals, and of the behaviour of mixtures of pairs of such compounds in producing mixed crystals, new compounds, or eutectic mixtures, are of the first importance. The accuracy of the methods employed and the thoroughness of the work guarantee the value of the results and their permanency. In addition to the establishment of improved, or entirely new methods of operation of a purely physical character tributary to the study of petrological problems, they have determined the physical behaviour of the lime-soda-feldspar series; the relations of the various lime-silica compounds to one another; those of the lime-magnesia-metasilicate series; the melting and transition points of quartz and tridymite, and the character of still other compounds.

Doelter and his pupils have studied the fusibility of the rock minerals and their solubility in one another, but the methods employed are less accurate than those just mentioned, and involve a large element of subjectivity. They are approximations to the facts desired, often of much value qualitatively, but sometimes misleading. Other recent and valuable qualitative work in this field has been done by Morozewicz, while earlier work is represented by the classic researches of Daubrée, Fouqué, Michel Lévy, and others.

The most obvious result of the earlier efforts was the demonstration of the adequacy of fusion and gradual cooling at ordinary atmospheric pressures to bring about the crystallisation of many minerals found in igneous rocks; and the necessity of some catalytic agency to promote the crystallisation of other minerals common to these rocks. Such actions were ascribed to "mineralising agents" or "crystallisers," assumed to be in most instances dissolved gases, chiefly H_2O. One of the most significant facts brought to light by the researches of Day and his colleagues is the new conception of high viscosity found in alkali-feldspars and quartz. Viscosities so great at temperatures near the transition point of liquid to crystal phase as to be indistinguishable within the two phases. That is, the viscosities of the amorphous glass, and of the crystallised mineral, are so nearly identical that the two phases of the substance react alike toward mechanical stress. Molecular mobility is so slight that readjustment from crystalline arrangement to the homogeneous chaos of liquid molecules is accomplished with such extreme slowness that the time of ordinary laboratory observation is not sufficient for its detection. However, the time available for ordinary "geological" processes, so called, is sufficient, as shown by the devitrification of volcanic glasses composed of these constituents—ancient rhyolitic obsidians. The function of a catalytic agent, as a gas dissolved in such a viscous liquid, is obvious. The viscosity is reduced and molecular mobility increased. If the transition is towards the liquid phase, solubility of the crystal is increased. If it is toward the crystal phase, the rate at which crystallographic molecular arrangement is accomplished is increased. The dissolved gas becomes a "crystalliser," or "mineralising agent". Other substances, such as mineral compounds, yielding less viscous liquids than those of the alkali-felspars and quartz, when dissolved in the more viscous liquids reduce their viscosity in the same manner, though not to the same extent, as dissolved gases. They must behave catalytically toward crystallisation as gases do. Their behaviour in this respect has not been generally recognised, though the function of certain liquid compounds as fluxes or as "mineralising agents" is well known.

Thus the improvement in methods of physical research is steadily enlarging the field of petrological investigation, and the advancement in the knowledge of physicochemical laws is furnishing the investigator with new tools for the work, and more efficient means for attacking the problems of igneous rocks. Foremost in the ranks of those who have attempted the application of modern conceptions of physical chemistry to the elucidation of the phenomena of texture and mineral composition, and of the genetic relationships of igneous rocks, is Vogt, whose earlier studies of furnace slags opened the way for the explanation of many analogous phenomena in the more refractory, volcanic lavas. Chief among these are: the apparent order of crystallisation of different minerals in slags as indicated by their shapes and relations to one another as inclusions; and the relation between these orders and the composition of the mixture from which they crystallised.

Vogt's observations were found to be in accord with modern theories of solutions, as Bunsen foretold in 1861, when he affirmed his belief that rock magmas are solutions of silicate compounds liquid at high temperatures. Vogt has called the attention of petrologists to these modern theories as developed by Arrhenius, van 't Hoff, Ostwald, Gibbs, Meyerhoffer, Roozeboom, and others. He has also made definite application of them to some of the phenomena and relationships mentioned. His publications have extended widely the horizon of modern petrology, which by the assumption of these broader, deeper phases of the study of igneous rocks, and of similar problems affecting metamorphic rocks, has passed beyond the narrower boundary of petrography, strictly so called.

The evolution of chemistry from a state of pure empiricism to one of comparatively logical sequence, largely through the assistance of its helpmate physics, has placed before us a collection of co-ordinated laws, which, while incomplete, or subject to numerous exceptions, furnishes us with means to postulate reactions between the constituent elements of rock magmas with reasonable assurance of correctness, or to explain the formation of mineral compounds hitherto in a measure enigmatical. Much remains to be more firmly established, both as to the chemical character of the elements and their compounds, and also with regard to theories relating to their reactions, even to the very nature of their existence in some instances. The silicate compounds constituting igneous rocks remain largely uninvestigated, so far as concerns their synthesis and reactions in mutual solution. And the physical study of solutions and of their transitions to the solidified components, especially the more complex mixtures, is far from completed. The present is a period of transition in the development of petrology, as were also times past. But the changes taking place at this time appear to be so many and so fundamental that it may well be asked whether the older methods of approach to the study of igneous rocks should not be replaced by others more in accord with present conditions of knowledge of chemistry, physics, and of the rocks themselves. The older method, in the nature of things, was, and is largely at the present day, objective, and the expressions of relationships or laws empirical.

It would seem more reasonable to begin a systematic study of igneous rocks with a consideration of the most fundamental characteristics of the magmas from which they have solidified; of their constitutents, together with their probable chemical reactions and the resulting mineral compounds; of the manner in which these may separate from a silicate solution, or rock magma; of the shapes they are likely to assume upon crystallisation and the consequent texture of the rock. Processes of molecular separation of magmas lead to the discussion of the differentiation of magma into chemically unlike parts, and the resulting different varieties of igneous rocks, together with their eruption and solidification as geological bodies of various kinds.

Assuming a certain elementary acquaintance with rocks on the part of the student, which is acquired in courses on general geology, the systematic treatment of the subject should begin by calling attention to the chemical composition of unaltered igneous rock as shown by analyses published in many descriptions of rocks, but most conveniently found in comprehensive collections in bulletins of the

United States Geological Survey and in the Table of Analyses edited by Justus Roth, and more recently by H. S. Washington. The extremely variable nature of these data and their great abundance present such an exceedingly complex set of numerical relations that their statement, or discussion, requires the aid of diagrams by which the problem may be greatly simplified.

In addition to the chemical elements noted in ordinary rock analyses there is a much greater number known to occur in rare minerals that crystallise from rock magmas in special instances, or that oftener appear in certain varieties of igneous rocks, such as pegmatites. A consideration of all known pyrogenetic minerals with respect to their chemical composition calls attention to the compounds that are repeatedly formed in igneous magmas by the union of the elements that existed in the magmas before their solidification. And by arranging them in accordance with the order of their constituent elements in the Mendeléeff series valuable information as to certain chemical relationships among these compounds is at once furnished.

The substances occurring in igneous rocks are in most cases solids, less often liquids or gases. The solid compounds are always in crystallised condition. Amorphous, glassy, solids that sometimes occur in igneous rocks are seldom, if ever, definite chemical compounds, but are mixtures. The crystallised substances (minerals) are rarely present as uncombined elements, such as gold, graphite, metallic iron. A few are simple compounds with invariable composition, as SiO_2 (quartz), TiO_2 (rutile), Al_2O_3 (corundum). Most of them are complex, and variable in composition owing to the presence of isomorphous mixtures, as the feldspars, olivine, amphiboles. There are very few examples of pleomorphism, such as quartz and tridymite. The apparent difference in the crystallisation of orthoclase and microcline is probably due to submicroscopic multiple twinning in the apparently more symmetrical form. Isomerism of some of the pyrogenetic compounds, as (Mg, Ca) SiO_3, which is known in laboratory products, is not clearly developed in pyrogenetic minerals.

Certain isomorphous mineral compounds are not developed in igneous magmas with like frequency, or in certain cases not at all. Such, for example, are the hexagonal compounds, $NaAlSiO_4$ (sodium-nephelite); $KAlSiO_4$ (kaliophilite); $LiAlSiO_4$ (eucryptite). Compare also the potash- lithia- and soda-micas. Other compounds that are analogous chemically and might be expected to crystallise isomorphously in igneous magmas have quite different crystal symmetry, as is the case with $KAl(SiO_3)_2$ (leucite); $NaAl(SiO_3)_2$ (jadeite); $LiAl(SiO_3)_2$ (spodumene).

Various silicate compounds involving different silicic acids; orthosilicic, metasilicic, polysilicic, and in rare instances disilicic, besides uncombined silica, may crystallise from the same rock magma. And even base-forming elements, as iron and aluminium, may under some conditions separate from rock magmas without combining with silica, which may itself separate as SiO_2. That is, hematite, magnetite, or corundum may crystallise in the presence of quartz. On the other hand, certain lower silicates do not form when there is sufficient silica to form higher silicates with the same bases. Thus, $KAl(SiO_3)_2$ (leucite) and $NaAlSiO_4$ (nephelite) do not occur pyrogenetically with SiO_2 (quartz).

Moreover, it is well known that some rock magmas, especially those of intermediate composition, crystallise under one set of conditions into certain combinations of minerals, and under others into other combinations. Certain minerals appearing in one case and not in another though the magmas from which they formed were chemically alike.

In order to account for the production of the mineral compounds known to occur in igneous rocks, as well as for the absence of others; and to understand the possibility of variation in the production of mineral compounds from any magma under variable conditions; and to comprehend the act of separation and crystallisation of such minerals upon the solidification of the magma; it is necessary to consider the probable physical and chemical character of liquid rock magmas, especially the known physicochemical laws regarding solutions.

Discussions of the behaviour of solutions under varying conditions of temperature and pressure involve theories of the possible molecular constitution of matter, gaseous, liquid, and solid, which must be kept in mind in order to form any clear conception of the processes under consideration. The kinetic theory regarding the behaviour of molecules of gas, liquid, or solid, under variable temperatures and pressures, furnishes definite pictures of changes of state at transition points from one phase to another. Those with which the problems before us are most concerned are the critical point of gases, the melting point of solids, the solution, or the separation, points of solids in liquids, and also the transition point between two solid phases of the same compound, such as that between quartz and tridymite.

Since liquid rock magmas are solutions of silicate compounds in one another, all that is known of the physical and chemical behaviour of solutions is germane to the discussion. This includes the solution of gases, liquids, and solids, in liquids; and eventually their solution in solids. The solubility of various substances in liquids of other substances; the possible molecular constitution of liquid solutions; the existence of molecules of different degrees of complexity, and the dissociation or ionisation of some compound molecules; the laws relating to diffusion, and the relative diffusibility of various compounds; those relating to the molecular concentration—the saturation and supersaturation of solutions. The chief qualifying factors in this discussion are the chemical composition of the several compounds; the viscosity of the solution; the temperature, pressure, and the time through which any operation acts. The possibility of producing in a colloidal condition one of the compounds: $Al(OH)_3$, $Fe(OH)_3$, or $Si(OH)_4$, by the interaction of hydroxyl (OH) and aluminium (Al), iron (Fe), or silicon (Si), is also to be taken into consideration.

In a solution containing the chemical elements common to igneous rocks reactions should take place between them in accordance with known chemical laws, and with results corresponding to observed pyrogenetic mineral compounds. Some of the fundamental laws relating to chemical reactions among the elements are based upon conceptions of chemical energy and activity, and of the conditions that modify their effects.

An important factor in chemical processes is, often, a catalytic agent that promotes reactions without itself appearing as a component of the final products. The chemical behaviour of ionic substances, and especially the hydrolysing action of ionised water are other factors in the problem under consideration. The relative strength of chemical activity in the base-forming, or acid-forming, elements and their ability to form acids and salts, lead to the discussion of the production of the pyrogenetic minerals from magmas composed of elements found in igneous rocks; many of these minerals having been produced in the laboratory by melting together the component elements in proper proportions.

Considering what should take place in a solution having the composition of an average of all igneous rocks, it can be shown, since the chief acid-forming elements present are silicon in large amount, and the more active element phosphorus in very small amount, that salts with these elements in the acid radical must be common. Other acid-forming elements occurring in small amounts are titanium and zirconium; while iron and aluminium may play this rôle under favourable conditions. The more active phosphoric acid forms unstable salts with the active base-forming metals, potassium and sodium, but a very stable compound with the less active metal, calcium, into which compound fluorine, or chlorine, enters; yielding apatite, an almost universal component of igneous rocks.

Silicon is known in the laboratory to form one definite acid, H_4SiO_4, orthosilicic acid; and other acids of silicon have not been isolated and identified. But very definite mineral compounds exist which indicate that salts from other silicic acids form under proper conditions. These are:—

H_4SiO_4 orthosilicic acid.
H_2SiO_3 metasilicic acid.
$H_4Si_3O_8$ polysilicic acid.
$H_2Si_2O_5$ disilicic acid.

It is significant that in laboratory experience with orthosilicic acid, H_4SiO_4, prepared from aqueous solutions, the compound may be made to lose water gradually until nothing but silica, SiO_2, remains. In this way free silica may be separated from a silicate compound, a hydrogen silicate; since an acid may be considered as a hydrogen salt.

Observations upon the pyrogenetic minerals, and laboratory experience with synthetical operations, show that salts of several kinds of silicic acids form by the side of one another, and that their character and amount depend on the nature of the base-forming elements present in the mixed solution. Orthosilicates, metasilicates, and polysilicates commonly form in the presence of one another, sometimes accompanied by uncombined silica. And it becomes more and more evident that the formation of the different kinds of silicic acid ions, or their salts, is controlled primarily by the strength, or chemical activity, of the base-forming elements: is dependent also on the amount of silica available in the solution; and may be modified, of course, by other factors. Thus, it appears that the most active metals command the highest silicic ions. The highest silicates common in igneous rocks are the polysilicates of the alkalies, potassium and sodium-orthoclase and albite.

Further, the abundance of aluminium in most rock magmas results in the presence of abundant aluminous compounds. And this element which is relatively inactive chemically, being found sometimes in the basic, sometimes in the acid radical, is oftenest combined with the strongest base-forming elements, potassium and sodium. These relations are illustrated by the following common, simple, pyrogenetic minerals:—

Polysilicates.		Metasilicates.	Orthosilicates.
K – $Al \equiv (Si_3O_8$ (orthoclase)	Na – $Al \equiv (Si_3O_8)$ (albite)	K – $Al = (SiO_3)_2$ (leucite)	Na – $Al \equiv (SiO_4)$ (nephelite) $Al \equiv (SiO_4)$ Ca < $Al \equiv (SiO_4)$ (anorthite)
		Ca = $(Mg\,Fe) = (SiO_3)_2$ (diopside) $(Mg, Fe_2 \equiv (SiO_3)_2$ (hypersthene)	$(Mg, Fe)_2 \equiv (SiO_4)$ (olivine)

It is well known that the orthosilicate of sodium and aluminium (nephelite) and the metasilicate of potassium and aluminium (leucite) do not form in the presence of free silica (quartz), while metasilicates and orthosilicates of the less active metals, calcium, magnesium, and iron (pyroxenes, olivine and anorthite) do. The relative chemical activity of all of the elements common to igneous rocks may be illustrated in like manner, and the probabilities of various pyrogenetic mineral compounds forming from different rock magmas may be made clear.

One of the most important factors in the discussion of the chemistry of igneous rocks is the rôle of hydrogen, whether as an active base-forming element, or as a catalytic agent, alone, as hydrogen (H), or combined with oxygen, as hydroxyl (OH). Its exact behaviour in each specific case is not definitely known, but the principles applicable to several distinguishable cases are clearly established.

Adopting the idea that an acid is a hydrogen salt in which hydrogen plays the rôle of a positive, base-forming element, an acid salt may be considered as one in which all of the hydrogen has not been replaced by other base-forming metals. Such an acid salt may be looked upon as a substitution derivative from a hydrogen salt (acid), or from a normal salt by the introduction of hydrogen in place of other positive metals. An example of such a compound among pyrogenetic minerals is to be found in muscovite $(K,H)Al(SiO_4)$. This might be derived from H_4SiO_4, $KAl(SiO_4)$ or $Al_4(SiO_4)_3$. The formation of such a compound involves the presence of active hydrogen to play the rôle of metal. Muscovite is a common pyrogenetic mineral in some igneous rocks rich in silicon, with much uncombined silica, and also in others comparatively low in silica, accompanying orthosilicates and nephelite. It forms by the side of polysilicates—orthoclase and albite—and even with the disilicate, petalite. The formation of muscovite must be ascribed to the action of hydrogen upon silicon, either directly in the first instance, or, if previously formed silicates of aluminium and potassium be assumed to be the source of the compound in question, then its action in replacing part of the potassium must be that known as hydrolysis, whereby the hydrogen ions from water replace metals in the salt through a process of double decomposition.

It is known that the chemical activity of hydrogen even toward a gas, like oxygen, is greatly increased by rise of temperature; hydrogen being rather inert at ordinary temperatures. The relative activity of hydrogen and potassium toward silicon is indicated by the fact that the highest hydrogen silicate definitely known is the orthosilicate, H_4SiO_4 (orthosilicic acid), whereas potassium commonly occurs in a polysilicate $KAlSi_3O_8$ (orthoclase). It has been found impossible to produce mica in open crucibles from which hydrogen, or water-vapour, naturally escapes at high temperatures. And muscovite is not formed pyrogenetically in surface lavas, or, if so, to a very small extent as compared with its occurrence in rocks crystallised under considerable pressure. From these facts it must be concluded that the formation of the acid orthosilicate (muscovite) in the presence of polysilicates and free silica must be assigned to the chemical activity of hydrogen at high temperatures under sufficient pressure to hold it in the liquid magma solution.

The same argument as to the action of hydrogen in rock magmas applies to the production of the other micas, biotite and lepidolite. These compounds are complex mixed salts, and the composition of biotite involves the production of orthosilicates of magnesium and iron, which are present in biotite. These orthosilicates develop in magmas together with metasilicates of magnesium and iron—pyroxenes and hornblende—and with uncombined silica, quartz. The same compounds when alone form olivine, which generally does not develop in magmas with uncombined silica, quartz, but probably occurs with quartz oftener than has been supposed. In both of these cases the production of orthosilicate of magnesium and iron in the presence of "free silica" in magmas in which the metasilicate might be expected to form is probably due to the hydrolysing action of water at high temperature. That is, the hydrogen at high temperature combined with some of the silicon, that otherwise would have united with magnesium and iron as metasilicate, and formed orthosilicate of these metals and orthosilicate of hydrogen.

$(MgFe)_2\,(SiO_3)_2 + 2H_2O\,(Mg, Fe)_2\,(SiO_4) + H_4\,(SiO_4)$. Should conditions of saturation favour the separation of the magnesium-iron compound in the solid phase, olivine would crystallise; and with falling temperature the hydrogen silicate would split up into water (H_2O) and silica (SiO_2), with the eventual crystallisation of quartz.

When the amount of silica is great as compared with that of magnesium-iron orthosilicate it is possible for quartz to separate before the orthosilicate, as is the case in many hollow spherulites and lithophysæ, where fayalite $(Fe, (Mg))_2\,SiO_4$ is apparently almost the last mineral to crystallise, and rests upon the surface of abundant quartzes. The dependence of these forms of crystallisation upon the presence of water in the magmas has been clearly demonstrated.

Other mineral compounds whose production in igneous rocks must be referred to the hydrolysing action of water are amphiboles, which, as Penfield has shown, contain as an essential constituent notable amounts of hydrogen. The development of hornblende in igneous rocks appears to be dependent on conditions similar to those controlling the development of biotite, for they commonly accompany one another in rocks of intermediate composition when either is present. The particular kind of amphibole which forms in rock magmas depends primarily on the proportion of elements present, and secondarily on attendant conditions which produce variation in amphibole from one magma. This is strikingly illustrated in the two igneous rocks from Gran, Norway, described by Brögger.* The magmas have almost the same chemical composition, yet one crystallised into a mixture of hornblende and lime-soda-feldspar, while the other crystallised almost completely into hornblende, which contains all the components of the feldspar and hornblende in the first-mentioned rock.

That hornblendes are less stable compounds in igneous magmas than pyroxenes and numerous other minerals is shown by the frequent occurrence of paramorphs of other minerals after hornblende, commonly seen in so-called black borders, and the absence of correspondingly changed crystals of other minerals.

Another chemical principle involved in the production of pyrogenetic minerals is that affecting the formation of compounds that possess common ions when in solution. It is known that when there are in solutions ions capable of entering two or more compounds, the concentration of the least soluble compound may be increased by the entrance of ions derived from other compounds into its molecules, and this may proceed to the complete incorporation of the common ions within one compound, upon its separation in the solid phase. This has sometimes been called erroneously "mass action." That compound forms at the expense of another in any particular instance which is the more stable under attendant conditions. Illustrations of this action are found: in the case of the complex amphibole in the hornblendite of Gran already mentioned; in aluminous pyroxenes (augites), which contains components capable of forming lime-soda-feldspars, and in numerous other rock minerals. This principle, together with that of the crystallisation of isomorphous compounds, is probably concerned in the production of the lime-soda-feldspars with notable amounts of albite molecules, as in andesine and labradorite, in magmas so low in silica as to necessitate the production of leucite from the potassium present, when the more active potassium should have combined with the silicon in a polysilicate (orthoclase), leaving the less active sodium to enter orthosilicate (nephelite).

Following out the discussion of all the probable compounds likely to form under known chemical laws from molten rock magmas upon cooling, and taking into consideration the relative chemical activities of the several constituent elements in igneous rocks, it is possible to deduce a probable mineral composition for any given magma, under given conditions of cooling. The mineral composition of igneous rocks then becomes a necessary consequence of the chemical reactions likely to obtain in molten rock magmas, and depends not only on the kinds and amounts of the elements present in each case, but also on the conditions of temperature and pressure modifying the chemical activities of the elements and the stability of the compounds. As these conditions are known to vary with the experience of different

* Brögger, W. C., Erupt. Gest. Kryst. Geb., vol. III., 1899, p. 93, and Quart. Jour. Geol. Soc., vol. L, 1894, p. 19.

magmas during eruption and solidification, the minerals produced in chemically similar magmas are not to be expected to be always alike, and the variations in composition are in this way understood.

Having considered the possible chemical reactions that may give rise to mineral compounds in rock magmas, the next step in the treatment of the subject is a discussion of the process and results of separation of various compounds or substances from magma solutions upon change of physical conditions attending the eruption of magmas. These may separate as gases, liquids, or solids, chiefly as solids. But gases escape in large volumes upon the eruption of lavas, mostly as water vapour. There are other kinds in smaller, though often in considerable amounts. The effects of this loss of gases are: in the chemical composition of the rock magma, in the concentration of the remaining substances, and in the viscosity of the magma, which may increase notably upon loss of gas.

Liquids, probably, do not separate as such from molten magmas to any considerable extent. Apparently liquid silicates are miscible in one another in all proportions, though suggestions that they may not be have been advanced by some petrologists. It is known that liquid sulphides and silicates are not miscible in all proportions at all temperatures. And where sulphides exist in large amounts separation in the liquid phase may take place with falling temperature.

Separation of solids from solution depends upon the attainment of a sufficient molecular concentration of substances to saturate the solution. Saturation may be brought about in several ways: by chemical reaction within the solution consequent upon a change of chemical equilibrium; by change of temperature, usually by lowering temperature; by change of pressure, either acting in an opposite manner from temperature, or by affecting the gas content.

Solids may separate when the point of saturation for them has been reached, or the liquid may become supersaturated, and separation be delayed. In this condition separation is often induced by the insertion of a solid of like composition, or of an isomorphous compound, or by agitating. Such a condition of a liquid has been called *metastable*, and in this condition, as shown by Miers in laboratory observations on liquids of organic compounds, crystallisation of the separating substance takes place, at relatively few points, and proceeds gradually, according to degree of concentration and other factors, until comparatively large individuals are formed. If supersaturation proceeds without separation of solid phase, a point will be reached when separation will take place spontaneously at many points in the liquid and continue rapidly. This is the *labile* condition of the liquid. When this condition is reached by a cooling, liquid crystallisation often takes place suddenly as a shower of minute individuals, as observed by Miers. The bearing of these facts on the textures of igneous rocks is apparent, and a knowledge of the laws relating to the separation of solids from liquids; the order in which those of different substances may follow one another in a mixed solution; the separation of isomorphous compounds; and the shapes that may be assumed by the resulting crystals of various minerals lead to an understanding of the texture of igneous rocks.

A supersaturated condition is more readily obtained in more viscous liquids, which are more apt to solidify without crystallisation, as glasses, than more fluid liquids. The most familiar illustrations of this law among igneous rocks are the persilicic (rhyolites) lavas, which often form glasses (obsidians). The question has been raised by Crosby, and others, whether an earthquake happening when a magma was in a sufficiently supersaturated metastable condition might not induce crystallisation of some of the constituent compounds.

Crystallisation may begin with different degrees of supersaturation of the liquid, and would proceed at different rates according to the degree of supersaturation, being more rapid the greater the concentration. It would also be more rapid the greater the molecular diffusibility, that is, the lower the viscosity of the liquid, and the greater the rate of cooling, so long as this does not increase viscosity too rapidly. Gradual or slow crystallisation at comparatively few centres would yield relatively few, large crystals; whereas sudden, rapid crystallisation from many centres would produce many small ones.

High fluidity in solutions would permit easy diffusion of separating molecules toward crystallising centres, favouring the growth of relatively large individuals. High viscosity would retard diffusion and favour the growth of many small crystals. This is well illustrated by the laboratory experience of Day with the crystallisation of various lime-soda-feldspars. Thus it was found that 100 grams of liquid anorthite crystallised completely in ten minutes to fair-sized crystals, and it required quick chilling to prevent its crystallisation and to produce glass. A mixture of equal parts of anorthite and albite ($Ab_1 An_1$) required a gradual cooling extending over several days to effect complete crystallisation. Whereas liquid albite could not be induced to crystallise through days of cooling in an open crucible. Comparing the size of the crystals of anorthite produced in ten minutes with those of oligoclase-andesine ($Ab_3 An_1$), which were produced by gradual cooling through two days, the former were from 3 to 5 mm. thick, the latter about 0·005 mm. thick. That is, the more liquid anorthite produced crystals 1,000 times as thick in about one three-hundredth the time. An apparent ratio of 300,000 : 1.

The rate of separation of solid from liquid also depends on the solubility and the amount of any substance in solution. The greater each of these factors the more rapid the rate of crystallisation and the larger the crystals, other things being constant in compared cases. This law has been expressed definitely by von Pickardt, as follows:—"The velocity of crystallisation (separation in solid phase) is diminished by the addition of foreign substances to the liquid phase of a substance, the diminution of the velocity being the same for equimolecular quantities of all substances."

The order of succession in the separation of different kinds of minerals from molten magma is a subject upon which there has been some difference of opinion among petrologists. It has been clearly demonstrated that the order is not an invariable one. The laws relating to the order of separation of solids from mixed solutions have been definitely determined for solutions of various compounds in one another, and the general principles are applicable to the study of igneous rocks. The attention of petrographers has been called to these laws by Vogt.

The order of separation of several compounds in solution in one another depends on the degree of saturation of each, that with the highest degree of saturation, or that one whose saturation point is reached first upon the cooling of the solution separates first. The relation between saturation, molecular concentration, and the melting point of each compound has been established in general terms for different sets of cases by Meyerhoffer, and further elaborated by Roozeboom, for the cases of crystals of isomorphous compounds. In all cases where the mixed compounds do not unite chemically to form new compounds, or physically as mixed crystals, there is one minimum point of temperature for a mixture of two compounds, and more than one in more complex mixtures, at which a certain proportioned mixture remains liquid. At this temperature the two components of a binary mixture will crystallise simultaneously. This minimum temperature and particular mixture are called eutectic.

Miers has shown that when supersaturation sets in and the labile condition is taken into account, as the state of the liquid in which spontaneous crystallisation takes place, the minimum temperature of separation and corresponding proportions of the mixture do not coincide with those already described as eutectic. These he has called hypertectic.

A study of these principles shows that there can be no invariable order of separation, or crystallisation, of the constituent compounds in a series of mixed solutions composed of like compounds. And that simultaneous crystallisation of pairs, or of more than two kinds of separating compounds, may take place in solutions of whatever composition. Eutectic mixtures may consist of more than two components. Moreover, the supersaturation of a solution by one component may affect the proportion between two or more components at the moment of synchronous crystallisation. Synchronously crystallised mixtures of certain kinds of components, therefore, are not necessarily similarly proportioned. The bearing of these principles on the crystallisation and texture of igneous rocks is manifold. A few ilustrations will suffice. Quartz may be the first mineral to separate from a molten magma when the solution is so rich in silica that upon cooling it becomes saturated with silica before being saturated with feldspar or some ferromagnesian compound, or even iron oxide. Quartz may be the last mineral to separate from magmas so rich in feldspar or ferromagnesian compounds as to become saturated by these upon cooling before being saturated with quartz.

Either labradorite or augite may separate first from a mixture of the two according to which saturates the solution first upon cooling, and this depends upon their relative amounts in the solution, and their order of crystallisation is further modified by the possibility of one or the other producing supersaturation in the liquid. This will account for the differences of texture often noted in certain gabbros, or basalts, of almost the same composition.

Eutectic mixtures, or those whose components crystallise simultaneously, often yield aggregates of intergrown crystals, the most familiar examples of which are found in graphic granite, and certain alloys. But Miers has called attention to the fact that the simultaneous crystallisation of two compounds in eutectic proportions does not invariably produce intergrown individual crystals, or graphic intergrowths. It may result in granular aggregations of concerted, adjacent, anhedrons, not intergrown, which corresponds to observations on the textures of igneous rocks; for many rocks of like composition in some instances exhibit graphic texture, in others evenly granular texture. Accepting graphic intergrowth as evidence of synchronous crystallisation, and of the existence of eutectic proportions in some cases between the several mineral compounds at the moment of crystallisation, it is to be noted that such intergrowths have been developed in igneous rocks between quartz and potash-feldspar; quartz and sodic feldspar; quartz and biotite; feldspar and pyroxene; feldspar and hornblende; feldspar and nephelite; pyroxene and iron oxide (probably magnetite); and between other pairs of minerals.

The separation of solids, that is, the crystallisation of minerals from rock magmas must be an extremely intricate process, because of the complex character of the solution, the variable and irregular changes in temperature and pressure consequent on the movements of eruption, the variations in composition due to changes in gaseous components, and the possibility of chemical reaction among the components with changes of chemical equilibria, as well as the probable supersaturation of the magmas by different components to various degres. This complexity will undoubtedly prevent exact statements of the relations between composition and texture, but approximations may be made to the proper explanation of some of the most common and characteristic textures, which will render them more intelligible to the student.

The crystallisation of a substance from solution involves molecular diffusion, and molecular orientation, and these are functions of molecular attraction, composition of the molecular compound, viscosity of liquid, composition of the liquid, temperature, pressure, and time, or rate of changing conditions. The combination of these factors in the case of any cooling rock magma results in the rock possessing a certain degree of crystallinity, which may range from a state of complete crystallinity, to the reverse, or complete glassiness. When more or less crystalline, the size of the crystals becomes a feature of consequence. The granularity, or the size of crystals in rocks, has been given a prominent rôle in most descriptions and classifications of rocks. The shapes of individual crystals clearly give distinctive character to the pattern, or fabric of rocks, and shape is largely a function of crystal structure and physical habit of specific minerals. The recognition of these relationships and their systematic treatment in the description and discussion of igneous rocks will lift the subject out of a mass of confusing, complex detail; usually treated in an uncoordinated and meaningless manner.

Application of principles of molecular diffusion; of laws relating to solution pressure, or osmotic pressure; of conditions controlling crystallisation, or the separation of solids from solutions; of conditions affecting the physical character of liquids, or rock magmas; to the observed variability in the composition of igneous rocks; and to the known relations between their composition, order of eruption, and mode of occurrence, leads to conceptions of their origin from other magmas, by processes called by the general designation of *differentiation.*

With such an understanding of the causes of heterogeneity in rock solutions the great variability in the composition of igneous rocks as shown by chemical analyses, and by a quantitative study of their mineral composition, appears as the natural, as well as the logical result of their mode of formation.

Mineralogical and constitutional facies of igneous rocks are readily comprehended; and the absence of fixed types of magmas, or of frequently recurring bodies of igneous rocks with definite or invariable composition becomes "natural" and is the thing to be expected. Variations in texture within one rock mass, and among rock bodies having various modes of occurrence are readily understood as the results of variability in the conditions attending volcanic eruption.

As to the possible character of volcanic eruption, some conception of it may be derived from a consideration of the probable condition of highly-heated rock material under great pressure deep beneath the surface of the earth, as well as its probable experience in moving upward and out upon the earth's surface.

The high temperatures of volcanic lavas when they reach the atmosphere; the fact that they were losing heat continually from the time of their first movement upward, the evidence that they were completely liquid at some stage in their eruption; together with the observed gradient of increase of temperature downward from the surface of the earth, all combine to show that rock magmas come from some region where the temperature is considerably above the melting point of igneous rocks. The behaviour of the earth as a rigid globe, and the known effect of pressure in counteracting that of heat, together with its estimated high gradient of increase downward within the earth, force the conclusion that at sufficient depth magma, though hot enough to be liquid, behaves as a solid. Such conditions of heat and pressure can not vary abruptly from place to place, but must be nearly the same for large volumes of material; and differences of temperature and pressure must obtain very gradually; chiefly in vertical directions. Magma in such a position must be in a virtually static condition until it experiences change of pressure or stress. Whatever its composition it must remain unchanged.

A change of stress may come about by movement in the overlying portion of the earth. Orogenic movement, readjustment of the upper rigid rock mass, from whatever cause, when profound, must affect the stresses in still deeper parts. The known crustal movements behave as bendings of the upper rock mass, which in places at the earth's surface appear to result in tensile stresses; in places, in compressional stresses. Beneath each of these the effective stresses must be of the opposite kind; under the tensile, compressive stresses; and under the upper compressive ones, tensile stresses. Tensile stresses should occur at some distance below ocean beds, and more especially along the borders of oceans and continents. Compressive stresses should occur in general beneath continental masses.

Tensile stress, as at the bottom of a synclinal arch, operating in a rigid mass must communicate downward as far as the mass behaves rigidly. Where the hot mass is potentially fluid—that is, is kept solid by pressure—change of stress must be followed by change of position of the mass. A tendency to pull apart or stretch in the potentially fluid mass must be followed by a yielding of the mass. At a point sufficiently cool for the mass to act as a solid a tendency to fracture and to open a fissure would be followed by a movement of the slightly more heated mass beneath to occupy the space between the fractured solid; these differences of temperature and of rigidity are to be understood in a mathematical sense as differential, there being a gradation of physical conditions between adjacent parts of the mass. There will be no open space, or fissure, in the ordinary sense. But it must be understood that at whatever depth the mass may be considered solid, there it may fracture, part, and become the walls of a layer or body of intruded liquid, provided the liquid has nearly the same density as the solid mass.

The statement made by Van Hise and Hoskins that open cracks, or fissures, cannot exist at greater depths than about 10,000 meters was made on the assumption that the filling is water; the difference in weight of the rock and the hydrostatic pressure of the corresponding column of water being compared with the crushing strength of the solid rock. When the liquid is heavier than water the same method of calculation allows fissures filled with such liquid to exist at greater depths; and if the weight of the column of liquid equals that of the wall rock, the two will remain in equilibrium at any depth. Consequently, at any depth in the earth mass where a tendency to part may exist, hotter and potentially more fluid material beneath may move up and permit the parting of the slightly more rigid mass to take place. This would appear to be the initial step in the eruption of rock magma.

As the mass shifts its position upward the pressure upon it decreases, resulting in some expansion of the volume, some decrease in density, some increase in mobility. And the rising mass is hotter than the masses between which it is rising, unless movement is at the same rate as the diffusion of heat. In proportion as the tensile stress is strong the upward movement will be pronounced, and may result in a flow of very dense, hot, viscous magma toward the surface of the earth. The greater the vertical distance traversed and the more rapid the rate of movement, the greater the difference in temperature between the magma and the inclosing mass.

That the eruption of rock magma is consequent upon the adjustment of accumulated stresses within the overlying rocks is indicated by the sequence of fractures and lava flows in the uppermost parts of the earth, and the opening of eras of great volcanic activity after profound orogenic movements have disturbed the comparatively quiet action of forces that have been gradually shifting the stresses within the outer portion of the earth. The magnitude of the adjusting action is evinced by the extent of territory simultaneously affected. As, for example, the initiation of volcanic action on a gigantic scale throughout western America at the end of Cretaceous time, after an enormous period of nearly uniform conditions of comparative quiet.

The eruptive impulse, or energy, causing the upward flow of magma, must originate in the expansion of the magma upon relief of pressure consequent upon the adjustment of stresses in the overlying mass, and from expansive energy of dissolved gases. That the eruptive force is of nearly the same order of magnitude as the stresses within the earth's crust is shown by the relatively small amount of material erupted upon the surface of the earth compared with the bulk of the whole; by the common intrusion of magma along fracture planes and along those of structural weakness, rather than at random through rock masses; and most conspicuously, by the evidence of equilibrium with the atmosphere maintained by lava in volcanic craters. Open vents are known to exist for centuries without great extrusion of rock magma, as at Stromboli. The stresses which produce condensation of volume in proportion to depth, and the results of expansion of volume, are, therefore, somewhat evenly balanced.

The effect of expanding gases is shown in the explosive character of many eruptions, and the periodic character of all eruptions from open vents (volcanoes). It must increase the volume of all magmas as pressure is relieved. Its effectiveness must increase with the amount of gas in the magma, which may result from diffusion of gas from greater depths of magma, and also from accession from adjacent rocks under favourable conditions.

Spasmodic eruption may follow sudden yielding of overlying rocks to long-continued stresses, as in the case of massive, or fissure, eruptions when there may have been no considerable explosive action of gas; or it may result from an accumulation of gas pressure sufficient to rupture overlying rock masses. Eruption is then accompanied by abundant evidence of explosion. Both causes undoubtedly operate together in most cases.

In so far as magmatic eruption is a result of volumetric expansion of the magma, due to relief of pressure, the shrinkage of volume due to cooling will retard eruption, or eventually stop it. Crystallisation will operate in the same direction. In proportion as eruption is due to expansion of dissolved gas, the escape of gas from magma, or the reduction of supply, will lessen the force of eruption, or eventually put an end to it. The supply of gas from great depths may be reduced by the gradual diffusion of whatever is in a position to be appreciably diffused; or the supply from rocks adjacent to intruded magma may be cut off by the closing of pores in these rocks through metamorphism: porous rocks becoming dense and almost impervious to gases. In these ways eruptive action initiated by crustal readjustment after continuing for variable periods may come to an end. Readjustment of stresses may recur from time to time in any region, either at such widely-remote periods that the volcanic activities associated with each readjustment constitute distinct and separate periods of action; or at such frequent intervals that the results of several profound movements are combined to form a prolonged period of complex volcanic eruptions.

Independence of action at neighbouring volcanoes, either as to period of eruption, volume of magma erupted, explosive or quiet character of action, or relative height of lava column in conduit of volcanoes, follows from local variation in the factors entering into the process of magma eruption, such as: the volume of magma involved in each conduit extending to profound depths, the shape of the conduit, the temperature of the magma, the rate of cooling, the amount of gas diffused in any given time, the character of the surrounding rocks, and the stability of the surrounding rock mass as a complex whole. The chemical composition of the magma is also a factor involved in the activity of a particular volcano. But the composition of the magma is also a feature by which volcanoes may show independence. The occasion for such differences in neighbouring volcanoes is to be sought in variation in the differentiation of magmas during the course of eruption from deep-seated to superficial positions.

Among the results of such differentiation may be mentioned the production of complementary rocks, which may occur in rock bodies of various forms. A special case of local differentiation, usually associated immediately with crystallisation and solidification of parts of a magma, is the production of contemporaneous veins and pegmatites. When complementary rock magmas are erupted so close to one another in space and time that they come in conjunction while still highly heated they may diffuse into one another, or blend to such an extent as to yield hybrid rocks, or mixed dykes, sheets, &c., as observed by Harker on the Isle of Skye.

The eruption of rock magmas through solid rocks and their solidification in various positions within or upon other rocks condition the modes of occurrence of igneous rocks, as those of lava streams, dykes, sheets, laccoliths, &c. And the parting or cracking of the solid rock, upon cooling, or its arrangement after fragmentation in various ways, leads to distinctive structures, such as columnar, spheroidal, brecciated, and so on.

Having acquired a knowledge of the general principles applicable to all igneous rocks, it is in order to consider more specifically those occurring in all known parts of the world: first, systematically, according to some comprehensive scheme of arrangement or classification, and then acording to the groups, or associations, in which they occur in various regions from which they have been described in considerable detail; that is, according to petrographical provinces, or comagmatic regions.

In order to describe many rocks a nomenclature is necessary, and the confusion existing in that in present use is best understood by considering the history of the growth of petrography, and the changes that have gone on in the definition and use of the oldest and commonest rock names and descriptive terms. With this review should be associated a sketch of the development of rock classification, which has been furnished to the student in an interesting form by Cross.

A successful treatment of the subject of igneous rocks along the lines indicated would go far toward the removal of petrology from a state of distracting empiricism, and the placing of it on a more rational foundation.

7.—THE KLONDIKE GOLD DISTRICT, IN THE YUKON VALLEY, CANADA.

By ROBERT BELL, I.S.O., M.D., D.Sc., LL.D., F.R.S., late Director of the Geological Survey of Canada.

Gold has been found in nearly every part of the Yukon Valley, but in the following paper I shall confine my remarks to the Klondike district, which has been surveyed and studied by officers of the Geological Survey of Canada and has been inspected by myself, so that I have the advantage of having seen what I will attempt to describe.

Geographical Position.

The district lies in the far off north-western part of Canada, close to the east side and near the central part of the straight line along the 141st meridian which divides the extremity of the Dominion from Alaska. The intersection of latitude 64 deg. north, and longitude 139 deg. west, is on Hunker Creek, within the district.

Climate and Conditions.

Being slightly north of the Arctic circle, the winters are severe, but the long days of summer are quite hot. The mild air from the Pacific Ocean has an important effect, and the climate is healthy for a white population. The whole region is covered with a northern forest of white and black spruce, aspen, balsam-poplar, and white birch, all of large enough size for use in building, mining, railway construction, &c. Hay and all the garden vegetables of the north temperate zone grow in perfection, and wheat almost ripens. I mention these things because an exaggerated idea of the climate has gone forth. The district is connected with the other world by a fleet of good steamers plying up the Yukon to the town of White Horse, 300 miles southward in a straight line, or 350 by the river, and the White Pass Railway, 90 miles long, from thence to Skagway, at the head of Lynn Canal, an inlet of the Pacific Ocean. There is also a telegraph line which forms a part of the continental system. So that the conditions of life are not too hard, and many men with their families have remained here continuously in comfort long enough to acquire wealth. When they return to live in their old homes in the United States and Canada, their places are taken by others. In the town of Dawson, at the north-west corner of the district, there is a strong detachment of the Royal North-west Mounted Police, living in permanent barracks, and, although the Klondike district is 5,060 miles from Halifax by the travelled route, law and order are as perfectly maintained throughout the whole region as in any part of England.

Geology.

The geology of that part of the Yukon region which includes the Klondike district is rather complicated. The rocks comprise representatives of various chronological divisions of the geological scale from the oldest to the newest, and also of every kind of physical action to which rocks of all kinds may have been subjected. Those within the Klondike district itself are of both igneous and sedimentary character, but most of them have undergone such changes in the course of their histories as to render it difficult to discover their original condition. The age of the bulk of the gold-bearing portion appears to the writer to correspond with the Huronian series or system of the more easterly parts of the Dominion. The Laurentian system may also be present.

A few words as to the meaning of these terms may be useful in this connection: We regard the Laurentian as the oldest rocks known —the foundation of the rocky crust of the earth. A lower and an upper division may be recognised in various parts of their distribution, which is very wide, comprising most of the north-eastern portion of North America, including Greenland. The rocks of the lower division are composed of only a few of the commonest minerals, quartz, and orthoclase being the principal ones, together with a smaller proportion of hornblende and a little biotite or phlogopite. Scattered small crystals of magnetite may be occasionally detected.

In this respect the Lower Laurentian contrasts with the Upper, in which there is a great variety of minerals, including ores of numerous metals, which, however, do not often occur in economic quantities, with the exception of iron, lead, and rarely copper. Structurally the Lower Laurentian may be described as consisting of heavy granitic gneiss or slightly laminated granite, which may be imperfectly banded owing to alternating belts of different shades of gray, pink, and light red. Although the average of the local strikes of these belts may show that a certain general direction prevails in a given area, the course of the lamination is generally quite local or ill-defined, with frequent changes, or it may be contorted. Again, by means of the alteration of shades, the bands may sometimes be found to form irregular parallel curves or zig-zags, and sometimes they follow imperfect concentric ellipses of low or high eccentricity.

Upper Laurentian.

The Upper or Newer division of the Laurentian system is made up principally of a variety of well-foliated gneisses, arranged in distinct bands, also beds of crystalline limestones and dolomites, some of which are of great thickness, together with anorthosites, norites, pyroxenites, granites, massive and schistose greenstones, &c. Minerals of many kinds are found in the series. Over 150 different species have been collected in the townships opposite to the city of Ottawa. Among the economic minerals which these rocks have so far produced in commercial quantities are ores of iron, lead, and in a few cases of copper; also apatite, mica, fibrous serpentine, barite, celestite, marble, and a variety of semi-precious stones. There is little doubt that some of the gneisses represent altered sediments. The parallelism of the members of the series and the structural arrangement or geographical distribution of their outcrops resemble those of altered and disturbed sedimentary rocks of other formations. In some localities the arrangement is tolerably regular, but in others it is considerably disturbed or corrugated.

The total area of the Upper division is less than that of the Lower, but the boundaries between them are only imperfectly known.

Huronian and Keewatin.

In the eastern half of the Dominion, or rather that greater part of it which lies eastward of the Mackenzie River, some large and many smaller areas are occupied by a great pyroclastic series, the different parts of which, until recent years, were provisionally grouped under the name Huronian. Before they could be satisfactorily divided, this name was understood to embrace all the rock-formations between the Upper Laurentian and the lowest Cambrian. As far as this series was concerned, while the Canadian geologists gave their attention mostly to the discovery and tracing out of the geographical distribution of the Huronian areas in our vast territories, a few of them in later years, as well as some of the United States geologists, devoted themselves to a closer study of restricted areas in the Lake Superior region. They found that the lower part of the series consisted of igneous rocks mingled almost everywhere with some local aqueous deposits. The name Keewatin (pronounced Keewaytin) was given to this division, while the name Huronian is retained for the upper and greater part of the system, which is made up principally of a variety of sedimentary rocks that are more or less altered in some districts. A part of the Laurentian series was supposed by some geologists to be represented in a few places in the Rocky Mountain region. One of these is near the Klondike district. If this supposition be correct, then the Keewatin and Huronian are probably there as well. The above short description of our oldest rocks is intended to prepare the way for some remarks on the position of the Klondike auriferous series, since the geological age of rich gold-bearing rocks is one of the most interesting points in connection with the whole matter.

Rocks of the Klondike Gold District.

The Klondike gold district lies in the angle between the east side of the Yukon and the south side of the Klondike River, and measures about 40 miles from north-west to south-east by about 25 miles at right angles to this direction. The gold-bearing series within this area embraces a variety of crystalline schists and other rocks, which are here mentioned in the approximate order of their abundance: Foliated quartz, porphyry, silicious sericite, quartz-mica schists, imperfect gneisses, sheared greenstones, chloritic, and graphitic schists, rhyolites, andesites, and diabase, the last-mentioned passing in places into serpentine. The schists of this group have been mostly derived from massive rocks by pressure and shearing, but some of them are altered sediments. Silicious limestone occurs in a few places associated with silicious and argillaceous schists. Epidotic and actinolitic schists occur in a few instances. Nearly all these rocks contain many small and some larger veins of white quartz, which in the aggregate make up a proportion of the whole mass worth noting. Small quantities of accessory minerals of various species have been found in this group of metamorphic rocks. More recent intrusions of massive rocks of several groups and ages, penetrating through the old schists and gray granite, like that which forms the great coast range, have been observed cutting schists of sedimentary origin. Throughout the district the strike of the bedding and that of the cleavage or schistosity generally coincide, and they have a prevailing north-west and south-east course, and dip at rather low angles to the south-west, but, on the large scale, these lines sweep round through the district in flattened parallel concentric curves belonging to three sets or centres.

Huronian Age of the Klondike Rocks.

The following are some of the reasons for classifying the gold-bearing rocks of the Klondike with the Huronian system:—No crystalline rocks of later age than the Huronian are known to occur elsewhere in this part of the Dominion, and there is no reason to assume that the Klondike series is exceptional in this respect. In the Rocky Mountains and other chains formed by profound upheaval through an immense thickness of strata, the oldest rocks are found in the central portions. Considerable areas, for 200 miles along the Yukon Valley, have been provisionally coloured as Laurentian by the western geologists. In the great region between Hudson Bay and the St. Lawrence Valley the older Huronian rocks are often conformable to the Laurentian and pass gradually into them. The Huronian is the great metalliferous series of eastern Canada and the adjoining States generally, and it has already been found to be more or less auriferous in nearly all parts of its distribution; whereas gold has been found, and only in traces, in but a few instances in the Upper and not at all in the Lower Laurentian. The Klondike rocks are certainly very ancient; the series belongs to the Huronian type, and it is not more auriferous here than the rocks of this system are in some localities in the east.

Geographical and Physical Conditions.

The Yukon River has a course of about 1,500 miles, from its source, a short distance inland from the Pacific Ocean at Lynn Canal, to its mouth in Norton Sound. The upper or Canadian portion runs north-west in a narrow valley through a mountainous country, but soon after it passes into Alaska, it is joined by a large branch from the east side called the Porcupine River; the valley broadens and the direction of the main stream changes suddenly from north-west to west-south-west, which is a continuation of the course of the Porcupine. Notwithstanding that the upper portion of the Yukon is closely flanked by mountains on both sides all along its course, it maintains an even grade throughout of about 3 ft. in the mile. In the season of low water it is only deep enough for flat-bottomed steamers, and flows at a nearly uniform rate of 3 or 4 miles an hour over a bottom composed of shingle, gravel, and sand. It is a clear-water stream, and has a width of about 200 yds. at White Horse and 400 at Dawson.

The Klondike gold district partakes of the mountainous character of the rest of the Yukon region. Its highest point, called The Dome, is a little north of the centre, and nearly all the ridges and valleys radiate from it. Its altitude is 4,250 ft. above the sea, or 3,050 above the Yukon River at the town of Dawson, which is 1,200 ft. over sea level. The district has been surveyed by the Geological Department, and the contour lines of the hills have been defined at 50 ft. intervals up to 2,000 ft.

The map representing this work shows in a striking manner how deeply the district has been dissected into a great number of ridges and hills by the small streams called "creeks," most of which, like the intervening ridges, radiate from The Dome. The average elevation of the ridges above the valley bottoms is about 1,500 ft. The crests of the ridges are unbroken, so that starting from The Dome and using the proper ridge for the purpose, one may reach any part of the district without crossing a valley. Although the flanks of the ridges are steep, their crests are rounded, with a little bare rock cropping out upon them in some places. Each deep valley starts from a cirque-like depression excavated in the side of a ridge, and it maintains for some distance down the character of a steep-sided ravine, but gradually expands, till, in its lower reaches, it becomes flat-bottomed, although not very wide, while the sides have become more or less distinctly terraced up to a height of 700 ft. above the valley bottoms.

At the beginning of the Pliocene epoch the whole Yukon region inside of Canadian territory, including the Klondike district, appears to have had an elevation above the sea of, say, 7,000 or 8,000 ft., and it seems to have maintained its stability for a very long period, during which the old crystalline rocks became deeply decayed and eroded, while the softened material was excavated on a large scale by almost innumerable brooks and some streams of greater size. The result was that the average altitude of the surface was reduced by denudation to the extent of perhaps 5,000 ft. Thus the smooth-sided mountains and valleys of the Klondike country were produced. After a great lapse of time, and while the slopes of the valley were deeply covered with the mixed débris from the disintegration of the softer and harder rocks, a gradual subsidence of the land took place, and was followed by a general elevation to an altitude exceeding that of the former surface by about 600 ft. The gradual subsidence of the land gave the incoming sea an opportunity to wash and modify the disintegrated rocky materials all the way up from the lowest to the highest levels, to round off the angles of the harder fragments, and to arrange them at many altitudes into beds which are sometimes of great thickness, even up to 100 and even 200 ft.

The White Channel gravels, described further on, belong to this period. The re-elevation to a height of about 600 ft. above the level, which had been so long maintained before the submergence permitted the retiring sea to cut the White Channel and other old gravels into terraces and beaches; and the increased height at which the land now stood enabled the streams in the Klondike district to deepen their valleys by about the same amount. The contrast between the steep sides and the angularity of the new valleys and the smooth and more gentle slopes of the old ones is easily recognised.

Source of the Placer Gold.

An attempt will now be made to interpret the surface indications in regard to the later geological history of the Klondike district, and to try to account for the richness of its placers.

The investigations of Mr. R. G. McConnell and Mr. J. B. Tyrrell, which extended over several seasons, have shown that, during and since the Pliocene epoch, more events and changes have taken place in that territory than might have been supposed possible, and all of these involved time. The evidences of some of these, such as the invasion of the district by the Klondike River at a certain period, an event of great geological interest, could only have been detected by experienced geologists. The numerous phenomena which have occurred during the Pliocene and Post Pliocene epochs in the Yukon region indicate a more varied history, and also the lapse of a greater length of time than had heretofore been suspected.

The small veins of quartz which have been mentioned in describing the Klondike rocks are quite abundant in almost every part of the district. Nearly all of them are white, and they are usually hyaline, but many have developed a finely-granular structure. They are generally short and lenticular in form and vary from mere threads up to several inches in thickness and occasionally reach a foot or more. They often occur in groups, the individual veins of which are nearly parallel to one another and to the lamination, but veins are also found which form angles with both the dip and the strike of the schistosity. In the universal disintegration and waste of the

Klondike rocks, the vein quartz, being the most resistant both as to decay and grinding down, has survived in fragmental form in much greater proportions than the country rocks that originally contained it, and it is now represented by heavy beds of shingle and gravel, which have received the name of the White Channel gravels, and these are found in great quantities at different levels in various parts of the district. Although these gravels look white in bulk, as compared with other gravels, yet about half of the individual stones are not quartz, but consist of rounded fragments of the harder and tougher kinds of the country rocks in the vicinity. The deeply disintegrated condition of the hillsides in the Klondike district would greatly facilitate the formation of gravel, and the quantities produced are enormous. On Trail and Lovett Hills alone, Mr. McConnell's assistants measured a total volume of 160,598,990 cubic yards of White Channel and Klondike gravels, the latter being the other high-level or older gravels associated with the former. The breaking up of the quartz veins and the liberation of the gold was facilitated by their freely jointed and slightly faulted character. The quartz cobble-stones and gravel sometimes contain specks and small nuggets of gold, and at the base of the White Channel deposits placer gold is always met with, and generally in commercial quantities.

Large nuggets are not common in the district. Most of the gold is, however, coarse and rough, but generally with the sharper angles and projections worn off. Much of it is as large as grains of barley and Indian corn, the remainder being mostly of the shape and size of somewhat flattened pellets of the smaller grades of shot. Only a small proportion is as fine as sand. In the unmodified rock-débris of the hillsides the newly-liberated gold is quite rough, and is sometimes crystalline. Here fragments of quartz from very small veins or threads are occasionally attached to crystals and rough nuggets of gold, showing that these have been derived, not from recognisable veins, but from small and thin sheets or lenses of quartz scattered through the country-rock. From all the foregoing evidence, the writer believes that a great deal of the gold of the Klondike, perhaps the major portion, has been derived from the thin, small, and inconspicuous lenses which follow the laminæ of the schistose rocks and sometimes cut across them. Grains and small nuggets of gold have been found elsewhere in the matrix of Huronian rocks, unconnected with any vein, stringer, or cavity, and it is quite probable that much of the gold of the Klondike may have had a similar origin.

Placers due to Great Concentration.

From the above short geological sketch, there appears to be no doubt that the extremely rich placers of the Klondike district are due to the concentration of the gold (during immense periods of time) from the enormous volume of only moderately auriferous rock which underwent decay and was removed by water, while the gold was allowed to remain behind on account of the absence of glaciation, which might have carried it away. Mr. J. B. Tyrrell has calculated that a depth of about 5,000 ft. of rock, which once existed above the present surface of the district, has been removed by decay and erosion. He has also shown that a very small value per cubic yard in this great mass of rock would account for all the gold which was left behind in the present surface deposits.

The placer gold found within the limits of each different class of original rock in the district is known to be sufficiently different in fineness and other characters to enable the assayers to recognise its source with certainty, and this is regarded as one of the proofs that the gold has merely sunk down, as it was liberated, within the original area of its matrix, while the lighter materials were being washed away, and that it has suffered but little horizontal movement.

The White Channel and Klondike Gravels.

The White Channel and the associated Klondike gravels are the oldest detrital deposits of the district, having been formed, as already described, by the first washing of the sea as the deeply decayed Mid-Tertiary land surface sank gradually beneath its waters, exposing every part in turn to its action. This is believed to have taken place in Pliocene times. Portions of these gravels having remained where they had been originally deposited, others, which have been subsequently formed at various periods, present a variety of relations to the older ones, which still remain the greatest in quantity. Sometimes the ancient gravels occur side by side with the newer ones in the valley bottoms, and both are profitably mined. On Hunker and Bonanza Creeks the volume of the white gravel increases in width and depth in proceeding down stream, showing a continuation of the conditions that accumulated this gravel, while the land sank and rose again. A considerable amount of gold has been concentrated under the gravel.

Great Interval Follows.

It has been already shown that since the close of the White Channel period, sufficient time has elapsed for the excavation of creek valleys to depths of 300 to 600 ft., through what was originally hard schist rock. This long period would permit of many geological changes taking place, some of which may have affected the arrangement of the auriferous deposits or caused a redistribution of the gold, and we must take this possibility into consideration in attempting to account for the present modes of occurrence of the precious metal. Therefore, the reason why some portions of the Klondike district are richer than others, and that certain peculiarities occur in the relative abundance of the gold in different parts, may not be entirely attributable to differences in the original productiveness of the rocks of the various localities, but may be due, in part, to this redistribution of the old auriferous gravels.

Remains of Mammals and Trees in Frozen Ground.

The Klondike district has experienced two long periods of rock decay—one before and one after the submergence in Tertiary times, already referred to. Towards the close of the latter period the disintegrated stony *débris* and accompanying earth, silt, &c., became deeply frozen at a time which probably corresponds to the latest glacial epoch. This frozen mass is the most recent formation of the district, and contains the bones of several extinct mammals of the quaternary period, together with those of some living species and the wood of a few kinds of trees which still grow in the district. Among the animal remains are bones and numerous large tusks of the mammoth, bones and horns of a great extinct bison, and of the existing American bison, the moose, the reindeer or cariboo, a bear, and an extinct horse, of which Mr. J. B. Tyrrell found only a few bones. A well-made copper spear-head, which the writer saw at Dawson, was found at some depth in this deposit.

Great Depth of Frozen Ground.

No animal or plant remains have been met with in any of the old gravels underlying this newest deposit.

This mass of unstratified material has resulted from the superficial decay of the rocks in the interval between the Pliocene and the latest glacial period. It is thickest on the lower levels and thinnest on the tops of the hills and ridges, as if it had gradually slidden down as it was formed, and accumulated in the valley bottoms. It is all permanently frozen to a great depth which, however, varies considerably according to situation. Borings at different places gave the following results:—Upon the ridge south of Eldorado Creek the bottom of the frozen mass was reached at 60 ft. from the surface, while in the valley of this creek unfrozen ground was first indicated by running water a little below 200 ft. On the plateau between the Klondike River and Bonanza Creek unfrozen ground was reached at 175 ft.

At the time of the writer's visit to Dawson, in 1905, a boring in progress near the centre of the town, and not far from the Klondike River, was down considerably more than 100 ft., and was still in frozen ground. In some of the excavations made by the miners in other parts of the district, portions of the frozen "ground" consisted of ice mixed with some earth. It is improbable that the ground would freeze to such great depths in the present climate of the Klondike. Where the living moss, or the deeper covering of muck is removed from the surface, the earth thaws in summer to a depth of 6 to 10 ft., but this becomes completely frozen again during the following winter, as it lies between the cold air and the underlying frozen earth, which has a temperature below 32° Fahr. Where the surface covering of vegetable matter is undisturbed the ground does not thaw all summer.

A record of the temperatures was being kept at the bore-hole above referred to in Dawson town, and it was found that the maximum cold had been reached at about 100 ft. from the surface. It was the opinion of the intelligent operator, with whom I conversed on the subject, that this was the general condition wherever the frozen ground had its full development. Since the usual depth of the frozen layer throughout the district appears to be about 200 ft., this would seem to show that the climate of the Klondike has so far improved since the last Glacial period, that the summer's thawing now penetrates to as great a depth as the winter's freezing. The great thickness of the frozen ground, and the low temperature of its mid-depth, indicate that the permanently frozen condition is a legacy from a colder period in the past, and that, if the climate continues to improve, it is probable a time will come when there will be a permanently unfrozen zone just below the superficial layer which would freeze every winter and thaw again in Spring. The concentration of the gold in a narrow streak on the bed-rock along the very bottom of the steep-sided valley of every creek indicates that this took place while the water was in a fluid state, and before the gravel had become frozen into a solid mass.

In order to get at these pay streaks, the miners require to excavate open cuts in the frozen gravels, or to tunnel under them. The courses of the existing creeks on top of the frozen gravels do not correspond with those of the pay streaks on the bed rock below, but run from side to side of the valley-bottom, frequently crossing and recrossing the underlying ancient channels along which the gold was deposited. Much gold is found under beds of water-washed sand and gravel, including the Klondike and White Channel gravels on the remains of old benches, which are now permanently frozen. It is evident, therefore, that the deposition of the workable gold of the Klondike in the ancient beds of creeks and under the gravel of old benches was due to water. There was no other means by which it could have been finally sorted out and concentrated in its present positions. It is equally evident that the deep freezing of the auriferous deposits, and of everything above them, took place since the gold was left where we now find it.

Glacial Movements in North America.

It was formerly supposed that the ice sheets which covered the northern half of the continent in the Glacial epoch, all moved from the northward to the southward; but it is now known that in some of the northern parts their motion was northward, or in other directions than towards the south. In the Yukon region, wherever glacial sheets existed at all, they moved towards the north; but the Klondike district was never scoured by moving sheets of ice. To this circumstance, and to the stability of the altitude of this part of the continent for long periods, have been due the accumulation of the gold of the Klondike in the lower levels, as its auriferous rocks decayed away and deposits of exceptional richness were formed by the action of water. Had the district suffered from moving land ice during the glacial period, which, as we have seen, was subsequent to the concentration of its gold, most of the precious metal might have been swept away and lost.

Discovery and First Workings.

Before the discovery of rich placers in the Klondike district, it had been known for some years that indications of gold could be found almost everywhere in the Yukon valley. In the summer of 1894 a party of prospectors discovered gold in workable quantity in the bed of Quartz Creek, a northern tributary of Indian River, in the southern part of the district. During the following winter, Robert Henderson found gold in Gold Bottom, a branch of Hunker Creek, which soon became one of the great producers. In 1896, a man named Carmack struck rich placers on Bonanza Creek, and the excitement following this led to the rapid development of the surrounding district.

Dimensions, Etc., of Claims.

The ordinary creek claims are 500 ft. in width, measured on a line following the general course of the stream, and from rim to rim at right angles to this line. "Rim rock" is the bed rock under the edge of the horizontal surface of the gravel of the valley-bottom, or where this gravel surface comes against the sloping rock of the side of the valley. Along most of the creeks, the breadth of the top of the gravel varies from about 200 to 1,000 ft.

Difficulties in Mining.

The difficulties in the working conditions are greatly increased, owing to the ground being everywhere deeply frozen by the long and severe winters, and the want of a good water supply for washing. During the first two or three years, the miners thawed the earth by the direct application of fires, for which the small northern trees of the district supplied the fuel. As soon as a few feet had been thawed in this way, the earth was shovelled out and a new fire kindled in the bottom of the pit. The fires burned better and thawed more earth than one might have expected under the circumstances. The process was repeated till the pay streak was struck. The dirt from it was placed in a separate pile and soon became refrozen. In spring, as it thawed out by the heat of the sun, it was washed by different methods, according to the quantity in stock.

This method gave place to a better one, by means of the steam thawer. This consists of an iron pipe, about 8 ft. in length, pierced all round the lower end by a number of small holes to allow the steam to escape, and plugged at the extremity with a sharp steel point. The upper end of the pipe is closed by a solid steel head, which receives the blows of the heavy hammers used to drive it deeply into the frozen gravel or earth. Hot steam is forced into the pipe near its upper extremity through an iron tube connected with a small boiler. The longer a thawer is allowed to remain forcing hot steam from one centre the wider will the softening extend in all directions, and, in this way, the frozen ground may be tunnelled along the pay streak to any distance, which was not possible by the wood fire method. The pay dirt is hoisted by a hand windlass, a horse, or by steam power, and dumped into elevated sluices, and water for washing is pumped from the creek or brought by a flume.

Accessibility of the Klondike.

When news of the discovery of a rich goldfield in the Klondike district reached the outside world, there was a rush thither of placer miners from Canada and other countries, and especially from the Pacific States of the American Union. In 1896 a continuous stream of eager men poured in from the port of Skagway, over the present route of the White Pass Railway to Whitehorse Rapids at the head of navigation on the Lewes River, the main upper branch of the Yukon. Now, the White Pass Railway from Skagway to Whitehorse, a distance of 90 miles, makes travelling easy between these points, and more than a dozen fine stern-wheeled steamers are running on the Lewes and the main Yukon, from Whitehorse to Dawson, without any interruption, a distance of about 350 miles by the stream. From Dawson the traveller may visit all parts of the Klondike district by driving over the smooth roads, with long easy grades, which have been constructed by the Canadian Government, at a cost of nearly two millions of dollars.

Fluctuations in the Population of Dawson.

The town of Dawson, situated where the Klondike River falls into the Yukon, at the north-west corner of the Klondike district, sprang into existence as soon as the gold-mining began. In 1900 it had a settled and floating population of about 20,000, but in 1905 this had diminished to about 4,000, and the number is still smaller at the present time, having continued to diminish with the gold yield. A strong detachment of the Royal Canadian Mounted Police has always been stationed at Dawson, and law and order have been as well maintained in all parts of the Yukon region as in any other part of Canada.

Yearly Values of Gold Produced.

From the time of the discovery of gold in the Klondike district till 1896 the output was small, and no correct record of it was kept, but in that year placer mining began to be an important industry. A royalty of 10 per cent. on the gross yield was imposed by the Canadian Government in the following year, but, about 1904, it was reduced to 5 per cent. A means was thus established of keeping a record of the greater part of the production. The annual yield since 1896 is given by the statistical branch of the Geological Survey of Canada as follows:—

	$		$
1896 ...	... 300,000	1903 ...	... 12,500,000
1897 ...	... 2,500,000	1904 ...	... 10,500,000
1898 ...	... 10,000,000	1905 ...	... 7,876,000
1899 ...	... 16,000,000	1906 ...	... 5,600,000
1900 ...	... 22,275,000	1907 ...	... 3,150,000
1901 ...	... 18,300,000	1908 ...	... 3,150,000
1902 ...	... 14,550,000		
		Total	...126,701,000

This gold has been all safely cared for and sent out by the Dawson agency of the Canadian Bank of Commerce.

Other Minerals of the Klondike District.

The whole of the abovementioned gold was obtained by placer mining, for, although the precious metal is known to exist in a number of irregular short veins of quartz, and may sometimes be detected in stones of the White Channel gravel, no one has had sufficient confidence in these occurrences to test their value on a working scale.

No other metal is known to occur in economic quantities within the district. Small indications of copper pyrites have been noticed in the solid rocks. Smooth, well-rounded pebbles of oxide of tin (cassiterite), generally of small size, are occasionally found in the gold washings. On fresh fracture they all have a fibrous or finely columnar structure (wood tin). It has been asserted that grains and small nuggets of platinum have been found in this district, and also on a bar in the Yukon, near Big Salmon River, but these statements have not been confirmed. Globules of native mercury, and small indications of cinnabar are said to have been observed at one locality in the district, but there is no scientific evidence of such occurrences.

Cretaceous coal, of fairly good quality, occurs on and near the Yukon River, some miles below Dawson, and also at a few places in the banks of the river higher up.

Meteorites.

Two meteorites which had sunk through the earth and gravel down to bed rock were found within the Klondike. These would never have been discovered had it not been for the working and washing for gold in that district. One of them, which weighed only about 2 lb., was of a flattened pear shape. It had a smooth surface, and, on polishing and etching a section of it, the Widmanstätten figures were found to be of a wide pattern and strongly marked. The other meteorite weighed about 30 lb., and its surface is said to be not deeply pitted, but rusty and scaly from long burial in the gravel. The conditions connected with the finding of these two meteorites suggest the possibility that many of these bodies which fall upon the earth where the surface consists of soft, loose, or shifting material, may have sunk out of sight and are now resting on some firmer foundation or on bed rock.

Future Production.

The days of placer mining in the Klondike by individuals and on a comparatively small scale are over, but a large annual yield may be kept up for a long time by dredging and hydraulicking. Dredging was begun some years ago in the bed of the Klondike and other streams, and by starting work on artificial excavations elsewhere, which soon filled with water, allowing the dredge to advance and enlarge the pond in any direction. This process has been so successful that it will, no doubt, be carried on more extensively in the future, and increase the present rate of production.

Hitherto, hydraulicking has been practised only to a limited extent, as but a small supply of water could be obtained at sufficiently high levels. In order to get a large enough supply, engineers found that it would require to be brought from a long distance at great cost, on account of the hills and the deep valleys which intervene. However, by the enterprise of the Messrs. Guggenheim's Sons, the difficulties are being overcome, and before long hydraulicking, sluicing, and any other process which may require much water, will be in successful operation. It has been ascertained that the frozen condition of the gravels, although it retards the process, does not offer an insurmountable obstacle to successful hydraulicking.

Are New Gold Districts Likely to be Found?

Shall we ever find another gold district like the Klondike? This question has often been asked since the returns from the latter have diminished so greatly. The probabilities are in favour of discovering other very productive gold districts in British Columbia, the Yukon territory, and the western and northern parts of the North-west territories. These great regions are, as yet, only very imperfectly explored. The rocks of the Klondike are probably repeated in some districts within the great regions just enumerated. The geological conditions of this district are sufficiently known to enable prospectors to recognise similar conditions if found elsewhere. The Tanana River, in Eastern Alaska, is a case in point. This stream flows parallel to the Upper Yukon, at about 120 miles west of it, and joins the Lower Yukon 200 miles below Porcupine River. Since 1904 its valley has been producing almost as much gold as the Klondike district. Mr. Joseph Keele, of the Geological Survey, who for the last few years has been investigating the Stewart River region, has found workable placers in several localities, and these may be only forerunners of richer ones which will be found in the same district. Discoveries of heavy placer gold have been lately reported on Dease River, which joins the Frances, to form the Liard, in latitude 60 degrees and longitude 128 degrees 30 minutes W. The writer has heard of discoveries of coarse gold in this region on two former occasions within the last twenty-five years. The placers of Cassiar district, which about twenty years ago were yielding the greater part of the gold then produced in British Columbia, are situated not far from Dease River. Possibly other goldfields may be discovered in the territory lying southward of Herschel Island, perhaps about 100 miles inland.

The Net Result.

The large quantity of gold from the Klondike which has been added to the world's supply may be of some service to mankind in general, but it is doubtful if the total removal of this virgin wealth out of the country has been any gain to Canada. The greater part of it went to the Pacific seaboard of the United States, and helped materially to build up such cities as Spokane, Portland, and Seattle. Very little of it remained in Canada. No permanent development worth much—no equivalent in any form—was left to pay for even a portion of the immense amount of gold taken out of the country. It would be better for Canada at this moment if the Klondike had remained undiscovered until we were in a position to secure the gold for ourselves. A greater sum than the amount of the royalties paid by those who were enriching themselves was spent in providing facilities, such as roads and bridges, for getting out and removing the gold, and this was also a direct loss to Canada. As soon as the pay streak along the bed of a creek was exhausted, the miners all abandoned their flimsy buildings, framework for machinery, flumes, pumps, sluices, and all kinds of appliances or apparatus, their rude furniture, and even their cheap bedding and old clothes. The next flood overturned and mixed up all these evidences of temporary habitation, and left only wreckage along the bottoms of the valleys—a sad spectacle, as if the tide had gone out and exposed the ruins of our richest goldfield.

Besides the actual gold taken away, the country is said to be "out" a large sum on account of such expenditure as large salaries to overpaid officials, cost of public buildings, courthouse, schools, governor's residence, post office, police barracks, also a park—all in Dawson town, to say nothing of frauds in making payments everywhere: so that the final result of the mining and all transactions connected therewith has been a serious deficit, apart from the loss of the gold itself.

8.—THE PROGRESS OF MINING AND GEOLOGY IN THE COMMONWEALTH OF AUSTRALIA AND THE DOMINION OF NEW ZEALAND.

By WILLIAM FRYAR, late Inspector of Mines, Queensland.

On a former occasion when the colony of Queensland was honoured with the assemblage of the scientists of the various British States of Australasia, the writer had the privilege of placing before the Geological Section some of the results of their labours in Queensland up to that time, now fourteen years ago. He would now endeavour to formulate a more general and comprehensive statement of the same nature, not with the detail with which the results in one State can be dealt, nor with the exclusion of all mention of the progress which has been made in the other States, which with Queensland have since become united as the Commonwealth of Australia, together with the former colony of New Zealand, which has also been accorded a higher title.

As the results of geological research in the north-eastern State were then given, they, at any rate, need not at present be given with any detail previous to that time, nor need those of the other States be dealt with minutely, as they have now become matters of history, although the general results may be of interest to those who are too deeply engrossed with the scientific details to have time or inclination to devote to the statistical results. And yet the expansion and extension of the mining indutry, having been such as to attract the attention of the mining and industrial world to a very considerable extent, to omit all reference to it on an occasion like the present would appear to be a dereliction of duty which would not be creditable to the members who have had any experience in statistical work, or rather on the part of those who have no leaning towards abstract science, no ability to discover and lay bare the secrets of Nature, but may put such together by entering into the labours of other men.

This, then, is the extent to which the present paper may have any claim to belong to a scientific subject, but, as Dr. Jack has dealt with the presence of minerals on the Pacific Coast, and Mr. Knibbs has shown the value of statistics, no further apology is needed for the intrusion.

New South Wales.—It need scarcely be said that the parent State or Mother Colony enjoys the distinction of having been the first in the contribution of minerals to the productions of the great Australian continent. Productions found in an early period of its history, such as shell, lime, and sand for mortar, and to those who now know Sydney it will be no secret that suitable building stone would not be far to seek. These, however, would be of little commercial importance at that time, although at the date of your former meeting in Queensland other minerals, including valuable metals, had been discovered and worked, which had been the means of drawing tens of thousands of people to her shores, and of adding millions sterling to her wealth.

It is unnecessary here, however, to do more than mention a few items. Coal had been worked almost from the inception of the colony, and gold was first found in that State. Its presence there had been known, geologically speaking, for many years, but it was only during the year 1851 that it was found to be in quantities industrially and commercially payable, and its discovery became an engrossing pursuit, and thence to the close of 1893, the latest for which returns were then available, it had yielded gold to the value of nearly forty millions; coal, shale, and coke to the value of more than thirty millions. The coke is usually included in the statistical tables, but more properly is a manufactured article, or residue from the coal. Silver was discovered in the early seventies, although not largely worked until 1884, but at the time of your meeting here had contributed nearly seventeen millions to the wealth of the State. The presence of tin was discovered in 1872, and by the time of your last assembling here, the smelted and extracted silver and ore had yielded to the skill of the geologists and the efforts of the workmen upwards of ten millions sterling worth of that metal. Copper, discovered in 1858, or seven years after the discovery of gold, had yielded six and a quarter millions. The value of iron, manufactured chiefly from scrap, otherwise waste, together with a little oxide of iron, and pig iron (although the pig could scarcely be raw material from the mine, but, like coke, more properly belongs to manufactures) is given as £425,999. So that the total production of the State at the close of 1893 amounted to £104,280,711, and this will form matter for comparison with the general progress of the State during the two periods of seven years each following. The first terminates with the commencement of our union as a Commonwealth, and the second with the year 1907, the latest to which we now can have the complete returns of mineral production. In addition to the mineral products mentioned, antimony, zinc, bismuth, limestone, alunite, manganese, opal, marble, cobalt, nickel, platinum, chromium, wolfram, diamonds, and various other minerals, many of which are of great value within the State, such as building stone, slate, and the like have been discovered, but for which no credit is taken except for what has been exported.

Victoria.—It is needless to say that gold was discovered in Victoria almost immediately after its discovery in New South Wales, and that its production soon eclipsed that of the parent colony, and up to the time of your previous meeting here, it may briefly be stated that the total value produced was £236,395,959. Gold yielded £235,090,220, and copper, tin, coal, lignite, iron, antimony, zinc, and other minerals, £1,305,739. These are mentioned to show how the presence of gold assists in the discovery and stimulates the working of other minerals, which otherwise might be left undisturbed and undiscovered. But an excellent beginning has been made on them, although the yield of gold up to the end of 1893 constituted about 99·5 per cent. of the total production of the colony from its inception.

QUEENSLAND.—The period antecedent to your former meeting in Queensland was fully dealt with during the sittings on that occasion, so that a bare summary of results is sufficient here. The great gold fields of the present day had all been then discovered, Gympie, Charters Towers, and Mount Morgan were in full swing, and the Palmer was dying off from its unparalleled alluvial yield—unparalleled as far as Queensland is concerned; and so fully was the thirst for gold occupying the attention of the people that all other metallic minerals were considered a nuisance. Hence the statement quoted from a report of one of the Northern Wardens, who said, "Copper, antimony, lead, and tin all exist in a large area of these fields, but for a long time to come they will be regarded as depreciating rather than improving the importance of the district. But, now, well it is not always safe to prophesy, for copper alone yielded more than half the production of gold in Queensland during the year 1907. But we anticipate, Queensland had then produced, that is, up to the close of 1893, minerals to the value of over forty-one and a half millions sterling, of which gold contributed £32,365,945, or about 78 per cent. of the whole; copper, two millions; tin, four millions; coal, one and a half millions; silver and lead, antimony, bismuth, zinc, manganese, cobalt, mercury, wolfram, and other minor metallic minerals, with opal and gems, yielded various amounts aggregating £1,439,032. So that Queensland possesses nearly all the metallic minerals and most of the earthy, including graphite, asbestos, mica, baryta, arsenic, gypsum, slates, limestones, granites, marble, and other ornamental stones. Fluor spar, magnesia, salt, valuable fire clays, bauxite, and kaolin, which had already made their presence known in Queensland, gave a guarantee that whatever fate might befall the agricultural, pastoral, or manufacturing industries, mining for either metalliferous or earthy minerals in Queensland had a grand future before it.

SOUTH AUSTRALIA.—With the exception of copper, South Australia has never been conspicuous in the production of minerals. This colony had at the time of your last meeting in Queensland produced more than twenty millions sterling worth of copper; gold to the amount of £301,322, silver £167,123, and tin to the value of £1,487, making a total production of £21,114,736. It possesses iron, bismuth, zinc, antimony, and some of the minor metallic and earthy minerals. But did not, at the close of 1893, promise to shortly again become a prominent mining colony or State. The Northern Territory had then produced gold to the value of over a million pounds sterling—viz., £1,043,720.

WEST AUSTRALIA.—At the time of your last meeting in Brisbane the Western colony had not made its mark as a producer of minerals, although they had been proved fifty years previous to that meeting, and both lead and copper were worked there in 1843. At the close of 1893 the production of gold had amounted to £941,325, from its discovery in 1851, almost simultaneously with that in New South Wales and Victoria, and it is a remarkable coincidence that gold was discovered at Gympie during the same year, but was not considered sufficiently important until Nash's subsequent discovery in 1867. The other metallic productions consisted of silver and its accompaniments

£169,000, copper £140,000, and tin £52,750, making a total of £1,303,075 for fifty years' work. West Australia was just then entering on its career of prosperity as the chief producer of gold for a long period of years, but only during the previous two years had any indication been given of the great future before it, as most of the gold now credited to it had been obtained during those years.

Tasmania.—The little island lying south of the south-eastern corner of the continent of Australia was settled comparatively soon after the discovery of the Straits which separated it from the main land, but for a purpose which was not conducive to the development of the mining industry, and, therefore, not much was heard of its mineral resources until several years after the attention of the people was directed to the subject of mining for gold in Victoria and New South Wales. But, although their published tables commence with the year 1880, it is evident that a considerable amount of mining was done previous to that time, but for gold and other minerals, a diagrammatic representation of the output being given in one of the subsequent reports without the corresponding figures. The amounts given previous to 1893 are: Gold, £2,161,920; coal, £298,647; tin, £4,796,877; silver, lead, &c., £335,765; and unenumerated, £31,988; making a total of £7,625,197. Already giving promise of a wealth of tin—although her promise of the silver and copper was not so apparent. The diagrammatic representation of the output includes for the period antecedent to 1880, gold, silver, tin, and copper; and aggregates slightly under half a million sterling. The output had thus amounted to about eight millions sterling. Gold and coal appear to have been discovered in 1870, and tin in 1872; copper later. The time of the discovery of silver being somewhat indefinite. The salubrity of the climate of Tasmania, being highly favourable to the British and European constitution generally, renders it probable that no step will be left untaken to discover any other such deposits as those of Mount Lyall, Mount Bischoff, and the like, which have added so much to the production and wealth of the State.

New Zealand.—The gold discoveries of 1851 had evidently put the few white men located here on the *qui vive* for anything of value in the ground, and possibly led to the discovery and extraction of the kauri gum, which has yielded many millions sterling to the science, enterprise, and industry of the Dominion, for its introduction into the industries of the Southern Hemisphere took place soon after that of gold digging, and four years before the discovery of payable gold in those islands, and kauri gum leads the way in the working of minerals, although scarcely reaching that stage at which its mineralised character would be acknowledged. However, coal and other substances have their progressive stages, and kauri gum can scarcely be remitted back to the vegetable kingdom. A discovery of gold was reported in 1852, but came to nothing; a further discovery was made in 1857, and this began the business of gold mining in New Zealand, which improved as time went on until the time of your last meeting in Queensland, when the output of gold had amounted to £49,300,939, whilst the inferior metals and minerals, comprising coal, kauri gum, silver, copper, chrome, antimony, manganese, hæmatite, and mixed minerals to the value of £11,617,524, made up a total of £60,918,463. In the last year of the period (1893) the total output of gold was

£913,138; silver, £9,743; coal, £383,958; kauri gum, £510,775; antimony, £3,467; manganese, £943; mixed minerals, £650; making a total output of £1,822,674 for the year. With the two most important elements of wealth, coal and gold, promising an abundant output for many years.

We can now see the total production up to the time of your previous meeting in Brisbane. It may be mentioned, however, that in the last year of the period now under consideration an important operation in mining and geology had been completed; the result of geological reasoning and practical work. The perforation of a thick seam of coal at a depth of nearly 3,000 ft. beneath the waters of Sydney Harbour is a gratifying result of the advantage of geological science applied to the useful arts of life. However, with the exceptional yield of gold in Victoria, so well supplemented by those of New South Wales, Queensland, and New Zealand, as well as the lesser production of the other colonies, gold mining (as distinguished from gold digging) had become fully established, and a promise of long continuance was held out by the prospects in West Australia, and at Mount Morgan in Queensland, then both quite recently discovered.

Not to encumber this paper with too many statistics, it may be said that the total production, up to the close of 1893, was approximately £473,000,000 sterling, of which Victoria contributed one-half, New South Wales 22 per cent., Queensland 8½ per cent., South Australia 4¾ per cent., West Australia ·28, Tasmania 1·6, and New Zealand 12·9 per cent. The relation of the production of gold to that of other minerals was as 100 to 31·2, or gold 76·20 per cent., and the others collectively 23·8 per cent. Thus the production of gold, chiefly the phenomenal yield of alluvial gold in Victoria, surpassed in value the mineral productions, other than gold, of all the colonies, including New Zealand, from their foundation by 219 per cent. But the relative proportion of production during the last year of the period was as gold 100 to other minerals 99·4, or as nearly as possible equal amounts, and the yield during that year exceeded the greatest collective yield ever obtained, even in the palmiest days of the alluvial of Victoria and New South Wales.

Table showing the production of the principal metals and minerals in each of the States of the Commonwealth of Australia and the dominion of New Zealand during the year 1893:—

Mineral Products.	New South Wales.	Victoria.	Queensland.	South Australia.	West Australia.	Tasmania.	New Zealand.	Totals.
	£	£	£	£	£	£	£	£
Gold	651,286	2,684,504	2,159,290	12,561	429,702	141,326	913,138	6,991,807
Silver, lead, and ore ...	3,035,925	...	42,408	605	...	198,610	9,743	3,287,291
Tin	229,743	2,170	106,953	...	11,400	260,219	...	610,485
Copper	58,426	...	3,822	214,775	...	...	...	277,023
Coal, coke, and shale	1,293,176	51,374	125,340	...	...	27,754	383,958	1,881,602
Kauri gum	...	...	...	...	...	...	510,775	510,775
Iron	16,312	...	...	...	...	...	...	16,312
Antimony	25,092	431	288	...	...	...	3,467	29,278
Bismuth	...	...	10,676	...	...	...	...	10,676
Gems and opal ...	12,315	...	4,500	...	...	...	...	16,815
Salt	...	...	...	...	...	...	...	...
Stone, clay, &c. ...	112,111	...	...	...	...	...	...	112,111
Wolfram	...	...	...	...	...	...	...	...
Manganese	...	...	...	6,359	...	...	...	6,359
Various minerals ...	4,146	45	...	190	...	...	1,593	5,974
	5,438,532	2,738,524	2,453,277	234,490	441,102	627,909	1,822,674	13,756,508

It is necessary to remark that in sundry details discrepancies may be discovered. The gold was valued at arbitrary rates in the different colonies in the early days; some included earthy minerals in the mining statistics, and others did not, except as to coal and its kindred shale, and the gems and precious stones; and some have first omitted and then included them, but the results given may be taken as a very close approximation to the actual production.

The period from the close of 1893 to that of 1900 will now be taken, with as little detail as possible. Coal and its kindred shale, the principal production of the parent colony, continued to increase, although the price may not always have been satisfactory. The gold of Victoria and the copper of South Australia fell off, but the production in all the other colonies increased largely, and other metallic minerals, as well as valuable non-metallic constituents of the crust of the earth, were pressed into the use and service of the human race, until there is scarcely a mineral known in the markets of the world or in the domain of science that is not found in the mines of the Commonwealth or of the Dominion. New Zealand had been favoured with a very valuable alluvial deposit of gold, which was unearthed chiefly between 1862 and 1880, but notwithstanding all the easily acquired wealth of the alluvium of Victoria, New South Wales, and New Zealand (which unfortunately was only of a transient nature), it is now found that the more prosaic and permanent form of mining, and that largely for the so-called useful metals, as distinguishing them from more ornamental or precious metals, is likely to enrich the southern hemisphere to a greater extent than has been done by the bountiful provision of Nature in the alluvial deposits above-mentioned.

The greatest production ever attained was about 13½ millions sterling, including the copper of South Australia and the gold, coal, and other products of New South Wales. Queensland was then a part of New South Wales, West Australia, Tasmania, and New Zealand were not producers. The production of minerals in 1893 exceeded the above amount, which was largely due to the increasing output of lead and silver, and coal, tin, copper, antimony, and other of the useful metals.

We cannot but regret the exhaustion of the alluvial deposits, nor can we say that Nature has ceased to operate, but a thousand years are but as one day in that respect, and we must take up the work as we find it. The geologist and miner step in and follow the lead which Nature has given them, and hence not only a supply of the precious metal is kept up, but others are discovered, and utilised in a similar manner, until, as has been indicated, the last year of the period in point of time is the first in point of production, and only half of it due to the production of the precious metal, gold. The proportion furnished by each colony has been given, but a great change had taken place, and during the year 1893 the mother colony supplied 39 per cent. of the total output, Victoria 19·63, Queensland 18·9, South Australia 1·73, Tasmania 4·5, West Australia 3·14, and New Zealand 13·05.

The kauri gum of New Zealand is, and has been, an important factor in keeping up the output of the Dominion; there is reason to fear, however, that it will prove in one respect too much like alluvial gold in the fact of its possible early exhaustion. The coal of New Zealand is also a valuable and much more permanent asset. During the period 1893 to 1900 the conditions above-mentioned continued; the production of gold from reef mining continued to increase, the silver, copper, tin, coal, and other important treasures of the earth lent their aid, and new sources of wealth were developed in the opening up of the wolfram, scheelite, molybdenite, and similar deposits. The production of gold was also greatly augmented by the rich reefing mines of West Australia, so that by the end of the first period of seven years the annual output had nearly doubled, the production of the year 1900 reaching the very respectable total of £24,413,257, in which production the parent colony kept the lead with 26·76 per cent., closely followed by Western Australia, whose share was 25·28 per cent. of the whole, and far behind comes Victoria with 13·85, and Queensland with 13·02, New Zealand with 11·07, Tasmania 7·75, and South Australia with the Northern Territory 2·27 per cent. making a hard struggle with copper and a few minor productions against the glittering gold of the Eastern and Western States, for notwithstanding the apparent falling off in the production of the precious metal and the very large increase in the production of coal, both in New South Wales and New Zealand, as well as the silver of Broken Hill, and the copper and tin of Queensland, gold is still the predominant factor in the statistical register, for during the seven years 1894-1900 inclusive the production of gold was nearly eighty millions sterling, while that of the inferior metals and minerals was little more than half that amount, being respectively 65 and 35 per cent. of the whole. The increase in the production of gold in 1900 being nearly 115 per cent. over that of 1893, the increase on other mineral production being 37 per cent. One important item in the increase, sudden and surprising, was the yield of gold in West Australia, while both Victoria and Queensland had a prosperous time. The total production during the seven years ending with the year 1900 was about fifteen millions sterling of gold, a proof that the industry of gold mining in the southern hemisphere was still a most important factor in the prosperity of the Commonwealth and the Dominion, and it was then seen that it became a powerful lever in developing the agricultural resources of the continent, as well as those of the islands of Tasmania and New Zealand. It has opened up as large a tract of country in West Australia for agriculture as would constitute two or three ordinary European kingdoms; it has made oases in the desert by the introduction or procuration of water; it has made possible the timber trade as a valuable adjunct to the commerce of the country; and has enlarged the opportunity of developing the enormous resources of silver, tin, copper, lead, and the other known metalliferous deposits existing there, and has brought within the arena of industrial possibility all the hidden treasures of more than a million square miles of country, whether for pastoral, agricultural, mining, or other occupation. And this has been largely due to the labours of the brothers Gregory, Nicolay, Hardman, Woodward, and the present staff in the office of the Government Geologist of that State, who have endured the hardships and enjoyed the privileges of examining the country from a geological standpoint, and have left it the richer, financially and intellectually, by the result of their labours.

Table showing the production of the principal metals and minerals in each of the States of the Commonwealth of Australia and in the Dominion of New Zealand during the year 1900, in pounds sterling :—

Minerals Produced.	New South Wales.	Victoria.	Queensland.	South Australia.	West Australia.	Tasmania.	New Zealand.	Totals.
	£	£	£	£	£	£	£	£
Gold	1,194,521	3,229,628	2,871,566	14,194	6,007,610	316,220	1,439,602	15,073,641
Silver, lead, and ore ..	2,743,263	..	16,071	21,908	4,127	279,372	38,879	3,103,620
Tin	120,932	5,017	74,041	774	56,702	269,833	. .	527,299
Copper	428,036	...	23,040	394,446	43,673	970,877	45	1,860,117
Coal, coke, and shale	1,799,182	101,599	173,705	...	54,835	44,227	588,778	2,762,326
Kauri gum	...	...	...	...	...	...	622,293	622,293
Iron	106,631	...	...	...	9,258	5,995	...	121,884
Antimony	2,429	...	...	...	...	...	101	2,530
Bismuth	5,640	...	1,865	...	...	...	...	7,505
Gems, opals, &c. ...	85,663	...	8,400	...	...	...	...	94,063
Salt	...	...	...	37,276	...	...	...	37,276
Zinc	44,187	...	...	...	...	...	...	44,187
Stones and clays ...	14,777	44,000	...	...	...	...	...	58,777
Wolfram	...	...	6,605	440	...	2,058	...	9,103
Undefined	...	...	4,628	616	3	113	13,449	18,809
	6,545,261	3,380,244	3,179,921	469,954	6,176,208	1,888,695	2,703,147	24,343,430

At the outset of our career as a Commonwealth we find that the mineral production of Australia and New Zealand for the previous year, that of 1900, was £24,343,430, gold having yielded nearly two-thirds of the amount, and we have to remember that gold is not like an agricultural production, which, like wheat or sugar, or tares, can be produced again and again from the same piece of land. When once removed that operation cannot be repeated. And yet, history tells us that the tin in Cornwall has been operated on for 2,500 years, and, to go still further back, Adam found that the gold of Havilah was good, and it was evidently very soon and very largely worked, and yet, gold is still being largely worked; and in Australia and New Zealand, where its discovery is of a much more recent date, it may be hoped that the period of its exhaustion is very remote, and that as successive meetings of your Association are held in Brisbane, successive statistical reports may show that the occupation of the gold miner is more than ever largely in demand.

The indications during the first seven years of our existence as a Commonwealth are in favour of an optimistic view, for while the increase has not been large, the former production has been fully maintained, and with half a million to the good; and during the same period the production of the useful metals and minerals has largely increased, having, perhaps, for the first time since the discovery of gold, in 1851, exceeded that of the precious metal itself. The increase during the year 1907 over that of 1900 is over 80 per cent., for which we are indebted to the silver-lead, &c., and the coal of New South Wales, and the copper, tin, and silver of Queensland and Tasmania.

The fact that the production of gold has "pursued the even tenor of its way" with only something less than 3 per cent. increase is sufficient evidence that there have been no startling discoveries during the interval. That, however, only refers to the last years of the respective periods, but when we compare the whole periods of seven years we find there was a very material increase, West Australia making an advance of thirty-four millions sterling, and New Zealand an advance of six millions sterling in that time, so that the increase of the gross amount was, of gold, nearly 50 per cent., and of the useful metals and minerals 80 per cent., the increase on the whole production being 60 per cent.

One matter that attracts the attention of the statistician is the great variety of valuable productions in the States, more especially of New South Wales and Queensland. And as proving the advantage of gold production in assisting in the production of the useful metals or stimulating the search for them, or causing their discovery when unlooked for, we find that during the seven years, 1901 to 1907, more than one and three-quarter millions of other ores were produced in the Western State, one-fourth of it in the last year of the period, showing the gradual improvement which is taking place in the production of that class of minerals in a State in which their existence has long been known, but until the advent of the gold miner, and the requirements of his craft, aided by the production of his hand and brain, opened the country, cleared the paths, brought in the railways, made the getting of supplies of food and other necessaries of life possible, the profitable extraction of the useful metals could not be attempted.

Table showing the production of the principal metals and minerals in each of the States of the Commonwealth of Australia and the dominion of New Zealand during the year 1907:—

Minerals Produced.	New South Wales.	Victoria.	Queensland.	South Australia and Northern Territory.	West Australia.	Tasmania.	New Zealand.	Totals.
	£	£	£	£	£	£	£	£
Gold	1,050,730	2,954,617	1,981,461	20,540	7,210,747	277,607	2,027,490	15,523,192
Silver, lead, &c. ...	4,290,128	4,355	187,870	11,780	31,469	572,560	169,484	5,267,646
Tin	293,305	10,531	496,766	...	158,648	501,681	...	1,460,931
Copper	727,774	2,356	1,028,179	698,000	80,387	869,666	595	3,506,957
Coal, &c.	3,113,788	79,731	222,135	...	55,158	50,057	965,781	4,486,650
Kauri gum	...	...	...	...	...	...	579,888	579,888
Iron and ore	188,300	...	24,327	38,100	438	1,150	5	252,320
Antimony	46,278	13,290	7,863	...	...	...	2,118	69,549
Bismuth	5,268	...	3,024	...	...	27	...	8,319
Scheelite	23,781	...	320	...	...	...	...	24,101
Wolfram	26,235	...	89,767	...	...	4,411	...	120,413
Zinc and conc. ...	536,620	...	...	...	...	...	...	536,620
Gems, opals, &c. ...	81,056	...	43,500	...	...	...	...	124,556
Building stones ...	164,125	...	...	13,880	...	...	...	178,005
Marble	2,200	...	35,808	...	...	...	...	38,008
Salt	...	...	...	37,500	...	...	...	37,500
Sundries	27,788	1,961	13,666	2,500	1,382	...	30,474	77,771
	10,577,376	3,066,841	4,134,686	822,300	7,638,229	2,277,159	3,775,835	32,292,426

It is a matter for regret that so little is heard of the mineral assets of the Northern Territory of South Australia. Whether it has fallen out of the ranks of the producing lands, or is so far distant from headquarters as to escape notice, need not be particularly stated, but little mention is made of it in the mining reports of the State. No eulogy could be stronger than has been given touching the mineral-bearing character of the country. Gold, silver, copper, tin, lead, and iron have all been found, to say nothing of the various minor metals and minerals, which promise to be sources of profit to the future inhabitants. It was once said by a Government Resident that "in the search for gold the European is not in it with the Chinaman," and probably for the present the white Australia sentiment deprives the

Commonwealth of the advantage of the production for which the Chinaman proved so eminently fitted, but which will reappear when the European constitution becomes acclimatised to the atmospheric conditions and the terrestrial environment, and we trust that the time is not far distant when "the peninsula of Arnhem Land will become one of the great mining centres of Australia."

It is pleasing to notice in recent reports that another territory claims a place in the statistical tables of the production of gold, for Papua or New Guinea figures in them for £39,710. This beginning from a country, the share of which allotted to Great Britain, with the islands on its coast, is of greater area than Great Britain itself, is but a premonition of the possibilities which are indicated by the general conformation of the surface, in which mountains arise rivalling the Rockies, which have yielded so much wealth in America, and on which, owing to their elevation, no difficulty will be experienced by the delicate European constitution.

The advantage of gold mining in the development of other metalliferous mining has been shown, and now we may illustrate its advantage in the encouragement of agriculture. The opening of the country, as in West Australia, has been mentioned, the case of Victoria whose agricultural industry has been founded and built up on the production of her gold mines is a point in that direction, and a case in Queensland, which is now attracting attention, shows a novel but quite practicable combination; the Mount Morgan Company, at their Many Peaks mine, with the concurrence and assistance of the Government, propose to have the land for ten miles along their railway reserved from selection by the general public in order that their workmen at the mine may secure agricultural homesteads in proximity to their work at the mine. The transit to and fro is done in the manner proposed at Bundamba now, and it was done underground three-quarters of a century ago—by horse traction where the workings were far from the shaft.

And this form of settlement need not be confined to the strictly agricultural farming (in the narrow sense of the word), but will more thoroughly serve its purpose by cattle raising, dairy farming, and fruit growing, which do not so constantly require the presence of the "head of the house" during the whole of the day or even the major part of it.

The visitors from the Dominion of New Zealand will know how largely the twenty millions of easily-gotten alluvial gold assisted in developing the agricultural industries along the seaboard of the Dominion, and how the population was increased, its wealth augmented, and commerce with other lands developed by the gathering in of this golden harvest.

It has been seen that mining for gold assists in the development of other metalliferous mining, also in that of agriculture and pastoral occupation, as well as in the more primitive operations of gathering the harvest already waiting on the land. But there is another class of mining and another form of enterprise to be considered, as well as the commerce engendered thereby. It is only necessary to refer to the great service that a good supply of coal does to the neighbourhood in which it is found, and the prominent position of the production of coal in New South Wales in 1907 proves that the demand exists for its use; it has become proverbial that a coal mining district means a manufacturing town. Their names are too well known in England, America, and these States to need recapitulation. Not only do they cheapen manufactures by supplying an indispensable requisite, but to some extent form a market for the manufactured articles. The coal mines of New South Wales supplied more than three millions sterling worth of coals last year, New Zealand nearly a million's worth, Queensland nearly a quarter of a million's worth, and West Australia, Victoria, and Tasmania gave smaller amounts, and it is one of the fortunate circumstances of our position that we can supply the possible demands of the Southern hemisphere with all its requirements in the matter of coal. This means its use in the commerce of the country, whether interstate or intercontinental, whether on land or sea, whether for light as gas or to gather and store the electric fluid. It is used to cool the mine and to raise the steam, to cook the breakfast, or to drive the leviathan of the deep. But all the interests are interdependent.

And while the wandering of the nomadic hatter and the working of the industrious miner have not infrequently become the means of discovering metals and minerals of which they were not in search, they have sometimes been rewarded beyond their most sanguine expectations by the discovery of such in immediate connection with those on which they were at work. Valuable gems, precious stones, even diamonds and sapphires, have been found in connection with the gathering of stream tin or otherwise, for we find that diamonds have been found in New South Wales; for in a single annual report mention is made of diamonds, emeralds, opal, and gems, and of the single item, noble opal, more than worth a million sterling has been obtained. Victoria claims the possession of diamonds, sapphires, &c.; Queensland possesses diamonds, sapphires (the sapphire fields of Anakie are in good repute), opal, emerald, the turquoise of Keppel Island, ruby, topaz, agates, and all the minor gem stones; South Australia has not been unmindful of these ornaments of the feminine form, and useful adjuncts to the stock of the lapidary and the craft of the jeweller. West Australia has produced them, so that all the continental States possess them. New Zealand, too, can lay claim to their possession, and probably is the most likely member of the group to yield them in quantity. Tasmania only goes the length of having a lease in force to search for precious stones. Tourmaline, rock crystal, amethysts, jasper, and the like are well known throughout the States, and doubtless many of these, and other stones more massive, but which take an excellent polish, will in a short time become objects of industrial pursuit and profit.

Another rare and valuable mineral, the representative of a class, is found both in New South Wales and Queensland, that is, platinum; it is, however, a metal, and found on the sandy shores of our coast, and may yet be found in the undisturbed alluvium of the littoral adjoining.

The minerals of which an account has been obtained, it will be seen. have amounted to £792,360,278, a large sum for the few people who have been in these colonies, and have been engaged in that enterprise; and, with the exception of New South Wales and Victoria, it does not appear that they include in that category the output of building stone, lime, cement, slates, flags, or clay, or any such materials, which are as necessary for use within the States as are the metalliferous minerals for exportation, and even the latter class may be largely used within the States under present conditions, as iron, mercury, and the like. Coal is not a metalliferous mineral, and is almost entirely used in, or in connection with, the States, but worthily finds a place in the statistics of production. The States have fallen into line in estimating the gold production by the return of fine ounces from the Mint, and they would do well to go further in that direction, and fall into line touching the inclusion of all such minerals as those indicated. We do well to aim at supplying our own wants, to cultivate that spirit of "self-dependent power which time defies," it saves the cost of transit and exchange. And taking these unconsidered trifles into account, as is done in Great Britain, the States would be on an equal footing, and the mineral statistics more complete and correct.

It may be stated briefly that the increase or benefit or "progress" achieved during the two septennial periods has been, on the total output, 77 and 32·6 per cent. The increases in each class have already been given. The increase since your last meeting has been, on gold, 122 per cent., and on other metals and minerals 149 per cent. On the whole production it has been 135 per cent.

The foregoing remarks deal almost exclusively with the progress of mining, whilst that of geology has not been so particularly specified, nor is the writer aware of any very special discovery having been made by the devotees of that science recently, but the regular routine work of examination, mapping, and reporting has been diligently and persistently carried on throughout all the States and the Dominion by energetic and competent men, whose hearts are in the work, and who feel that they are adding to the sum of useful human knowledge, laying bare the secrets of Nature, and opening avenues of profitable employment for thousands of their fellow men, who will follow in their wake as prospectors, miners, and others for whom such openings provide employment. The proper function of the geologist is not to usurp the legitimate duties of his followers or successors; the scientific aspect of the land in which we live is the field of his exploration; he may indicate the nature of the formations which come under his notice, he may suggest the possibility, even the probability, of their containing metalliferous deposits, he may state that this is a carboniferous area, and may contain coal and iron. That is an ancient granite, which may contain tin lodes, or being decomposed by atmospheric and other influences, may give rise to a deposit of tin in the plains or the streams below. Another may be metamorphic, gneiss, clay, slate, or any of the various grades, which indicate silver, copper, or other metallic minerals. He paves the way for the prospector and miner, who, having been preceded by the geologist, are not likely to sink large fortunes in boring and sinking for coal, as has been done in England, where no coal could possibly be present. The benefits which geological science has conferred on these States and the Dominion in pointing out the probable position of metallic deposits, or in actually discovering them, have been enormous, and in one matter alone it is quite impossible to estimate the benefit which has been conferred, that of indicating the presence of artesian water, and the possibility of releasing it. It does not require an unreasonable stretch of imagination to believe that this one outcome of the science on which your minds are bent may be worth as much to the States where it is available as all the gold which can be obtained in that State; and while the working of the metals and minerals gives employment to something like 150,000 men, it will be admitted that this means the direct support of 600,000 people, and, indirectly, to the support of at least as many more. It may be that other occupations, other forms of enterprise, other methods of stimulating the outpouring of the gifts of Nature, yield more wealth, but do they give regular support and occupation to a greater number of people? In many cases a farming population may create a township and support it, but a mining township creates an agrarian population, who are made the richer and happier by their proximity to a township which produces wealth and makes a market for their produce. This is of greater mutual advantage than when the produce of the farm has to bring in the cash to support both town and country.

The number of men employed is necessarily variable, nor is it at all times easily ascertainable. The numbers at the end of 1907 may be taken in round numbers as—New South Wales 44,000, Victoria 27,000, Queensland 22,000, South Australia 6,500, West Australia 20,000, Tasmania 7,500, and New Zealand 13,000. These sum up to 140,000. There is, of course, a large number of timber-getters, horse or bullock drivers, carters, and others who are necessary and find regular employment but are not miners, and others who, having farming homesteads, take an occasional spell in the gullies but can scarcely be called miners, and for these 10,000 may be allowed, making as above suggested 150,000.

To give a bare catalogue of the minerals which have been noted and named in Australia would require a volume on its own account, solid they have chiefly been, liquid in the case of mercury found in Queensland, New South Wales, and New Zealand, petroleum oil found in New Zealand, and recently we have had evidence of something of the kind in a gaseous form, the optimistic view of which is that it indicates the presence of large accumulations of oil, or it may be the exudations of gas from large and deep-seated seams of coal. In either case, with cavities in the vicinity without any outlet, gas would exude, and be retained until the pressure was equal to that of its source, or until it found an outlet. It is, however, another indication of our limited knowledge of the composition or contents of the crust of the earth, even to the depth of a few hundred feet, which those who study geognosy estimate to be solid for a few hundred miles out of the four thousand which are comprised in the radius of this little globe which we inhabit.

Table showing the production of Gold and other Metals and Minerals in the States of the Australian Commonwealth and the Dominion of New Zealand from their foundation to the close of the year 1893; and thence to the foundation of the Commonwealth at the close of the year 1900, and to the close of the year 1907, the latest for which returns are now available.

States, &c.	1893.			1900.			1907.			Total Production.		
	Gold.	Other M. and M.	Totals.	Gold.	Other M. and M.	Totals.	Gold.	Other M. and M.	Totals.			
	£	£	£	£	£	£	£	£	£	£	£	£
New South Wales	39,853,942	64,426,769	104,280,711	7,988,138	20,872,423	28,860,561	7,522,802	42,473,686	49,996,488	55,364,882	127,772,878	183,137,760
Victoria	235,090,220	1,305,634	236,395,854	22,296,228	3,963,520	26,259,748	22,085,147	1,167,552	23,252,699	279,471,595	6,136,706	285,908,301
Queensland	31,051,044	9,148,988	40,200,032	17,627,648	2,376,410	20,004,058	17,635,836	8,485,000	26,120,836	66,314,528	20,010,398	86,324,926
South Australia and Northern Territory	333,857 1,043,720	20,732,099	22,109,676	153,583	2,020,519	2,174,102	239,559	3,535,122	3,774,681	1,770,719	26,287,740	28,058,459
West Australia	941,325	361,750	1,303,075	21,533,500	906,655	22,443,155	55,517,412	1,782,917	57,300,329	77,995,237	3,051,322	81,046,559
Tasmania	2,161,920	5,463,277	7,625,197	1,892,634	5,704,421	7,597,055	1,976,089	10,162,868	12,138,957	6,030,643	21,330,566	27,361,209
New Zealand	49,300,939	11,617,524	60,918,463	8,105,161	7,0[illegible]1,357	15,186,518	14,122,878	10,295,205	24,418,083	71,528,978	28,994,086	100,523,064
TOTALS	359,776,967	113,056,041	472,833,008	79,599,892	42,925,[illegible]05	122,525,197	119,[illegible]99,723	77,902,350	197,002,073	558,476,582	233,883,696	792,360,278

9.—FURTHER OCCURRENCES OF TANTALUM AND NIOBIUM IN WESTERN AUSTRALIA.

By EDWARD S. SIMPSON, B.E., F.C.S., Government Mineralogist and Assayer of West Australia.

At the Adelaide meeting of the Association, in 1907, I had the honour to present a paper embodying all the then available information with regard to the occurrence of tantalum and niobium in Australia. Whilst no new finds of minerals containing these metals in the Eastern States have come under my notice in the meantime, a considerable amount of further information has been collected with regard to West Australian occurrences, which it is the object of this paper to describe.

Until quite recently it was a matter of impossibility to separate occasional fragments of black tantalates and niobates from parcels of black stream tin except where they showed well-developed crystal faces or other prominent characteristics. The publication, in Volume VIII of the "Journal of the Chemical, Metallurgical, and Mining Society of South Africa," of Prof. G. H. Stanley's "New Test for Cassiterite," has very materially altered the aspect of affairs. This method is invariably used by the author in his examination of tin ores for rare minerals. A shallow dish about 4 inches by 3 inches is made by turning up the edges of a piece of stout sheet zinc; in this are placed the concentrates in the form of sand or coarse fragments up to ½ inch diameter, and then covered with dilute (5E) hydrochloric acid. In about one or two minutes the acid is poured off and replaced with water, when all fragments of cassiterite which have been in contact with the zinc are found to be coated with a bright deposit of metallic tin so that they can easily be picked out, leaving a residue of other minerals which are not appreciably affected by the short immersion in dilute acid. This residue is submitted a second time to the same process, as possibly it may contain some fragments of cassiterite which are not coated because they have not been in contact with the zinc. After drying the final residue, it is freed from magnetite with a hand magnet, and if necessary from ilmenite by a weak electro-magnet. Hand-picking will remove quartz, monazite, &c. The final residues are then examined by chemical and physical tests for the tantalum minerals, tantalite, euxenite, &c.

If the method here outlined were applied to all samples of tin concentrates in the possession of members of the Association, it is possible that our knowledge of the distribution of tantalum and niobium in Australia would be greatly extended.

MOOLYELLA.—In my previous paper mention was made of the recognition of two small pieces of mangano-tantalite in Moolyella stream tin ore, whilst it was suggested that in such material others might easily be overlooked. During the collection of exhibits for the Franco-British Exhibition some most interesting bulk samples of concentrates came to hand from Moolyella. One was marked "Sluice-box residues, Macdonald's Lead", and subsequent inquiries elicited that it was representative of the lighter waste material obtained by resluicing the first concentrates obtained from the sluicing of alluvial tin wash.

These "residues" were somewhat coarse grained, the particles averaging about 3mm. in diameter and only 0·2% passing a 10-mesh screen. A separation effected on the lines described above showed its composition to be—

Cassiterite	26·3	per cent.
Monazite	26·2	,,
Garnet	1·0	,,
Columbite	46·5	,,
	100·0	per cent.

The chief base present in the columbite is manganese. The average specific gravity is 6·1, indicating the presence of about 40% of tantalic oxide and 43% of niobic oxide. The mineral is opaque and black in colour, and rather dull on the surface. The majority of the fragments are quite irregular in outline, but a large number are in flattened pieces, in which the faces XX, a, and a¹ are well developed. Faces b, c, and possibly u are imperfectly seen.

Columbite having been found in such profusion in this material, a search was made for it in three one-hundredweight parcels of stream tin concentrates from the Moolyella district. The first was from Moolyella proper, the second from Tadgebanna, the third from Mud Springs. The following results were obtained:—

	Moolyella.	Tadgebanna.	Mud Springs.
Size—Refused 20 mesh ...	67·0	89·4	96·3
Passed 20 mesh ...	33·0	10·6	3·7
Metallic tin by wet assay ...	61·08%	61·21%	65·17%
Tantalic and niobic oxides	12·34%	10·86%	6·95%
Equal to columbite ...	15·5%	13·5%	8·5%

Some of the carefully separated columbite was found to be identical in appearance with that obtained from the "Sluice-box Residues". One unusually large fragment had a specific gravity of 5·80 corresponding to a mangano-columbite with 26% of tantalic oxide and 56% of niobic oxide. Associated with the cassiterite and columbite were small proportions of an almost colourless garnet, monazite, magnetite, quartz, and in one case albite.

Cooglegong.—This continues to maintain its reputation as a mineral field of exceptional interest. In my previous paper reference was made to the occurrence at this spot of euxenite, monazite, and gadolinite. I have now to record further the occurrence of fergusonite for the first time in Australia. A parcel of alluvial material recently forwarded to me from Cooglegong, and described as coming from a gully on the sides of Trig Hill, was found to consist wholly of this mineral in a more or less weathered state. Individual fragments varied from about $\frac{1}{2}$ gramme up to 6 or 7 grammes in weight. They were mostly angular pieces devoid of crystalline form, but some were somewhat fan-shaped imperfect crystal aggregates. Externally the pebbles were mostly dull and covered with a brownish red or grey adherent coating, consisting of decomposition products. On a fresh fracture the mineral is brownish black and brilliantly vitreous. It is opaque except in very thin splinters under the microscope, when it is transparent, colourless or very pale greenish brown in colour, and completely isotropic. This latter characteristic is of considerable interest, and has not been previously recorded. Normally the mineral being tetragonal is anisotropic. An analogy, however, is found in other minerals containing the rare earths—viz., gadolinite, thorite, and allanite, all of which are normally anisotropic but become by alteration abnormally isotropic. The powder is light ash grey in colour.

The specific gravity of various fragments differed considerably, the following values being obtained:—5·82, 6·01, 6·24, 6·48, 6·65. This variation may be due either to differences in the water content, or to differences in the relative proportions of tantalic oxide and niobic oxide. A crystalline fragment weighing about 6 grammes was selected for analysis and coarsely crushed, all particles showing weathered surfaces being then rejected. The unweathered portion remaining had a specific gravity of 6·236 at 22·9°, and a hardness of 6. Before the blowpipe it was infusible and did not decrepitate or glow, but turned light yellow in colour. In the closed tube it yielded water. On crushing it yielded a greyish white powder. Its composition was:—

Fergusonite, Cooglegong.

	Per Cent.	Molecules.
Tantalum pentoxide	55·51	12·5
Niobium pentoxide	2·15	·8
Titanium dioxide	2·20	2·7
Tin dioxide	nil	—
Thoria	1·02	·4
Yttria	23·00	10·2
Erbia	8·38	2·2
Ceria	·94	·3
Lime	2·18	3·9
Iron protoxide	trace*	—
Manganese protoxide	·87	1·2
Uranium trioxide	1·18	·4
Ignition loss (mainly water)	3·36	18·7
	100·79	

The water is evidently an alteration product and probably varies in different parts of the one specimen. Neglecting this, we get the usually accepted formula for Fergusonite, viz.:—

$$R_2O_3.Ta_2O_5.$$

This particular example of fergusonite differs from all others hitherto described in two interdependent factors—viz., in its high specific gravity and in the very high proportion of tantalum relatively to niobium. It is probably one of the two minerals "allied to euxenite in physical characteristics" alluded to by Mr. B. F. Davis.

The mineral collection of the Perth Museum having now been amalgamated with that of the Geological Survey, opportunity has occurred for examining in detail the parcel of euxenite in the former collection referred to in my 1907 paper. This parcel was found to

* Less than 0·10 per cent.

consist (except for three fragments) of euxenite in angular pieces from half a gramme up to fifty-seven grammes in weight. Several showed indistinct traces of crystal faces. Associated with the euxenite was one piece of cassiterite and two of gadolinite. The locality of this specimen is undoubtedly Cooglegong, and it is alluvial in origin. The surface of the mineral is dull and brown in colour from decomposition. On a fresh fracture it has a brilliant resinous lustre, and is olive brown in colour. On wetting, the colour is seen to be somewhat mottled, varying from light to dark olive brown. In mass it is opaque, but in a powder under the microscope it is transparent, light brown and, like the fergusonite, isotropic. Its hardness is 7 and specific gravity 5·1 to 5·4. The central portion of a fragment weighing about twelve grammes was taken for analysis.

Euxenite, Cooglegong.

Tantalum pentoxide	23·10	per cent.
Niobium pentoxide	4·35	,,
Titanium dioxide	30·43	,,
Tin dioxide	nil	
Thoria	1·76	,,
Yttria	15·76	,,
Erbia	9·27	,,
Ceria	1·82	,,
Lanthana and didymia	1·73	,,
Lime	1·02	,,
Iron protoxide	trace	
Manganese protoxide	·34	,,
Magnesia	·35	,,
Uranium trioxide	6·69	,,
Alumina	·76	,,
Ignition loss	2·82	,,
	100·20	per cent.

Sp. gr. 5·37.

A sample of alluvial tin ore from Cooglegong in the Geological Survey collection (No. 2026) was examined by Prof. Stanley's method. 30 grammes yielded 28·3 grammes of cassiterite and a residue of thirty-one small fragments, three of which were quartz, three magnetite, and one monazite. The remaining twenty-four appeared to include both euxenite and fergusonite.

A parcel of alluvial monazite concentrates from Cooglegong contained small proportions of cassiterite, euxenite, columbite, and probably fergusonite.

Another sample of alluvial tin ore from the Shaw Tinfield, near Cooglegong, was also examined. It was somewhat fine grained, 70% passing a 10-mesh sieve. Twenty-five grammes of the coarser particles were tested and yielded 93% cassiterite. Most of the balance was monazite, but a few small crystals of tantalite were present.

Wodgina.—In my previous paper mention was made of the occurrence of microlite in this district, and as this mineral had not previously been recorded in Australia an incomplete analysis of it was submitted to you. The analysis has since been completed, the final results being:—

Microlite, Wodgina.

Tantalum pentoxide	73·54
Niobium pentoxide	3·62
Tin dioxide	·90
Lime	13·46
Magnesia	·42
Iron protoxide	3·64
Manganese protoxide	·60
Potash	·20
Soda	1·66
Ignition loss	1·28
	99·32
Sp. gr.	5·422

No traces of ceria or yttria were detected in it.

Another interesting mineral has recently been received from the Wodgina district. It occurs in a very fresh state in a matrix of granular albite, the latter with a little quartz and muscovite forming about 72 per cent. of the ore. The remaining 28 per cent. consists of a tantalate with a somewhat resinous lustre, and varying in colour from pale cinnamon brown to dark brown. It occurs in indistinct crystalline aggregates, the system of which has not been determined. In thin slices it is subtransparent, and apparently homogeneous except for gradual slight variations in the depth of colour, which apparently deepens under alteration along cleavages, &c. Carefully selected material was analysed with the following results:—

Ixiolite (?), Wodgina.

	Per Cent.	Molecules.
Tantalum pentoxide	70·49	15·9
Niobium pentoxide	7·63	2·8
Tin dioxide	8·92	5·9
Manganese protoxide	10·87	15·3
Iron protoxide	1·34	1·8
Lime	·42	·7
Magnesia	·37	·9
Ignition loss	·18	—
	100·22	
Sp. gr.	7·36	

If the tin is present in combination this yields a formula—

$$3MnO.3Ta_2O_5.SnO_2.$$

In the large proportion of tin oxide and in the light brown colour of the powder it resembles the ixiolite of Nordenskiold (Kassiterotantal of Hausmann), until, however, its crystallographic system has been determined and its apparent uniformity in tin contents confirmed, its exact species must remain in doubt. The typical mangano-tantalite of Wodgina differs from it in several respects, viz.:—

(1) It contains far less tin oxide (0·5% as against 8·9).

(2) It is not quite so hard (6·5 as against 7·0).

(3) It is quite opaque even in very fine powder.

(4) Its colour is black and streak brownish black.

(5) Its lustre is very different.

It resembles on the other hand this mineral somewhat closely in

(1) Specific gravity (7·4 and 7·1).

(2) Ratio of basic protoxides to acidic pentoxides being one to one.

(3) Chief base being manganese, chief acid tantalic.

(4) Absence of rare earths from both.

Greenbushes.—Up to the time of the writing of my previous paper no traces of crystalline form had been observed on any of the Greenbushes tantalite. I have since seen a water-worn fragment of 25 grammes in weight which exhibits a radiated structure similar to that seen in some of the Moolyella ore.

A number of stream tin ores from Greenbushes have been examined for tantalite and stibio-tantalite with negative results. It would appear as if these minerals were confined to a small portion only of the field. Tantalum has, however, been detected in clean cassiterite from this field. A clean crystal from a lode on the South Cornwall Mine was found to yield the results given below, whilst a rolled pebble from North Greenbushes yielded 1·15% Ta_2O_5.

Cassiterite, Greenbushes.

Tin dioxide	97·63	per cent.
Tantalum pentoxide	1·76	,,
Iron oxide, &c.	·61	,,
	100·00	,,

Bellinger.—This is a new locality for tantalates, situated close to the South Coast. The rock formation is granite traversed by veins of pegmatite, one of which, twelve miles west of Point Malcolm, gave promise of yielding muscovite of commercial quality. A mineral lease, 112H, was taken up on this vein during 1907 in order to open up the mica, and in the course of operations small quantities of a black mineral were met with, which was thought to be tin ore. Examination proved it to be tantalate and niobate of iron and manganese varying from ferro-tantalite to mangano-columbite in composition. The specific gravities recorded were 5·59, 6·60, 7·10, 7·60, indicating percentages of tantalic oxide from 15 up to 75. Most of the mineral was in irregular, broken fragments, but a few imperfect tabular crystals were noticed in which the faces "a" and "b" were prominently developed, whilst traces of "u" were also seen.

10.—NOTES ON THE PHYSIOGRAPHY OF NORTH QUEENSLAND.

By WM. POOLE, B.E., F.G.S.

Two and a-half years ago, while travelling to Mount Molloy from Biboohra, the writer noticed the long stretch of flat plain extending from the Barron River, at Biboohra, in the direction of Mount Molloy. On the return journey, *viâ* the Two-mile Creek, the writer saw a low, wide, billabong-like creek, coming within 1½ miles of the Barron River. On inquiry the writer was astonished to find that the creek ran into the Mitchell and not to the Barron. Time did not then permit of further investigation, but the opinion was then advanced, that this was an instance on a large scale of river capture, in short, that the Barron above this locality was formerly the head waters of the Mitchell.

After heavy rains the surface water at points as near as ¼ to ½ mile from the banks of the Barron flows away in the opposite direction to the Mitchell. The grade in this direction is so flat that the plains are under water for some time after heavy tropical rains. There are large swamps in the intervening strip of two miles between the Barron River and Two-mile Creek. These two streams flow across a flood plain of recent fluviatile alluvium. The hydraulic grades of the Two-mile Creek and Mitchell are flat, while that of the Barron is much steeper; the latter stream, even when low, flows with a fairly rapid current. The Barron has not been known, during the period of white settlement, to overflow its banks on to the plains at this locality. The bed of the stream at Biboohra is still in the stage of incipient rejuvenescence. The writer is of opinion that the capture of the upper waters of the Mitchell at this point is of very recent date. It is probable that to the east the neighbouring streams of meridional direction have been successively captured at earlier dates. The writer had not time, however, to pursue investigations in this direction.

The Upper Barron, which has been captured from the Mitchell, is the main contributing stream of the Barron River. The capture of this stream and the probable capture of other contributing streams from the Mitchell will have undoubtedly increased the erosive action at the Barron Falls. These falls, the largest in Australia, are about 1,000 ft. high, and are situated at the end of a deep gorge about 3 miles long. The retrocession of the Barron Falls and the elongation of the gorge have left as hanging valleys the beds of tributary streams, such as Surprise Creek. This creek joins the lower Barron in falls of about 1,000 ft. down the steep face of the gorge. It is interesting to note that the Barron Falls have cut back 1½ miles from this point, while the Surprise Creek Falls have cut back only about 70 yds. from the face of the gorge.

The physiography of this portion of the country presents some interesting features. The high land in which the Barron rises may be termed the Mother of Rivers from the number of large and important streams rising therein—viz., Barron, Mulgrave, Russell, Johnson, Wild and Walsh Rivers, the last-mentioned flowing to the Gulf of Carpentaria. All of these streams head within a few miles of each other. The mountains range up to 3,700 ft. in height. There are numerous extinct volcanoes studded throughout this district, many of them existing as dry craters or crater lakes; the rainfall is abundant, and the soil very fertile. Bellenden-Ker, in the Mulgrave-Russell watershed, is an eastern extension of the above-mentioned high land. The peaks of Bellenden-Ker are the highest in Queensland—viz., 5,000 to 5,400 ft. This short range rises steeply from almost sea-level at a distance of about 4 miles from the sea, the crest of the range running roughly parallel to the coast, from which it is about 7 miles distant. The Mulgrave River coming from the north and the Russell River coming from the south, unite opposite the centre of Bellenden-Ker, and enter the sea through a gap in a strongly marked coastal range. This coastal range, which extends southwards from False Cape, near Cairns, and is known as Murray-Prior Range, Grey Peaks, Bell Peaks, Malbon Thompson Range, Graham Range, &c., rises abruptly from the sea, and is parallel to but separated from the main mountain range by a valley 2 to 3 miles wide, and but little above sea level.

There are in close juxtaposition, on the one hand, the range of high mountains and tablelands, with their marked features of deep valleys and gorges, waterfalls (Barron River Falls 1,000 ft., Tully River Falls 2,000 ft.), presenting strong evidence of considerable upheaval and widespread volcanic action within recent geological time; on the other hand, there is the coastal strip and shelf extending to the Great Barrier Reef, showing strong evidence of undoubted subsidence, likewise in recent geological time. The elevation of the one portion being apparently contemporaneous or almost so with the subsidence of the other portion. The valley of the Lower Mulgrave and Lower Russell presents an interesting field for determining, if possible, if the elevation of the mountainous country and the subsidence of the coastal strip and shelf have been effected by folding, extensive faulting, or a combination of both means. Proceeding southward to Mackay, &c., similar evidence is found of subsidence—viz., in the hilly and mountainous islands of Hinchinbrook Island, Palm Island, Magnetic Island, Whitsunday Island, &c., hilly and mountainous masses connected to the main land by low sand flats, the Hinchinbrook and Whitsunday Passages, &c., and of elevation of the continental mass in the rejuvenescence of the lower Burdekin River. This river, one of the largest, both in volume of water and size of catchment, on the eastern seaboard of Australia, flows in the neighbourhood of Charters Towers across an extensive peneplain, studded with isolated mesas and occasional ranges of hills. The tributaries coming from the Main Dividing Range also flow across similar country. The Main Dividing Range is here a weakly-defined feature. This peneplain has an elevation of 800 to 1,200 ft. Towards the lower end of its course and comparatively near the sea, the Burdekin flows as a series of rapids and falls through an almost impassable gorge. This locality is known as the Falls of the Burdekin. In the course of 3 miles the river is said to fall about 600 ft.

In the portion of North Queensland referred to in this paper it is interesting to note that the highest peaks, often rugged and almost isolated, are situated very close to the coast, in fact, some of them, as on Hinchinbrook Island, are distinctly within the area of subsidence. The line of contraflecture between elevation and depression follows very closely an ancient mountain range.

In considering elevation and depression in this paper the main movements are noticed without attempting to differentiate into periods, or to take notice of small oscillations.

11.—RECENT ADVANCES OF OUR KNOWLEDGE OF VICTORIAN GRAPTOLITES.

By T. S. HALL, M.A., D.Sc., Melbourne University.

In 1899 I summed up our knowledge of Victorian graptolites* in a paper contributed to the "Geological Magazine." Since then a large number of graptolites have passed through my hands, and have been dealt with in the Proceedings of the Royal Society of Victoria and in the Records of the Geological Survey. The sequence that was established in my earlier paper is as follows:—

SILURIAN.—Characterised by *Monograptus, Cyrtograptus* (F. Chapman in Nat. Mus.), *Retiolites, Diplograptus* (?).

ORDOVICIAN.—*Upper:* Characterised by *Dicranograptus, Dicellograptus, Leptograptus, Nemagraptus, Didymograptus* (rare), *Diplograptus, Climacograptus, Cryptograptus, Glossograptus, Lasiograptus, Retiograptus, Retiolites. Lower:* Characterised by *Clonograptus, Bryograptus, Dichograptus, Tetragraptus, Didymograptus, Dictyonema, Glossograptus, Lasiograptus,* &c.

Very little has been added to our knowledge of the Silurian species and of their distribution. *Monograptus dubius* has been identified and figured, and a fairly large area near Matlock has been definitely fixed as of Silurian age. In the Upper Ordovician, abutting on the Silurian and to the west of it, an extensive area of rocks of this age has been proved by the collecting of Mr. Wm. Baragwanath, who surveyed the district. The fauna proved rich, and in a fairly good state of preservation. It has been dealt with in the "Records of the Geological Survey." East of this area, as already mentioned, Silurian comes in. The other limb of the geosyncline with an almost identical fauna comes up along the Wellington River, where Mr. E. O. Thiele secured a fine collection. This has been supplemented by other collectors. Dicranograptidæ are abundant and varied, and just lately *Nemagraptus gracilis*, J. Hall, has been found. Stray fossils of similar age have been gathered along a comparatively narrow belt striking north-westerly from here. The Matlock Upper Ordovician area is in the middle of what has hitherto been regarded as Silurian country, and the Wellington River series in Devonian. Everett's, 8-in. map consequently needs revision here. The boundaries of the Ordovician, to the east again of the Silurian, are not well defined, but from numerous scattered observations it is clear that Upper Ordovician, as characterised by Dicranograptidæ, alone is represented. This Upper Ordovician belt strikes northwards into New South Wales as far at any rate as Orange.

Our Lower Ordovician graptolite distribution is better known, and our knowledge has lately been considerably added to. The division indicated in my previous papers is:—

LOWER ORDOVICIAN.—*Darriwillian*: Characterised by *Glossograptus, Lasiograptus,* &c. *Castlemainian*: Characterised by *Loganograptus, Didymograptus caduceus, D. bifidus,* &c. *Bendigonian:* Characterised by *Tetragraptus fruticosus, T. pendens, T. serra, T.*

* Geol. Mag., 1899, pp. 438-451.

bryonoides, *Phyllograptus typus*, *Dichograptus*, and many *Didymograpti*. Some of these pass up. *Lancefieldian*: Characterised by *Bryograptus*, *Clonograptus magnificus*, *C. flexilis*, *C. rigidus*, *Dictyonema macgillivrayi*, &c.

Most of the work done on these four series was in the localities from which they take their names, but since then our knowledge has grown.

Mr. T. S. Hart, M.A., F.G.S., has done a great deal of careful collecting in the Daylesford district, and has proved independently that the whole sequence as established in the Castlemaine district is correct.* Thus, *Tetragraptus fruticosus* is found at first without *Didymograptus bifidus*. Then the latter appears, outlasts *T. fruticosus*, and is succeeded by *D. caduceus*. I am inclined to think that my previous statement that *D. caduceus* was found associated with *T. fruticosus*, is incorrect, and founded on wrong identifications.

Till recently the only Lancefieldian known was at Lancefield itself, but two fresh areas have been discovered. From Bendigo westerly, nearly to Bealiba, a distance of close upon 40 miles, the country has been pretty well explored for Graptolites. In the Dunolly district this has been carried out mainly by the indefatigable zeal of Mr. W. H. Ferguson. The general strike, as is usual with our older Palæozoics, is north and south. The western 20 miles proves to be Lancefieldian, and includes the goldfields of Dunolly and Tarnagulla. East of this comes the overlying Bendigonian, which continues apparently right to Bendigo, though basaltic lava flows hide much of the intervening country.

One interesting stratigraphical fact has come out among others. *Tetragraptus approximatus*, Nicholson, found hitherto only in Canada and Victoria, turns out to be an important zonal fossil. It was first found near Dromana, on the Mornington Peninsula, associated with *Tetragraptus fruticosus*, the typical Bendigonian fossil. This showed the Lower Ordovician age of a tract that for forty years had been considered Silurian. *T. approximatus* next appeared along a line of strike in Bendigo itself, although Bendigo had apparently been well searched for many years without its appearing. Then Mr. Ferguson secured several examples from Inglewood, where it was associated not with Bendigonian, but with Lancefieldian forms. It consequently is of value as fixing the base of the Bendigonian and the summit of the Lancefieldian. It may be mentioned that for 30 miles approximately along the Inglewood strike, from Inglewood south to Smeaton, we find Bendigonian Graptolites, the former place being, of course, almost on the boundary line.

The age of the Ballarat Goldfield has never yet been determined, but it is gradually being arrived at. A Graptolite has been found, but it is quite indeterminate, although I suspect it to be a Dichograptid, but I am not at all sure. Phyllocarids are common in several places, and appear to be *Rhinopterocaris maccoyi*, which ranges throughout the Lower Ordovician. To the south and south-east of Ballarat we have a variety to choose from. Darriwill itself is 30 miles to the south-east; 10 miles nearer is Elaine, where we get, on the east, undoubted uppermost Bendigonian, nine identifiable species being represented. A short distance to the west we get Lancefieldian from half a dozen

* Proc. Roy. Soc., Vic., 20, 1907.

localities, and with seven recognisable species. A little nearer to Ballarat, and somewhere about the same strike, we get at Clarendon a mixed Bendigonian and Lancefieldian fauna. We are again on the border line as we were at Inglewood, and *T. approximatus* is again in evidence.

We have then about a dozen miles south-easterly from Ballarat, at Clarendon, a basal Bendigonian fauna, succeeded on the east by Lancefieldian. If the strike continues unchanged, this line would pass through Ballarat. On the continuation of the same line, and 40 miles to the north, we reach Wareek, where again we find Lancefieldian. The presumption is that Ballarat is low down in the Ordovician.

Westward of the Bealiba-Ballarat line of strike is a large area of ancient rocks that have yielded no fossils as yet. The excellent results that have ensued from the painstaking investigation of the unpromising rocks of the Dunolly district lead us to hope that careful search among these western rocks may not be without valuable results.

In conclusion, I have to thank Mr. E. J. Dunn, the Director of Geological Surveys, for allowing me to give some unpublished facts which have come to my knowledge during my examination of Graptolites for the Department of Mines.

12.—PETROLEUM.

By DAVID DAY, United States Geological Survey.

13.—GOLD MINING IN WEST AUSTRALIA, WITH REFERENCE TO THE GEOLOGICAL FEATURES OF THE STATE.

By C. O. G. LARCOMBE, Curator and Lecturer, School of Mines, Kalgoorlie.

14.—THE METEOR CRATER OF ARIZONA.

By GEORGE P. MERREL, Head Curator of Geology, U.S. Natl. Museum, Washington, D.C., U.S.A.

In 1891 public attention was first called to a remarkable crater-like depression on the plain in the neighbourhood of Canon Diablo, Coconino County, Arizona, through the finding in its vicinity of numerous masses of meteoric iron. So numerous were these—several thousands, large and small, having been found—and so remarkable was the crater, that it was early suggested that there might possibly be a genetic relationship between them. The subject was studied systematically by Mr. G. K. Gilbert, of the U.S. Geological Survey, who gave the substance of his results in 1896 under the caption of "The Origin of Hypotheses." It is sufficient for our present purposes to state that Mr. Gilbert did not find such data as he felt warranted him in accepting any such conclusions, and he was forced to accept, tentatively, the alternative hypothesis of vulcanism, though the complete absence of volcanic products in the vicinity was recognised as unaccountable, excepting upon the ground that the crater was formed

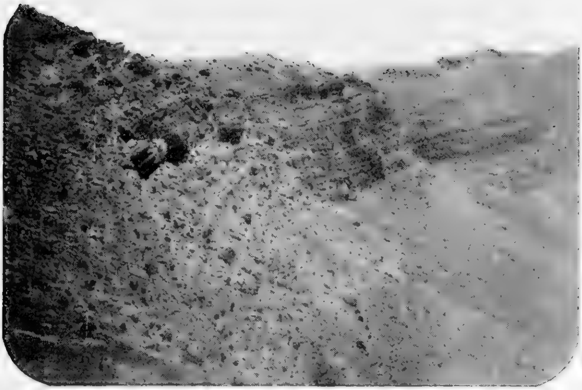
Slide 1.

METEOR CRATER, DISTANT VIEW.

Slide 2.

LOOKING ACROSS AND INTO CRATER FROM THE NORTH.

Slide 3.



INTERIOR VIEW OF CRATER LOOKING NORTH.

Slide 4.

CRATER WALL—INTERIOR.

simply by a steam explosion accompanied by none of the usual after effects of volcanic eruption.

A few years ago, some enterprising mining men, tempted by the alluring thought of an abundant supply of nickel-iron which might prove of commercial value, began a systematic series of borings from the bottom of the crater, accompanied by the sinking of a few shafts and the digging of numerous trenches in the material forming the crater rim. These operations afforded facilities for investigation not before available, and led the present writer to take up the subject anew. It is proposed here to give in brief, the results of these investigations, the details of which have been largely published elsewhere.

The prevailing formations in the region are a carboniferous limestone (the Aubrey limestone of the U.S. Geological Survey), somewhat arenaceous, and of a buff colour; this is some 300 ft. in thickness; underlying this is a light gray, highly siliceous, saccharoidal sandstone some 500 ft. in thickness, and under this again, a red-brown sandstone, the thickness of which at this immediate locality has not been determined. At intervals over the surface are small residual buttes of a red-brown sandstone that once covered the entire region. These rocks all lie approximately conformable and horizontally, and little changed by dynamic or metamorphic agencies.

The crater-like depression is limited almost wholly to the Aubrey limestone and sandstone, though occasionally a little of the red or butte sandstone is involved. As seen from a distance, this crater appears as a low, very irregular ridge of light gray colour, sufficiently differentiated from the red buttes to be very conspicuous to the trained eye (slide 1). Nearer approach shows it to be composed mainly of fragmental material—limestone and sandstone—in masses varying from the finest dust to blocks weighing thousands of tons, all in a state of greatest confusion. This rim is at its maximum some 160 ft. above the level of the surrounding plain. Standing upon its crest one's eye is greeted by the remarkable view shown (slide No. 2)—a nearly circular crater, some 500 ft. in depth and 4,000 ft. in diameter, with precipitous, in places overhanging, walls, and a floor of many acres covered around the margin by talus, and throughout the central portions by wind-blown sands and lake bed deposits. The crater walls as seen from the inside are formed of the sharply upturned edges of the limestone, capped by sand and loose blocks of the limestone, from the crater interior. Little of the underlying sandstone is visible in these walls, owing to the friable nature of the same and to the talus fallen from above (slides Nos. 3 and 4). Owing to the aridity of the region, there is little vegetation, and the wild, barren ruggedness of the scene is impressive in the extreme. It is, however, the question of the origin of this remarkable, and apparently wholly unique feature that must concern us here.

An examination of the outer rim, as above intimated, shows the same to be composed wholly of fragmental material which was plainly ejected from the crater itself. Huge, rugged masses of rock, thousands of tons in weight, down to particles of microscopic proportions, are scattered in wild profusion over areas of several square miles. The larger blocks are wholly of limestone, but this is due in large part to the friable nature of the sandstone, which causes it to disintegrate rapidly under the trying conditions of a desert atmosphere and upwards of 5,000 ft. above sea-level. An important feature is the presence in this rim of enormous quantities of crushed and bleached sandstone, which will be referred to later under the name of "rock flour" and "ghost sandstone." Trenches and shafts which have been sunk into the rim at various points bring to light only fragments of the lime and sandstone, all tumbled together in the wildest confusion, and wholly without order. On the north side of the crater there were uncovered in the trenches numerous masses of partially oxidised meteoric iron, of a nature so susceptible that their preservation in a moist climate has proved a matter of the greatest difficulty. These occur in such association with the rock detritus as to leave no doubt but that they were thrown out of the crater together and at the same time as the materials in which they occur.

In the early stages of the exploring operations, two shafts were sunk in the bottom of the crater. These, after penetrating something like 100 ft. of wind-blown material and lake bed deposits, passed into a mass of *rock flour* formed from the smashing of the sandstone, which presented such mechanical difficulties to the work that the shafts were abandoned and recourse had to borings. From these shafts there were, however, brought up occasional peculiar, white and platy or spongy masses of rock, which microscopic and chemical examination showed to consist of true quartz glass, resulting from the fusion of the crushed quartz, and of a completely recrystallised rock, consisting wholly of quartzes with a well-developed rhombohedral cleavage, and showing, optically, a condition of molecular strain. This crystalline variety showed also a secondary platy structure, such as could be produced only by dynamic agencies. An intermediate stage of metamorphism was shown in the so-called *ghost sandstone.*

The drilling was carried on by means of iron pipes some 3 in. in diameter, the cutting tool being a hardened steel bit. A series of twenty-eight holes was driven at various points in the crater bottom, the deepest extending to a depth of upwards of 1,100 ft. The character of the material passed through was made evident by means of a stream of water forced downward through the pipe, and finding its way to the surface again through the space immediately around the outside of the revolving drill. The implement was not such as to make the securing of a core in all cases possible, since not merely was the boring, as a rule, discontinued, when what was beyond doubt solid rock, was struck, but the weight of the column of water in the pipe was sufficient, on withdrawing the drill, to force out anything that might have been otherwise obtained. In seven cases out of the twenty-eight, however, small sections of cores were obtained, and such were submitted to microscopic examination with the results noted later.

The general result of these borings may be shown by the following record from Hole No. 17:—

	Feet.
(1) Surface material, soil, sand, and wash from cliffs	0- 27
(2) Lake-bed formations, lying horizontally, and containing diatoms, shells of mollusks, and abundant gypsum crystals	27- 88
(3) A sand which gives reaction for nickel and iron and contains fragments of metamorphosed sandstone, sandstone pumice, &c.	85-220

	Feet.
(4) Sand and rock, sand grains crushed slightly, if any, and not metamorphosed, barren of meteoric material	220-520
(5) Sand and "silica" (rock-flour), with abundant slag-like material containing iron and nickel, and metamorphosed sandstone	520-600
(6) Fine silica powder (rock-flour) and sand, no meteoric material	600-620
(7) Bed-rock, a grayish sandstone rapidly becoming yellow and harder, not metamorphosed ...	620-720

The material mentioned under 3 and 5, as reacting for nickel, contained nothing that could be identified beyond question as of meteoric nature. There were occasional minute magnetic particles which gave a reaction for nickel and phosphorus, and greenish siliceous particles resembling, under the microscope, furnace slag. There would seem to be no doubt as to its meteoric nature; but, as stated, this could not be absolutely proven. In all cases the drill passed through a variable thickness of the material called "rock-flour," of the same nature as that found outside on the crater rim, and which the microscope and chemical tests showed to consist of almost pure silica and derived from the gray sandstone. This material, it is important to note, was not the result of a simple mechanical disintegration of the sandstone, but every granule had been shattered as though by a sharp, sudden blow from a hammer, or perhaps a shock such as might be imported by a blast of dynamite. As above noted, the drilling was stopped in nearly every case when firm rock was reached. The seven cores examined came from varying depths below the bottom of the crater up to 1,080 ft. They were in all cases of a brown-red sandstone, firm, intact, and wholly unchanged by any of the forces that had operated on the overlying materials.

Summing up then this all too brief résumé of the subject, it appears that if the results of these borings are to be considered as final, the phenomena of the crater are wholly superficial and limited to the limestone and gray sandstone; that both of these rocks have been shattered as by a mighty blow from extraneous sources, and their material scattered about over the surrounding plain; that incidentally, a portion of the quartz sand has been fused, and converted into a silica pumiceous form and a portion actually rendered crystalline, this variety occurring in masses with a secondary, platy structure not conformable with the original bedding. No meteoric material has been brought to light by the borings other than noted, nor in quantities sufficient to suggest a body of such size as could have produced the crater. If it were thus produced, we are forced to the conclusion that the mass was practically all dissipated through the heat of impact and the subsequent weathering. It is felt that there is no doubt but that the meteoric irons—the shale-ball irons found in the crater-rim—were thrown out together with the débris from the interior. Whether or not this indicates a steam explosion subsequent to the problematic impact, cannot be considered as settled. For a discussion of this part of the subject I have to refer to my original paper, as well as to a discussion of the relation of these buried forms to the iron masses found scattered over the surface of the plain.

15.—OUTLINE OF THE GEOLOGY OF THE BLACK DIAMOND REGION OF BAHIA, BRAZIL.

By JOHN C. BRANNER, Ph.D., F.G.S., F.G.S.A., &c.

There seems to be a disposition the world over to suppose that diamonds are to be looked for only under those geological conditions under which they are found in South Africa. The object of the present paper is partly to point out to the geologists of Australasia that valuable diamonds and carbonados occur in paleozoic sediments in Brazil, and to suggest the possibility of similar deposits being found in other parts of the world.

Occurrence of Diamonds in Brazil.—Diamonds are found in Brazil in three widely separated districts. The first, and formerly the most important, is in the vicinity of the city of Diamantina, State of Minas Geraes; the second, and now the most important, is in the interior of the State of Bahia, about the city of Lençoes; the third is on the head waters of the Paraguay River, near the town of Diamantino, State of Matto Grosso.

The writer has visited all three of these districts, and what he offers here is, therefore, derived from a personal knowledge of them. Most of the diamond washings in all three districts are in stream deposits, either ancient or modern. In the Matto Grosso deposits the stones have never been found save in alluvial or stream deposits, and nothing further is now known of their origin. In the State of Minas, however, one place was seen where the diamonds evidently came directly from disintegrated itacolumite. Professor Gorceix, who visited the diamond mines at Grao Mogor, some 300 kilometres north of Diamantina, says the stones at that place are derived directly from palæozoic conglomerates which he regards as a part of the series containing the itacolumites‡—that is, in the Minas series of the table below. In the State of Bahia both the ordinary diamonds and the black diamonds, carbons, or carbonados are derived directly from palæozoic quartzites and quartzitic conglomerates, though many of the washings are in stream deposits of recent date.

The Rocks of the Diamond Region.—One of the chief difficulties in a study of the geology of the Bahia diamond region lies in the fact that none of the rocks of the several series represented contain any recognisable fossils. It is, therefore, impossible to give the ages of the rocks with certainty. There are, however, physical breaks and lithologic characters, which, taken in connection with the structure that has been worked out over large areas, have afforded satisfactory evidence of the relative ages of the various beds and throw much light

‡ Gorceix, Bul. Soc. Géol. de France, XII., 538. Paris, 1884.

upon the geologic history of the region. The following table shows the sequence and the chief subdivisions of the rocks of the region in so far as they are now known:—

Names.	Thickness.	Ages.
	Metres.	
Alagoas series	?	Tertiary
Sergipe series	?	Cretaceous
Salitre limestones	350	Jurassic ?
Estancia red beds	350	Trias ?
Lavras series (diamond bearing)... ...	700	Carboniferous ?
Cambao quartzites	100	
Caboclo shales	500	Devonian ?
Jacuipe flints	100	
Tombador sandstones	400	Silurian ?
Minas series	1,000	Cambrian ?
Crystalline complex	...	Pre-Cambrian in part ?

In Mr. Derby's paper on the Bahia diamond region he speaks of the Lavras series and of an underlying series which he calls the Paraguassú.‡ The later work of the writer shows that the diamonds and carbonados are not confined to any one horizon, and that, therefore, the Paraguassú series of Derby can only be regarded as a local subdivision of the entire series. Mr. Derby's name, Lavras, seems very suitable for the whole diamond-bearing series, however; and it is, therefore, retained for the entire series.

It should be distinctly understood that, while the divisions here suggested are perfectly clear, the ages assigned all of those below the Cretaceous are without palæontological warrant, and must therefore stand subject to such readjustments as future discoveries may require. The stratigraphic relations, however, are known to be correct, but the thicknesses vary as usual from one place to another, and in some places some of the members are altogether wanting.

It will be noted that the Cambao quartzites and the Jacuipe flints are not assigned to any age. This is because it is not clear whether these divisions belong with those above or below—that is, whether the Jacuipe flints are Silurian or Devonian.

The Diamond Bearing Beds.—The diamonds and carbonados are found in the Lavras series of this section. The rocks of the Lavras series are pinkish quartzitic sandstones and conglomerates with some interbedded clays. The coarser beds are strongly false-bedded, and the series is faulted in some places, and is everywhere folded and denuded. The rocks of the series are thus bunched as synclines in some places, and in others they are separated by denudation into isolated patches.

There are no eruptives in the diamond-bearing beds as a whole, but there are some basic dykes cutting them at a few places. These dykes are diabase-like rocks, but, inasmuch as the diamonds are found more than 100 miles from any known dykes of this kind, these particular eruptives clearly have no genetic relations to the diamonds.

‡ Economic Geology, I., 134-142, Dec., 1905.

The writer has never seen a diamond in place in the Lavras rocks. The evidence that they are derived directly from this series lies in the fact that they are taken from the disintegrated beds of this series. Many illustrations of this fact might be cited, but only a few typical examples will be mentioned. Near Andarahy, where the rocks of the Lavras series are at the surface, the soil and disintegrated rocks have been removed by the diamond miners with great care down to the hard rock, and the whole has been carefully washed for diamonds. At and about Morro do Chapeo the trenches in which the diamonds and carbonados are found are entirely in the rocks of the Lavras series. Diamonds and carbonados have been found in loose materials resting upon other rocks, but in every instance the stones are readily and directly traceable to the Lavras beds. For example, at Ventura the stones are found resting upon the underlying Caboclo shales, but this is because the streams flowing over and from the Lavras series have carried them down into the channels cut into the underlying beds. Diamonds have also been found well away from the rocks of the Lavras series, but along or in streams flowing over and from the latter beds.

The writer has seen a large number of both diamonds and carbonados from this Bahia region. Of the stones known to have been taken from the Lavras beds (we mean those not found in stream beds far removed from their original positions), not one showed any signs of wear; of those taken in streams leading away from the Lavras beds, some showed a little wear. Of the carbons nothing can be stated with certainty. So far as examined, their surfaces were always smooth, but it was not clear whether this smoothness was due to wear in streams.

Origin of the Diamonds.—Two theories of the origin of the stones naturally suggest themselves: First, that they may have originated as independent crystals in the Lavras sedimentary beds; second, that they may have been produced, like the South African diamonds, in connection with peridotite effusions, and may have passed down from one series of sediments to another to find their resting-place in the Lavras series.

There seems to be nothing inherently impossible or improbable in such a theory, but it must be confessed that the satisfactory support for it is yet to be found. It is interesting in this connection to note that the diamonds are not confined to any one horizon, and neither are they evenly distributed throughout the Lavras series.

When the field work was being done in this region it was supposed that support for the second theory was entirely lacking. Upon working over some of the rocks collected in the field by the writer, it was found that there is an area of serpentine at least 3 miles long lying along the eastern margin of the diamond fields of Bahia. The rock is so altered that its true nature was not recognised when it was found, and it was only discovered to be serpentine after a microscopic examination and a quantitative chemical analysis. This serpentine was set down in the field as a part of the crystalline complex underlying all these sediments. It is possible, however, that it may be of somewhat later age. In any case its presence in the vicinity of the diamond-bearing beds suggests that the diamonds of Bahia may have originated in the same way as those of South Africa, and that the cutting down of these old eruptives furnished the diamonds that are now found in the Lavras sediments. If this latter theory is correct, the diamonds may yet be found in any of the more resisting portions of the newer rocks—that is, in the Minas series or in the Tombador sandstones and conglomerates. It should be added, however, that no such theory would have occurred to the writer in this case had it not been suggested by the well-known conditions in Africa.

Geographic Distribution as Determined by Geologic Structure.—The only other point of special geologic interest is the effect of structure and denudation upon the distribution of the diamond and carbonado bearing beds.

Aside from certain patches of soft beds that are probably tertiary, the highest rocks found in the diamond district of Bahia are the Salitre limestones. These and the Estancia beds were laid down on top of the Lavras series. After the deposition of the Salitre limestones, the region was folded and faulted and subjected to denudation. In many places the folds are so closely appressed that the rocks stand on edge; at others the folds are but gentle. Denudation has done what one would expect in such a region: In places the anticlines have been removed right down to the underlying Caboclo shales, thus leaving isolated patches of infolded or infaulted diamond-bearing beds around the main central synclinal area. Where the synclinal folds are large, the limestones are still the surface rocks, while the diamond-bearing beds are deeply buried.

Governmental Neglect of the Geology.—Of all the remarkable things about this remarkable region there is none more impressive to the geologist than the neglect it has suffered at the hands of the Government. Statistics of diamond production are necessarily defective, and especially so when the diamond mining industry is scattered far and wide among small operators and individuals. But when the Government places a heavy duty upon these small and easily concealed stones, the statistics of production must be accepted as but little more than suggestions of the total output. About all one can be sure of is that many millions of dollars worth of both diamonds and carbonados have been taken from the Bahia mines.

These facts are mentioned merely to emphasise another fact of interest to scientific men; and that is that, though diamonds have been mined in this district since 1844 up to the year 1905, the Government had never made any geological study of the region nor even a map of it. The miners have been left to expend their money and their energies in the blindest ways imaginable. In 1905 the Secretary of Agriculture of the State of Bahia, at that time Dr. Miguel Calmon du Pin e Almeida, had the courage to get Professor O. A. Derby, formerly State geologist of Sao Paulo, to pay a visit to the diamond district. Mr. Derby spent a week or two there, and handed in a short report which was afterwards published in the United States "Economic Geology," Vol. I., pages 134-142. That is the first paper ever published on the diamond regions of Bahia that gives any clear idea of its geology. Professor Derby, however, did not have time to do more than determine the horizon from which the diamonds came in one part of the field, and to note that the diamond-bearing series of sediments, which he called "the Lavras series," was underlain by another barren one, which he called "the Paraguassú series," and that they were both somewhat folded.

Though much remains to be done in order to give a full account of the diamonds of Brazil, this brief outline may be of some service to geologists in other parts of the world who may have occasion to study the diamond question under conditions that appear at first to be widely different from those under which they are found in Africa.

It is hoped that it may be useful also in reminding intelligent citizens that every enlightened Government owes something to its mining industries in the way of scientific study of the geology upon which the success and existence of those industries depend.

Section D.

BIOLOGY.

ADDRESS BY THE PRESIDENT,

CHARLES HEDLEY, F.L.S.

Assistant Curator of the Australian Museum, Sydney.

THE MARINE FAUNA OF QUEENSLAND.

1.—A PLEA FOR A BIOLOGICAL STATION.

The occupant of this chair has the privilege of delivering an address on some subject with which his section is concerned. The nearer that subject is to speaker and audience the better, and I find a topic at hand for discussion in the Marine Fauna of Queensland.

We will consider this fauna politically as a public asset, and scientifically as a field for investigation.

The man of science, who is a good citizen, while indulging in the intellectual pleasures of his work, keeps watch on matters within his ken of public weal.

So we will first discuss the advantage of establishing a biological station. Last year the Royal Commission which reported on the pearlshell and bêche-de-mer industries, recommended that a competent staff of marine biologists should be stationed in Torres Strait to discover and publish information on the pearlshell and bêche-de-mer.

In its marine fauna, Queensland has a great national asset. Few countries are so well endowed. Even without cultivation a rich harvest has been reaped of oysters, pearlshell, bêche-de-mer, turtle, tortoiseshell, fish, dugong, and other products. The great extent of sheltered water offers facilities for the cultivation of these, and of foreign articles, such as sponge and precious coral.

It is so simple to gather and to sell the produce of the sea, that we fail to realise how the fisherman's earnings may be increased by exact knowledge and systematic research. But the reward which the miner has obtained, and which the farmer is reaping, is in store for the fisherman also.

For it was the science of metallurgy that raised mankind from the Stone Age. It was the science of the commercial and industrial arts that placed Europe in the lead of the world. The successful application of science to agriculture has been demonstrated in the Queensland sugar-mills, butter-factories, and frozen-meat trade. Last among industries to feel the fructifying touch of science are the fisheries.

In Ceylon, for twelve barren years the pearl fisheries lay idle. Then the aid of skilled investigators was sought, and the industry placed on a sound footing. For the last five years an annual harvest worth £100,000 has been reaped.

But for the last decade in Queensland there has been a steady decrease year by year. Thus:—

Total Take for—	Tons of Pearlshell.	Total Take for—	Tons of Pearlshell.
1897 ...	... 1,223	1903 ...	... 908
1898 ...	... 1,061	1904 ...	... 777
1899 ...	... 1,200	1905 ...	... 527
1900 ...	... 1,060	1906 ...	... 444
1901 ...	... 867	1907 ...	... 567
1902 ...	... 910		

and, alas, the tide has not yet turned.

Not only in Ceylon, but also in Japan and the United States of America, has the Government granted the means for the study of marine life. And these efforts have everywhere proved remunerative.

A well-organised and liberally-endowed establishment is required. From time to time in the past, Queensland has met this call by appointing a single officer, without aid or equipment. Some of the problems of our fisheries are as difficult and intricate as any which confront science. Time and the combined efforts of skilled zoologists are required for their solution.

Opinions delivered by the judge from the bench or the priest from the pulpit carry a weight which does not attach to an unofficial utterance. And so, speaking from this Presidential Chair, I express the earnest hope that the Queensland Government will soon give effect to the chief recommendation of the Royal Commission of 1908, and establish a biological station in Torres Strait.

2.—THE EVOLUTION OF THE QUEENSLAND COAST.

The uniformity of the Indo-Pacific marine fauna is a theme of text-books. From the Red Sea to the Hawaiian Islands is an enormous distance, yet the marine fauna of this belt maintains a constant aspect and numerous species range throughout. This Indo-Pacific Province is subdivided into regions, among which the Solanderian, as I have termed that under consideration, is as distinct as any. On the south the Queensland fauna is limited by the cooler waters of New South Wales, and on the north the volume of fresh water issuing from the Fly and neighbouring rivers is an impediment to emigration and immigration.

A considerable proportion of our fauna is as yet unknown abroad. Further research will, however, alter the proportion of endemic forms both by the discovery of Queensland forms beyond our limits, and by the recognition in our waters of species described from Japan, the Philippines, and elsewhere. But the completed returns will follow the direction indicated by incomplete data. We note the absence from our beaches of several genera, such as *Harpa*, which otherwise range over the whole Indo-Pacific area. *Cypræa mauritiana*, one of the commonest and widest-spread Indo-Pacific forms, is yet one of the rarest Queensland shells, presumably a recent immigrant not yet established.

A glance at the physical evolution of the Coral Sea and east coast of Queensland, may suggest a clue to the isolation and peculiarity of our fauna.

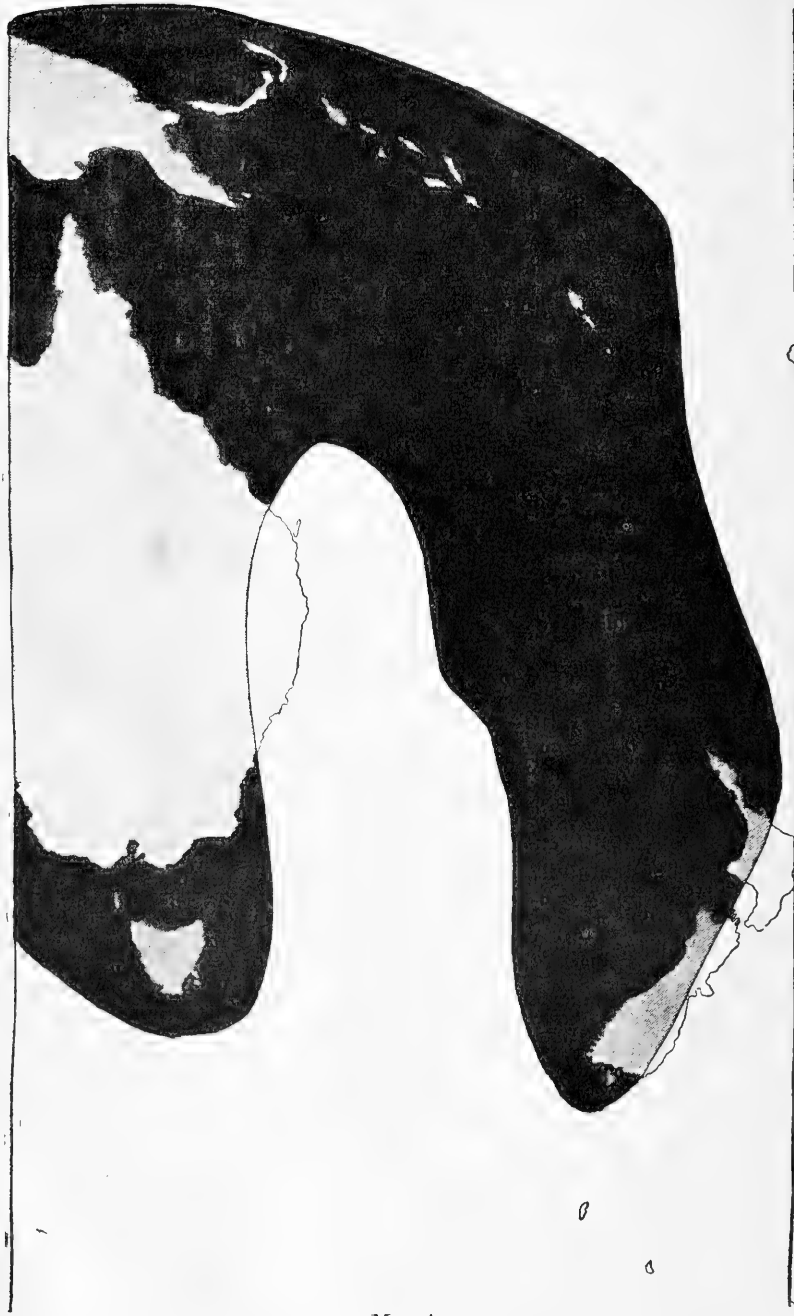
According to Neumayr (Denkschr. k. Akad. d. Wiss. Wien., Math., Naturw. cl. L., Abth. I., Karte I.), a meridional crease in the earth's crust produced in Jurassic times a gulf, which he called the Gulf of Queensland, whose western shore transgressed the present east Australian coast (Map A). Enlarging through geological cycles this gulf grew into what we now know as the Tasman and the Coral Seas.

South of the Louisiades, and east of Cape Melville, there occurred a sink which I venture to suggest originated in the Mesozoic, and increased during the whole Tertiary Period. It developed into the Carpenter Deep of modern geographers. Our knowledge of this basin is drawn from the observations of the "Challenger." In a traverse of 1,000 miles this great basin preserves an unbroken depth of more than 2,000 fathoms. Temperature readings show it to be enclosed by an unmapped rim, whose lowest point is 1,300 fathoms.

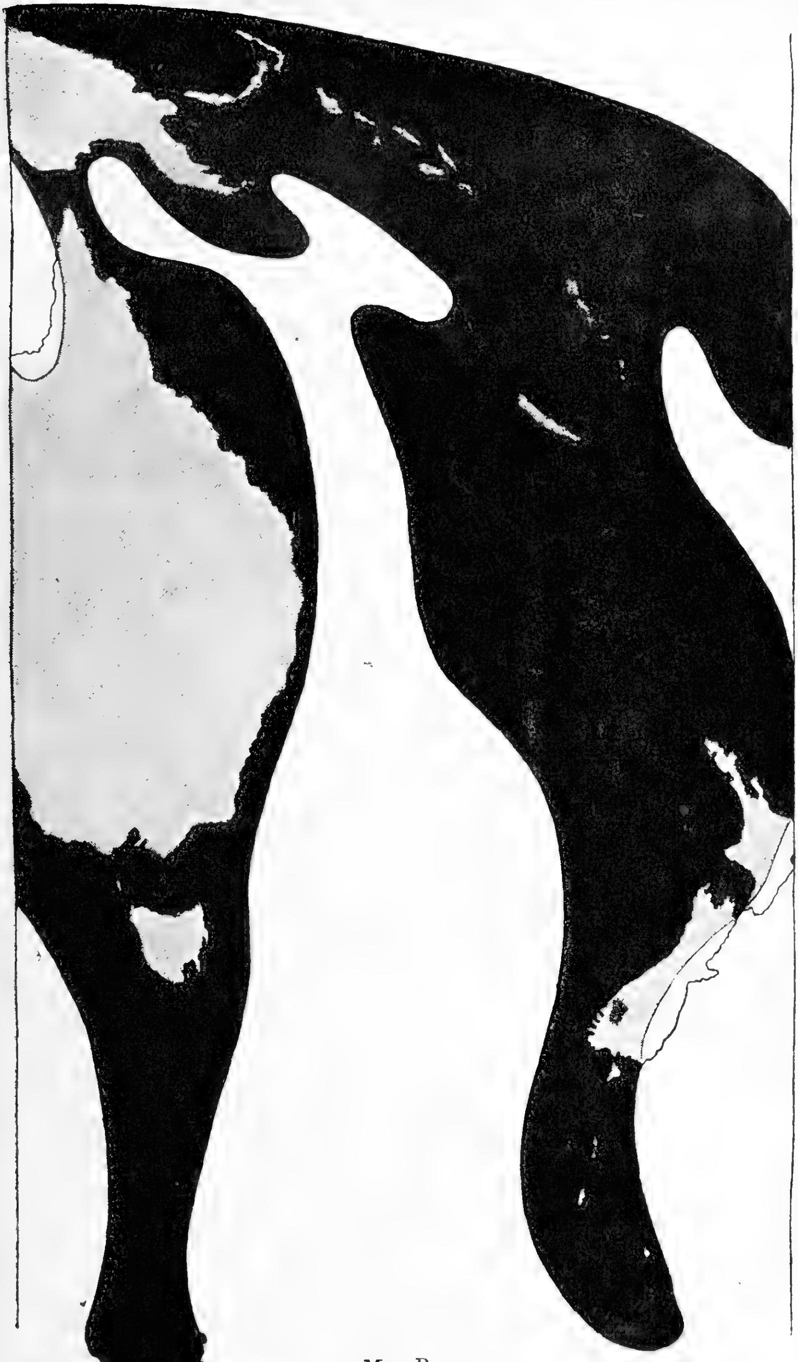
As the Mesozoic sink enlarged its periphery it became a dominant factor in land configuration. First it broke through an older inner earth fold of which New Caledonia and the Louisiades are relics. Then continuing its work to the eastwards, it submerged a younger outer continental ridge on which the Solomons stand. Westerly it crumpled up the former coast of North Queensland, and, by a furthest western effort, broke open Torres Strait.

While the Coral Sea was yet a prolongation of the old Gulf, and had more or less the appearance sketched in Map B, it offered a refuge to old forms of life. The low latitude afforded a warm unchangeable climate, and the surrounding continent secluded its inhabitants from the incursion and competition of other tropical fauna. When, however, continued subsidence to the east at last burst through the Melanesian Plateau, a flood of active competitors must have swept in from the open Pacific. This reached the Queensland coast either by creeping along the land round the Papuan Gulf or by direct, usually larval, transit across the Coral Sea.

With the opening of Torres Strait, and the consequent outgoing current, the Queensland fauna was spread along North Australia to the Moluccas. By this route there escaped such forms as *Trigonia*, *Nautilus*, *Meleagrina maxima*, and *Megalatractus*. Had such been retained east of Torres Strait they would have greatly heightened the peculiarity of the Solanderian fauna.



MAP A.
THE QUEENSLAND COAST IN TRIASSIC TIMES, AFTER NEUMAYR.



MAP B.

THE QUEENSLAND COAST AT THE CLOSE OF THE MESOZOIC EPOCH. ORIGINAL.

3.—HISTORICAL SKETCH OF INVESTIGATION.

It is curious to reflect that, unless Flinders was over generous in ascribing his own discoveries to his predecessors, the first known part of Queensland was that with which the world is now least acquainted—viz., Batavia River, Pera Head, Duyfhen Point, and Cape Keerweer in the Gulf of Carpentaria.

A naturalist first trod Queensland in 1770, when a party from the "Endeavour" under the command of Captain Cook landed at Bustard Head. Solander, a pupil of Linné and a marine biologist, was there, and he doubtless made a collection of which history has left no record. Further opportunities were given him when the ship put into Broadsound, when she called at the Palm Islands, at Cape Grafton, when she grounded on the Endeavour Reef in Weary Bay, and, lastly, when she was beached for repairs where Cooktown now stands. A final visit was paid to Possession Island, but here etiquette would insist that all the gentlemen attend the ceremony in full dress and opportunity for collecting would be denied them.

After Cook, Queensland lay long unvisited by men of science. The famous Brown accompanied Flinders in his exploration of the coast, but his record belongs to the botanical side of our science.

Two French men-of-war, the "Astrolabe" and the "Zélée," then on a scientific mission round the world, sailed by way of Bligh Entrance into Torres Strait on 31st May, 1840. They anchored under Darnley, whose native name they write "Aroub," and landed a party of observers. Proceeding through the Strait, both ships were stranded on the reef near Tut or Warrior Island. The "Canal Mauvais" of modern charts recalls the perils they endured. Finally they cleared the Strait on 12th June. Their dangers and discomforts were not conducive to zoological investigation, but Hombron and Jacquinot, the historians of the voyage, have figured a fish and some shells from Queensland waters. Subsequent writers refer to numerous other species of their collection.

H.M.S. "Fly" was detailed for the survey of the Queensland coast. She carried a brilliant zoologist and ardent collector, J. Beete Jukes, the chronicler of the expedition. He was supported by two other naturalists, John MacGillivray and Dr. Gray's nephew, Lieutenant Ince. During 1843-4-5, the vessel traversed the coast from the Bunker Group to Darnley Island. Jukes' account of the Great Barrier Reef has become classic. In appendices to his book, Owen dealt with the dugong; White describes two crustacea, and Gray named a sea-snake, six marine shells, and five species of Asteriadæ. A few other notices of what was evidently a large collection are scattered in literature.

In continuation of the work of the "Fly," the hydrographic survey from Moreton Bay to Torres Strait was conducted by H.M.S. "Rattlesnake," from October, 1847, to November, 1849. MacGillivray again acted as naturalist, and wrote an account of the cruise. Professor Huxley, who made a special study of the pelagic life, served on board as junior surgeon, and many of his sketches illustrate MacGillivray's book.

In various appendices, two Queensland crustacea are figured and described by White; Busk recorded twenty-seven Polyzoa; and Professor

Forbes wrote an admirable account of the "Bathymetrical Distribution of marine Testacea on the Eastern coast of Australia."

This fragment suggests how great was the loss which science sustained through the waste of material carried to London. These explorers found the British official authorities indifferent and apathetic. London had no Lamarck to grasp the opportunity, to value what had been gathered with such difficulty and danger, and to infuse his zeal into others for the realisation of knowledge from the raw material.

The naturalists of the "Endeavour," the "Fly," and the "Rattlesnake" had laboured hard, and accumulated important collections. These seem either to have been thrown into the vaults of a museum, or to have been dissipated among fanciers and curio-mongers. The plants gathered by Captain Cook's party were lately published after a hundred years of neglect. Those brought home by Dampier in 1688 and 1699 lay undetermined for an even longer period.

The shells of MacGillivray seem to have passed into the hands of Cuming. Hugh Cuming was an illiterate sailor, whose history shows him as a man of strong character, a master organiser, and one born to success. He aimed to have the finest collection of shells in the world, and he reached it. Unfortunately his plans did not regard the advancement of science, and the strong man wastes no energy on aught but the attainment of his object.

For purposes of sale or exchange an unnamed shell was of less value to him than one named, so names were needed for his wares. More time for determination and description was required by careful writers. But worse authors quickly supplied names good or bad, and doubtless better submitted to Cuming's dictation as to what constituted a different species.

So the leading conchologists of his generation in England, Gray, Woodward, Forbes, Hanley, and Carpenter had little or no dealings with Cuming. Gray, indeed, seems to have quarrelled outright. The naming of Cuming's huge collection fell to weaker men—Reeve, the Sowerbys, and the Adams. It has happened that these renamed the same species twice or thrice. The least amount of work necessary to carry the name satisfied them.

Though "the exact locality, depth, and character of habitat of each species of mollusk taken" by MacGillivray "were carefully noted at the time of capture," these valuable field notes were despised by the dealer into whose hands they passed, and failed to attain publication.

The name of Strange is one that occurs frequently as a collector of type specimens of Queensland shells. Frederick Strange was a native of Aylsham, Norfolk, England. He was an early visitor to Brisbane, a friend and probably pupil of MacGillivray. He collected vigorously round Moreton Bay. In June, 1852, he returned to England after fourteen years' absence, and sold the large natural history collection he had gathered. The shells were purchased by Cuming. On his return to Brisbane he renewed his zoological work by fitting out a small vessel to collect along the Barrier Reef. On 15th October, 1854, he landed on Percy Island No. II., in company with Mr. Spurling, a conchologist, and Mr. Walter Hill, afterwards Director of the Botanic Gardens of Brisbane, and first Colonial Botanist of Queensland. Hill pushed into the interior for plants, while his companions strayed along the beach for shells. On his return, Hill found the bodies of his comrades, murdered by the aboriginals.

From October, 1853, to November, 1855, Samuel Stutchbury, then Government Geologist for New South Wales, travelled through extra-tropical Queensland. He apparently collected marine animals where opportunities occurred, but there is little record of his work. *Melampus Stutchburyi*, Pfeiffer, perpetuates his memory.

Commodore Loring, C.B., when in command of H.M.S. "Iris," dredged off the coast. He obtained *Nucula loringi,* Adams and Angas; and *Limopsis loringi;* the date of his work is about 1856-7-8.

About 1858, George French Angas, some time Secretary to the Australian Museum, Sydney, visited Queensland on a collecting and sketching expedition (*vide* autobiography, "The Little Journal," London, May, 1884, Vol. I., No. 3, pp. 230-234). Some Queensland records are scattered through his conchological papers.

In 1868 an energetic lady, Frau Amalie Dietrich, visited Queensland in the interests of the Godeffroy Museum in Hamburg. She collected at Brisbane, Rockhampton, Mackay, Bowen, Holborn Island, and Cape York, and remitted to Europe extensive series of fish, mollusca, crustacea, echinodermata, corals, and alcyonaria.

An expedition to observe the solar eclipse of 1871 was organised by Australian astronomers. Mr. J. Brazier accompanied the party, and collected at Percy, Fitzroy, and No. VI. Claremont Group; the latter subsequently known as Eclipse Island. He described the collections then gathered in the Proc. Zool. Soc., 1874, pp. 668-672, Pl. LXXXIII.; and Journ. of Conch., II., 1879, pp. 186-199. A new species was dedicated to each astronomer of the party.

A new era was inaugurated by the visit of the "Challenger," which, during her famous voyage round the world, spent a few days at Cape York, and passed through Torres Strait.

On 31st August, 1874, a collecting party was landed on Raine Island, while the ship proceeded to sound and dredge in the vicinity (Station 185). A couple of hauls were taken in 135 and 155 fathoms respectively.

For a week following 1st September the "Challenger" anchored under Cape York, while the scientific staff were engaged dredging and shore collecting round the Cape, Somerset, Albany Island, and Albany Pass. On 8th September the ship sailed for Wednesday Island (Station 186) and hauled the dredge in 8 fathoms north of the island. Meanwhile, Mr. J. Murray had spent the day dredging from a boat along Flinders Passage. On 9th September a party was landed on Booby Island, where the lighthouse now stands, while the dredge and trawl were worked in the vicinity (Station 187). The "Challenger" then left Australian waters, and proceeded on her voyage to the Aru Islands.

Cape York proved a rich collecting ground, the results were exhaustively worked out, and afford a wealth of information on Queensland zoology. From Stations 185-187, nearly eight hundred marine animals are recorded, comprising the following groups:—Fish, 33; Tunicata, 6; Mollusca, 223; Bryozoa, 17; Crustacea, 119;

Echinodermata, 41; Annelida, 4; Myzostomidæ, 5; Actinozoa, 35; Hydrozoa, 8; Spongidæ, 23; and Foraminifera, 268. Detailed descriptions of most of these appear in the various zoological reports of the expedition.

A voyage of zoological research was undertaken by Sir William Macleay, the results of which were published by the society he founded. Such expert collectors as Messrs. Masters, Petterd, Brazier, and Spalding were included in his staff. His vessel, the "Chevert," touched first, 29th May, 1875, at the Percy Group. Then Brooke, North Barnard, and Fitzroy Islands were visited in succession. The coral cays of Low Woody and Turtle Reef engaged his attention. On 9th June the ship anchored at No. 4 Howick Group. Cruising northwards by easy stages, the Flinders Group, Cape Grenville, and Cape Sidmouth were visited. From an anchorage near Somerset, the party spent more than a week in exploring Cape York and the Albany Pass. Leaving the mainland on 26th June, the expedition entered Torres Strait. Waraber [Sue] and Tut [Warrior] were visited, whence the "Chevert" steered for the Papuan coast. Becoming involved in the maze of reefs, she retraced her route south, and proceeded to Erub [Darnley] by way of Giaka [Dungeness], Sasi [Long], Burar [Bet], Waraber [Sue], Masig [Yorke], and Edugor [Nepean]. From 31st July to 13th August, the most profitable time was spent at Erub, dredging and shore collecting. And here, as far as Queensland is concerned, the expedition terminated.

The fish, estimated at 800, were studied by Dr. Alleyne and Sir W. Macleay in the early volumes of the "Proceedings of the Linnean Society of New South Wales." The Gasteropoda, exceeding 600, procured by the "Chevert," were catalogued by Mr. J. Brazier, in the first three volumes of the same serial. Professor Haswell's "Monograph of Australian Crustacea" (1882) include the "Chevert" captures. Echini were determined by the Rev. J. E. Tenison-Woods (P.L.S., N.S.W., I., pp. 145-176), who also dealt with the corals and polyzoa (*op. cit.*, III., 1878, pp. 126-135). And the Annelids were described by Professor Haswell (*op. cit.* III., pp. 341-347).

A vessel of the German Navy, S.M.S. "Gazelle," circumnavigated the world on a scientific mission. She made a successful dredge haul in 76 fathoms, a few miles north of Cape Moreton, on 27th September, 1875, and procured 10 mollusca, 9 crustacea, 4 worms, and a coral ("Forschungreise Gazelle," Zool. III., 1889, pp. 262-266). An enforced stay in quarantine gave the naturalists an opportunity of searching Moreton Bay and dredging round Peel Island.

On behalf of the Australian Museum, Messrs. W. A. Haswell and A. Morton visited North Queensland in the spring of 1879, and collected round Port Denison and Holborn Island. Some of the species procured are noted by the former; crustacea (P.L.S., N.S.W., IV., pp. 403-5) and polyzoa (l.c. V., pp. 33-43, Pls. I.-IV.). Tenison-Woods dealt with a coral (l.c. V., p. 460).

The Rev. J. E. Tenison-Woods visited Port Douglas in 1879, and wrote an interesting article on the ecology of the beach of that district (P.L.S., N.S.W., V., pp. 106-131).

H.M.S. "Alert," during a cruise round the world, visited the coast of Queensland. From April to October, 1881, she examined the coast from Port Curtis to Torres Straits. Her naturalists, Dr. R. W.

Coppinger and Prof. W. A. Haswell, lost no opportunities of dredging and shore collecting. A large series of marine animals were accumulated, on which the British Museum produced a special volume. From Queensland Dr. A. Gunther identified fifty species of fish, which he refrained from cataloguing. Three new fish were described and the Australian Cephalochorda reviewed. A valuable critical account of 180 species of Mollusca was contributed by E. A. Smith. Of Echinodermata, 97 species were treated by F. Jeffrey Bell; Crustacea, 150, by E. J. Miers; Alcyonaria, 30, by S. O. Ridley; and Spongidae, 74, by the same. The Annelides taken on the Queensland coast were discussed by Haswell (P.L.S., N.S.W., VII., pp. 250-295, Pls. VI.-XI.).

Icthyology is almost the only branch of marine zoology that has attracted the notice of residents in the State. From 1882 to 1892 numerous papers on it appeared in the "Proceedings" of the Linnean Society of N. S. Wales and of the Royal Society of Queensland, from the pen of Mr. C. W. De Vis, Curator of the Queensland Museum. Since 1893 he has been succeeded in that study by Mr. J. D. Ogilby.

Prof. A. C. Haddon, who had not then forsaken zoology for the charms of anthropology, visited Torres Strait on a collecting expedition in 1888. During August and September he travelled from the Cockburn Islands and Boydong Cays in the south, *viâ* Albany Pass, Cape York, Thursday Island, Hammond Island, Wednesday Island, Jervis Island, Ormans Reef, the Brothers, and Warrior Island, to Saibai, in the north, and to Murray Island in the east. The following contributions to marine zoology resulted from his labours:—

Cephalochorda, A. Willey, Quart. Journ. Micros. Sci., XXXV., 1894, p. 361.

Mollusca, Melvill and Standen, Journ. Linn. Soc., Lond., XXVII., 1899, pp. 150-206, Pls. X.-XI; M. F. Woodward, Proc. Malac. Soc., I., 1894, p. 143; J. Thiele, Zeit. f. Weiss, Zool., LXXII., 1902, p. 249.

Crustacea, W. T. Calman, Trans. Linn. Soc., VIII., 1900, p. 1; H. Coutiere, Bull. Mus. d. hist. nat., 1900, p. 411; E. H. Carpenter, Proc. Roy. Dub. Soc., VII., p. 552-8, Pl. XXII.

Hydrometridæ, Carpenter, Proc. Roy. Dublin Soc., VII., pp. 142-146, Pls. XII.-XIII.

Corals, Haddon, Proc. Roy. Dublin Soc., VII., pp. 127-136, Pl. XI.

Hydrocorallinæ, Hickson, Proc. Roy. Dublin Soc., VII., pp. 496-510, Pl. XVIII.-XXII.

Actiniæ, Haddon and Shackleton, Sci. Trans. Roy. Soc. Dublin, IV., 1893, pp. 673-701, Pl. LXI.-LXIV., *Id.*, VI., 1898, pp. 393-498, Pls. XXII.-XXIII.

During the years 1889-90-91, the late Mr. W. Saville-Kent held office as Commissioner of Fisheries for Queensland. He studied the marine fauna with energy and enthusiasm, but his unconventional spirit did not produce the orderly and methodical work expected from a trained biologist. Various memoirs appeared as Parliamentary Reports, one on the Queensland Fishes, with figures of 65 species; others on the oyster, the pearl-shell, and the bêche-de-mer, the latter with figures of five supposed new species.

His sumptuous work on the Great Barrier Reef was apparently intended for a popular rather than for a scientific audience. In it a number of marine animals are figured, but not systematically described.

As a collector, Kent was very successful. The British Museum catalogues of the Reef Corals record 160 species brought by him from Queensland. The latter volumes of these coral catalogues are unhappily marred by the rejection of binomial nomenclature. That so staid and conservative an institution should suddenly plunge into scientific nihilism was a startling development.

It is a temptation to speculate how a memoir would be received in London if written on the British Roses by a resident of the North Pole, whose eyes had never beheld a living plant. Such study of the influence of environment on corals as the excellent work of Dr. F. W. Jones will show that with fuller knowledge the Linnean system is as applicable here as elsewhere.

Kent was succeeded by Mr. J. R. Tosh as Government Marine Biologist. He published a memoir on the Whiting of Moreton Bay (Proc. Roy. Soc. Q'land, XVII., 1903, pp. 176-184, pls. VIII.-XIV.).

Prof. Richard Semon, of Jena, visited Torres Strait in 1892. His chief object in Australian travel was the study of marsupial development, but he devoted some time to marine zoology. From 13th February to 14th April he dredged and collected around Thursday Island. The following results are published in his "Zoologische Forschungreisen":—

Prof. Max Weber names 18 Fish; Sluiter, 9 Tunicates; von Martens, 31 Mollusca; Meissner, 8 Bryozoa; Ortmann, 47 Crustacea; Sluiter, 10 Holothuria; Döderlein, 40 other Echinodermata; Fischer, 1 Gephyrean; Collin, 9 Polychæta; Kwietniewski, 2 Actinozoa; Burchardt, 8 Alcyonaria; Hentschel, 1 Gorgonia; Weltner, 7 Hydrozoa; and Schulz, a Sponge.

Prof. Alexander Agassiz chartered the s.s. "Croydon," and with Dr. W. McM. Woodworth and Mr. A. G. Mayer as assistants, examined the Queensland coast. He cruised from Breaksea Spit to Lizard Island in April and May, 1896. The coral geology is fully discussed (Bull. Mus. Comp. Zool., XXVIII., No. 4, 1898), but little seems to have been written on the fauna. *Ptychoderma australiensis*, Hill, is noted from Dunk Island (p. 124). A medusa (Agassiz and Mayer, Bull. Mus. Comp. Zool., XXXII., 1898, p. 16) and three planarians (Woodworth, *loc. cit.*, pp. 63-67, Plate) are also published.

In the years 1897-98-99, Mr. Stephen Pace was investigating the biology of the pearl-oyster on behalf of a Torres Strait shelling company. He wrote a paper on a coral (Ann. Mag. Nat. Hist. VII., 7, 1901, pp. 385-7), and another on a mollusc (Proc. Malac. Soc. IV., 1901, p. 202).

Mr. A. E. Finchk, of the Sydney University, visited Lizard Island in January-February, 1901, and made considerable zoological collections. His foraminifera were described by Messrs. Jensen and Goddard.

In July and August, 1901, Mr. E. C. Andrews and I examined the coast between Townsville and Cairns. The coral geology of the district was discussed by my friend. (P.L.S., N.S.W., XXVII., 1902, pp. 146-185). The foraminifera obtained off the Palm Islands were identified by Messrs. Jensen and Goddard (*op. cit.* XXIX., 1905, p. 827; XXXII., 1907, p. 296). Among the mollusca, especially from the Palms and Green Island, are several new and interesting forms.

As the guest of Dr. W. E. Roth, then Protector of Aborigines for Queensland, I cruised down the Gulf of Carpentaria in May and June, 1903. Opportunities occurred for dredging off Mapoon and in Van Diemen's Inlet, where interesting collections were made. Material was utilised in an article on Megalatractus (Rec. Aust. Mus., VI., 1905, pp. 98-100, Pls. XXI.-XXII.)

In October, 1904, the writer organised a party to study the southern extremity of the Barrier Reef. The point selected was Masthead Island. A large collection of crustaceæ and mollusca has been worked out (P.L.S., N.S.W., XXXI., 1906, pp. 453-479, &c.), and a few records of other groups have also appeared.

Another party was formed in August, 1906, to search the reefs off Cooktown. An essay on their structure by Mr. T. G. Taylor and myself appeared in the last volume of this Association.

Finally, Mr. A. R. McCulloch and I were despatched by the Australian Museum to collect in Torres Strait from August to October, 1907. A large zoological collection is now in course of study and publication. A new Cephalocordate (Haswell, Rec. Austr. Mus., VII., 1908, p. 33) was the first fruits of the trip.

This chronicle may be concluded by a reference to the charming book on the natural history of Dunk Island, "Confessions of a Beachcember," published by Mr. E. J. Banfield a few months since.

4.—THE FIELD FOR WORK.

The marine fauna of Queensland will provide fruitful material for the study of generations of investigators. Such work is too great for individual effort, too long for individual life. A biological survey should be organised and directed by an institution, such as a museum, a university, or a fisheries' bureau.

A few specimens, intelligently selected, properly preserved, and accompanied by field notes of habit and environment, with sketches of appearance in life, are of more service to science than great quantities of numerous species carelessly collected. For the continuity of research it is essential that types of species should not remain in private hands where they are ultimately destined to disappear or to lose their identity.

For an orderly examination our first step must be the enumeration of the species. Let preliminary catalogues of the fauna be produced, group by group. At first these lists will be imperfect through errors of omission and misidentification. They will form a target of criticism by every writer and collector. Growing better through several editions by correction and supplement, such lists may ultimately grow into systematic monographs. Then the way will be open for higher and more fascinating studies of morphology, taxonomy, and the analysis and synthesis of philosophical deduction.

"He who leads must lift," is President Roosevelt's stirring saying. That I may not seem to lay on fellow-workers a task that I would not handle myself, I now submit a preliminary list of the marine mollusca of Queensland.

While we know so little of the life of our beaches and estuaries, we, of course, know still less of the life of the deep sea. A few casts by the "Gazelle" and the "Challenger" are the only attempts made to penetrate beyond a few fathoms.

A magnificent field of research which lies at the convenience of the Queensland naturalist is the Great Barrier Reef. Here is the finest show of corals, and possibly the richest marine fauna in the world. And here, perhaps, is the best view point for considering the vexed questions of coral growth. In the Central Pacific the atolls are of great size, and separated from one another by great distances of open sea. Many are perched on the summits of huge submarine mountains, and it is questionable how their development may be distorted by the features of their foundation. But in Queensland the student may inspect rapidly and with ease innumerable miniature models of atoll growth. The small size of these admits of more intelligible survey. Their number and proximity allow an easy comparison, and the level floor on which they are based eliminates the irregularity which a mountain peak may reflect in its superincumbent atoll.

As an unworked field in ecology, I invite your attention to the mangrove swamp. The whole facies of this strange fauna and flora, which lies, as the sailors say, between wind and water, is utterly unlike that of the open sea or of fresh water. To pass in a few yards from one to the other is as great a change of scene as to travel half round the world or to step from one geological period to another.

It has been the fashion to regard a mangrove swamp as a noisome, repulsive, and unpleasant place. But I find it pretty, interesting, and attractive. Looking down from a hilltop, the mangrove swamp stretches below like some vast green meadow, and if the tide be full the green is veined with silver. Transported to the silver streak one may row up a long green lane hedged in by walls of dense and glossy foliage.

To my taste, the mangrove flora is both quaint and beautiful. A delightful recollection of bygone years is a stream winding through a glorious avenue of dwarf Nipa palms, whose lordly fronds arched over 30 ft. of water. Again, I have a picture in my mind's eye of still water, in the foreground, then an expanse of brown mud, where a litter of calling crabs have burrowed; they raise the defiant claw, and illumine the mud bank with vivid scarlet or orange patches; behind, the hedge of mangrove advancing on great stilt roots of hoops arching from a complex of great and greater hoops. Above and beyond a background of dark and glossy foliage massed like an orange grove.

In adverse climates the pioneer of the mangrove forest is Avicennia, which as a dwarfed bush struggles south to New Zealand and South Australia. Before the Queensland border is reached, first Ægiceras and then Rhizophora has joined it and going north the forest gains recruits with every few degrees of latitude.

For protection against wind and weather the mangrove forest is girt with the tough, firm-rooted Rhizophora. Behind its shelter grow the weaker trees. Where the water turns from brackish to fresh is the sweet-smelling Ægiceras. A delightful chapter in the story of this weird world is Dr. H. B. Guppy's account of the fructification of

Rhizophora. The first volume of these "Proceedings" contains an interesting article by Dr. J. Bancroft on the respiration of the roots of mangroves.

Though the order Rhizophoreæ is typical of the mangrove formation, yet many other families contribute. Mr. F. M. Bailey has kindly furnished me with the following list of the florula:—

Salomonia oblongifolia, Polygaleæ.
Calophyllum inophyllum, Guttiferæ.
Hibiscus tiliaceus, Malvaceæ.
Suriana maritima, Simarubeæ.
Carapa moluccensis, Meliaceæ.
Sophora tomentosa, Leguminoseæ.
Cynometra ramiflora ,,
Rhizophora mucronata, Rhizophoreæ.
Ceriops candolleana ,,
Bruguiera rheedii ,,
gymnorrhiza ,,
,, caryophylloides ,,
,, parviflora ,,
Carallia integerrima ,,
Lumnitzera coccinea, Combretaceæ.
Sonneratia alba, Lythrarieæ.
Samolus repens, Primulaceæ.
Ægiceras majus, Myrsineæ.
Ochrosia elliptica, Apocynaceæ.
Tournefortia argentea, Boragineæ.
Acanthus ilicifolius, Acanthaceæ.
Ægialitis annulata, Plumbagineæ.
Lippia nodifora, Verbenaceæ.
Avicennia officinalis ,,
(*See* also some Chenopodiaceous plants).
Euphorbia atoto, Euphorbiaceæ.
Actephila latifolia ,,
Excæcaria agallocha ,,
Malaisia tortuosa, Urticaceæ.
Nipa fruticans, var. neameana, Palmeæ.
Pandanus pedunculatus, Pandanaceæ.
odoratissimus ,,
Triglochin striata, Naidaceæ.

On the zoological side the lord of the swamp is the crocodile. By the creek bank it stacks its nest and lays it eggs. Banfield gives a list of the birds that haunt the mangrove swamp.

Among fish, the curious Periopthalmus is everywhere conspicuous. The smaller, *P. Koelreuteri*, is generally distributed, but the larger, *P. australis*, is confined to the north. By its partiality to the swamps *Mugil dobula* has earned the name of "Mangrove Mullet."

In the muddy pools lies Balanoglossus. When stirred up, it appears for an instant as a primrose-yellow worm, and then immediately buries itself again.

Among crustacea the calling crabs are the first to catch the eye. Mr. A. R. McCulloch tells me that there are many species of Uca in Queensland. At Port Curtis he finds the common species to be

U. dussumieri and *U. arcuata*, but at Cooktown *U. marionis, var. nitida.* Another burrowing crab is *Sesarma bidens.* The active *Metopograpsus messor* darts over the ground and climbs among the roots. The hermit crabs are numerous among the mangroves. Far above the tide mark swarm Cœnobita; *C. spinosa, var. olivieri*, and *C. rugosa.* Globose shells, such as Neritina and Natica, are the favourite apartment for *Clibanarius virescens*, while *C. padavensis* is partial to the more elongate Telescopium shells.

High up among the mangrove branches roost several marine molluscs of the genera Litorina, Cerithidea, &c. On the roots cluster the oyster, and here will be detected by some conchologist more fortunate than myself the strange *Ænigma ænigmatica.* Among the roots crawl a variety of gasteropods, ranging downward in size from the great Telescopium and its relations of the Cerithiidæ. The Auriculacea *Nerita*, *Onchidium* and *Stenothyra*, are characteristic of this zone. The large Cyrena is a common form; *Lucina corrugata* and some of the Tellinidæ represent the bivalves.

In conclusion, I will express the hopes that the study of the Marine Fauna will not be left to visitors and foreigners, but that Queensland's own children will take up this fascinating subject; that their Biological Station may be soon established; that the Queensland Museum may be enlarged and more liberally endowed; and that from the promised university there may flow an ever-increasing stream of knowledge.

APPENDIX.

CATALOGUE OF THE MARINE MOLLUSCA OF QUEENSLAND.

No Catalogue of the Marine Mollusca of Queensland has yet been compiled. The following list is merely preliminary, and any serious effort would greatly enlarge it. In 1888 Professor Tate estimated the marine mollusca from tropical Australia at 1,500; now more than 1,800 are known from Queensland alone. But Hidalgo calculates the marine mollusca of the Philippine Archipelago at over 3,000. The marine mollusca of the Japanese Empire amount to nearly as many. The fauna of the Australian tropics will probably prove comparable with these.

The addition of the author, date and original genus to the name, will enable students to recover the original description at a single consultation. Sherborn's invaluable Index Animalium is the readiest means of tracing the older species. If earlier than 1835, Deshayes' edition of the Animaux sans vertebres will probably contain the species. If the date be later than 1864, the Zoological Record will be the most convenient guide. Between 1835 and 1864 most entries may be found in the decennial indexes of the Zoological Society's Proceedings. Sykes' Digesta Malacologia may also be consulted with advantage.

Pelecypoda.

Nucula loringi, Adams and Angas, 1863
    simplex, A. Adams, 1856
    superba, Hedley, 1902
    torresi, Smith, 1885
Leda corbuloides, Smith, 1885
    crassa, Hinds, 1843; *Nucula*
    darwini, Smith, 1884
    neariformis, Smith, 1885
    novae-guineensis, Smith, 1885
    watsoni, Smith, 1885
Cucullaea concamera, Bruguiere, 1789

Limopsis loringi, Angas, 1873
macgillivrayi, A. Adams, 1862
multistriatus, Forskal, 1775; *Arca*
torresi, Smith, 1885
Arca afra, Gmelin, 1791
antiquata, Linne, 1758
clathrata, Reeve, 1844
corpulenta, Smith, 1885
dautzenbergi, Lamy, 1907
decussata, Sowerby, 1833; *Byssoarca*
disparilis, Reeve, 1844
fasciata, Reeve, 1844
foliata, Forskäl, 1775
fusca, Bruguière, 1792
granosa, Linne, 1758
imbricata, Bruguière, 1792
lateralis, Reeve, 1844
navicularis, Bruguière, 1792
pilula, Reeve, 1844
plicata, Chemnitz, 1795
semitorta, Lamarck, 1819
tenebrica, Reeve, 1844
tenella, Reeve, 1844
tortuosa, Linne, 1758
trapezia, Deshayes, 1839
ventricosa, Lamarck, 1819
wendti, Lamy, 1907
Glycymeris capricornea, Hedley, 1906
cardiiformis, Angas, 1879; *Pectunculus*
crebriliratus, Sowerby, 1886; *Pectunculus*
fringilla, Angas, 1872; *Axinœa*
pectunculus, Linne, 1758; *Arca*
queenslandica, Hedley, 1906
tenuicostatus, Reeve, 1843; *Pectunculus*
vitreus, Lamarck, 1819; *Pectunculus*
Philobrya scabra, Hedley, 1906
recapitula, Hedley, 1906
Pinna assimilis, Reeve, 1858
fumata, Reeve, 1858
nigra, Dillwyn, 1817
serrata, Sowerby, 1825
stutchburii, Reeve, 1858
vexillum, Born, 1778
Perna attenuata, Reeve, 1858
isognomum, Linne, 1758; *Ostrea*
lentiginosa, Reeve, 1858
Melina cumingii, Reeve, 1858; *Perna*
Crenatula flammea, Reeve, 1858
picta, Gmelin, 1791; *Ostrea*
Pteria ala-corvi, Chemnitz
aquatilis, Reeve, 1857; *Avicula*
crocea, Chemnitz
lata, Gray, 1845; *Avicula*
macroptera, Lamarck, 1819; *Avicula*
malleoides, Reeve, 1857; *Avicula*
muricata, Reeve, 1857; *Avicula*
rufa, Dunker, 1848; *Avicula*
smaragdina, Reeve, 1857; *Avicula*
zebra, Reeve, 1857; *Avicula*
Meleagrina anomioides, Reeve, 1857; *Avicula*
flexuosa, Reeve, 1857; *Avicula*
lucunata, Reeve, 1857; *Avicula*
margaritifera, Linne, 1758; *Mytilus*
maxima, Jameson, 1901; *Margaritifera*
sugillata, Reeve, 1857; *Avicula*
tegulata, Reeve, 1857; *Avicula*

Malleus albus, Lamarck, 1819
legumen, Reeve, 1858
malleus, Linne, 1758; *Ostrea*

Vulsella vulsella, Linne, 1758; *Mya*

Ostrea cerata, Sowerby, 1871
cristagalli, Linne, 1758; *Mytilus*
cucullata, Born, 1778
imbricata, Lamarck, 1819
nigromarginata, Sowerby, 1871
tuberculata, Lamarck, 1804

Trigonia uniophora, Gray, 1847

Pecten medius, Lamarck, 1819

Chlamys crassicostatus, Sowerby, 1842; *Pecten*
crouchi, Smith, 1892
cruentatus, Reeve, 1853; *Pecten*
cuneatus, Reeve, 1853; *Pecten*
dringi, Reeve, 1853; *Pecten*
flabellatus, Lamarck, 1819; *Pecten*
fricatus, Reeve, 1853; *Pecten*
funebris, Reeve, 1853; *Pecten*
lemniscatus, Reeve, 1853; *Pecten*
lentiginosus, Reeve, 1853; *Pecten*
limatula, Reeve, 1853; *Pecten*
lividus, Lamarck, 1819; *Pecten*
madreporarum, Sowerby, 1847; *Pecten*
maldivensis, Smith, 1904
pallium, Linne, 1758; *Ostrea*
pseudolima, Sowerby, 1842; *Pecten*
pulchella, Reeve, 1853; *Pecten*
senatorius, Gmelin, 1791; *Ostrea*
singaporinus, Sowerby, 1842; *Pecten*
strangei, Reeve, 1852; *Pecten*

Amusium scitulum, Smith, 1885
pleuronectes, Linne, 1758; *Ostrea*
torresi, Smith, 1885

Cyclopecten murrayi, Smith, 1885; *Pecten*

Spondylus barbatus, Reeve, 1856
foliaceus, Chemnitz
hystrix, Reeve, 1856
multisetosus, Reeve, 1856
nicobaricus, Chemnitz
pacificus, Reeve, 1856
tenebrosus, Reeve, 1856
tenuispinosus, Sowerby, 1847
victoriae, Sowerby, 1859
zonalis, Lamarck, 1819

Plicatula australis, Lamarck, 1819
imbricata, Menke, 1843

Lima angulata, Sowerby, 1843
arcuata, Sowerby, 1843
alata, Hedley, 1898
bullata, Born, 1778; *Ostrea*
fasciata, Linne, 1758; *Ostrea*
inflata, Lamarck, 1819
lima, Linne, 1758; *Ostrea*
linguatula, Lamarck, 1819
tenera, Chemnitz

Limea torresiana, Smith, 1885; *Limatula*

Patro elyros, Gray, 1849; *Anomia*

Placunanomia ione, Gray, 1850

Ænigma ænigmatica, Chemnitz; *Tellina*

Placenta placenta, Linne, 1758; *Anomia*
lobata, Sowerby, 1871

Brachyodontes curvatus, Dunker, 1857; *Mytilus*
hirsutus, Lamarck, 1819; *Mytilus*
Modiola arborescens, Chemnitz, 1795; *Mytilus*
auriculata, Krauss, 1848
australis, Gray, 1827
lignea, Reeve, 1858
philippinarum, Hanley, 1844
Stavelia horrida, Dunker, 1857; *Mytilus*
Lithophaga canalifera, Hanley, 1844
cinnamomea, Lamarck, 1819; *Modiola*
corrugata, Philippi, 1846; *Modiola*
gracilis, Philippi, 1846; *Modiola*
hanleyana, Reeve, 1857; *Lithodomus*
laevigata, Quoy and Gaimard, 1835; *Modiola*
straminea, Reeve, 1857; *Lithodomus*
teres, Philippi, 1846; *Modiola*
Modiolaria barbata, Reeve, 1858; *Lithodomus*
cumingiana, Reeve, 1857; *Modiola*
cuneata, Gould, 1861
miranda, Smith, 1884
perstriata, Hedley, 1906
splendida, Dunker, 1856; *Volsella*
Myrina coppingeri, Smith, 1885
Congeria lunata, Hedley, 1902
Septifer bilocularis, Linne, 1758; *Mytilus*
Julia exquisita, Gould, 1862
Pholadomya arenosa, Hedley, 1904; *Thraciopsis*
haddoni, Melvill and Standen, 1899
Anatina faba, Reeve, 1863
gracilis, Reeve, 1860
prolongata, Reeve, 1863
vagina, Reeve, 1863
Thracia modesta, Angas, 1867
Thraciopsis speciosa, Angas, 1869; *Thracia*
Myochama anomioides, Stutchbury, 1830
Myodora australica, Reeve, 1859; *Thracia*
brevis, Sowerby; *Pandora*
pulleinei, Hedley, 1906
trigona, Reeve
Cœlodon elongatus, Carpenter, 1846
Clavagella torresi, Smith, 1885
Aspergillum agglutinans, Lamarck, 1818
strangulatum, Chenu
Verticordia australiensis, Smith, 1885
deshayesiana, Fischer, 1862
torrida, Hedley, 1906
Poromya australis, Smith, 1885
lævis, Smith, 1885
Cuspidaria brazieri, Smith, 1885; *Neæra*
fallax, Smith, 1885; *Neæra*
latesulcata, Ten. Woods, 1878; *Neæra*
Trapezium angulatum, Lamarck, 1819; *Cypricardia*
vellicatum, Reeve, 1843; *Cypricardia*
Crassatellites janus, Hedley, 1906
kingicola, Lamarck, 1804; *Crassatella*
rhomboides, Smith, 1885; *Crassatella*
torresi, Smith, 1885; *Crassatella*
ziczac, Reeve; *Crassatella*
Cuna delta, Tate and May, 1900; *Carditella*
flava, Hedley, 1906
Cyrena coaxans, Gmelin, 1791; *Venus*
Batissa triquetra, Deshayes, 1854
Carditella torresi, Smith, 1885
infans, Smith, 1885

Cardita calyculata, Linne, 1758; *Chama*
cardioides, Reeve, 1843
crassicosta, Lamarck, 1819
incrassata, Sowerby, 1825
insignis, Smith, 1885
marmorea, Reeve, 1843
semiorbiculata, Linne, 1758; *Chama*
variegata, Bruguière, 1792
Venericardia amabilis, Deshayes, 1854
Condylocardia ovata, Hedley, 1906
porrecta, Hedley, 1906
trifoliata, Hedley, 1906
Chama divaricata, Reeve, 1846
fimbriata, Reeve, 1847
jukesii, Reeve, 1847
pulchella, Reeve, 1846
reflexa, Reeve, 1846
spinosa, Broderip, 1835
sulphurea, Reeve, 1846
Codakia bella, Conrad, 1837; *Lucina*
congenita, Smith, 1885; *Lucina*
cristata, Smith, 1885; *Lucina*
exasperata, Reeve, 1850; *Lucina*
interrupta, Lamarck, 1818; *Cytherea*
munda, A. Adams, 1856; *Lucina*
oblonga, Hedley, 1899; *Lucina*
reevei, Deshayes, 1863; *Lucina*
strangei, A. Adams, 1856; *Lucina*
Loripes haddoni, Melvill and Standen, 1899
icterica, Reeve, 1850; *Lucina*
Phacoides eucosmia, Dall, 1901; *Parvilucina*
Myrtæa desiderata, Smith, 1885; *Lucina*
Divaricella angulifera, v. Martens, 1880; *Lucina*
macandreæ, H. Adams, 1870; *Lucina*
Corbis fimbriata, Linne, 1758; *Venus*
elegans, Deshayes
Diplodonta adamsi, Angas, 1867; *Mysia*
conspicua, Smith, 1885
corpulenta, Smith, 1885
ethima, Melvill and Standen, 1899
globosa, A. Adams, 1856
scalpta, Smith, 1885
subcrassa, Smith, 1884
subglobosa, Smith, 1885
sublateralis, Smith, 1885
Joannisiella sphaericula, Deshayes, 1855; *Cyrenella*
moretonensis, Deshayes, 1855; *Cyrenella*
Lucina corrugata, Deshayes, 1843
edentula, Linne, 1758; *Venus*
Kellia cycladiformis, Deshayes, 1850
physema, Melvill and Standen, 1899
suborbicularis, Montagu, 1804; *Mya*
Rochefortia acuminata, Smith, 1885; *Montacuta*
ephippiolum, Melvill and Standen, 1899; *Tellimya*
paula, A. Adams, 1856; *Pythina*
Cyamiomactra mactroides, Tate and May, 1900; *Cyamium*
Solecardia alberti, Smith, 1884; *Scintilla*
aurantiaca, Deshayes, 1856; *Scintilla*
cuvieri, Deshayes, 1856; *Scintilla*
hyalina, Deshayes, 1856; *Scintilla*
purpurascens, Sowerby, 1874; *Scintilla*
strangei, Deshayes, 1856; *Scintilla*
turgescens, Deshayes, 1856; *Scintilla*
Galeomma denticulata, Deshayes, 1863

Cardium bechei, Reeve, 1847
biradiatum, Bruguière, 1789
dianthinum, Melvill and Standen, 1899
dupuchense, Reeve, 1845
elongatum, Bruguière, 1789
flavum, Linne, 1758
fornicatum, Sowerby, 1841
fragum, Linne, 1758
hemicardium, Linne. 1758
hystrix, Reeve, 1844
imbricatum, Sowerby, 1841
laevigatum, Linne, 1758
lacunosum, Reeve, 1845
lobulatum, Deshayes, 1855
lyratum, Sowerby, 1841
maculosum, Wood, 1815
multispinosum, Sowerby, 1840
productum, Deshayes, 1855
reevianum, Dunker, 1852
rubicundum, Reeve, 1844
serricostatum, Melvill and Standen, 1899
skeeti, Hedley, 1906
tenuicostatum, Lamarck, 1819
transcendens, Melvill and Standen, 1899
unedo, Linne, 1758
variegatum, Sowerby, 1841

Opisocardium subretusum, Sowerby, 1841; *Cardium*
Tridacna crocea, Lamarck, 1819
derasa, Bolten, 1798; *Tridachnes*
elongata, Lamarck, 1819
gigas, Linne, 1758; *Chama*
lamarcki, Hidalgo, 1903
Hippopus hippopus, Linne, 1758; *Chama*
Dosinia amphidesmoides, Reeve, 1850; *Artemis*
cærulea, Reeve, 1850; *Artemis*
deshayesii, A. Adams, 1856
exasperata, Philippi, 1847; *Cytherea*
histrio, Gmelin, 1791; *Venus*
nobilis, Deshayes, 1853
sculpta, Hanley, 1856; *Artemis*
tumida, Gray, 1838; *Artemis*
Clementia papyracea, Gray, 1825; *Venus*
Gafrarium angasi, Smith, 1885; *Circe*
australe, Sowerby, 1851; *Circe*
australica, Reeve, 1863; *Dione*
bullatum, Sowerby, 1851; *Cytherea*
coxeni, Smith, 1884; *Cytherea*
inflatum, Sowerby, 1856; *Cytherea*
jucundum, Smith, 1885; *Circe*
lenticulare, Deshayes, 1854; *Cytherea*
navigatum, Hedley, 1906
obliquissimum, Smith, 1885; *Circe*
pectinatum, Linne, 1758; *Venus*
rivulare, Born, 1778; *Venus*
scriptum, Linne, 1758; *Venus*
tumidum, Bolten, 1789
yerburyi, Smith, 1891; *Cytherea*
Cytherea anadyomene, Anton, 1839; *Venus*
calophylla, Philippi, 1836; *Venus*
capricornea, Hedley, 1908; *Chione*
chemnitzii, Hanley, 1845; *Venus*
embrithes, Melvill and Standen, 1899; *Chione*
foliacea, Philippi, 1846; *Venus*
lamellaris, Schumacher, 1817; *Antigona*
laqueata, Sowerby, 1853; *Venus*

Cytherea lionota, Smith, 1885; *Venus*
listeri, Gray, 1838; *Dosinia*
puerpera, Linne, 1771; *Venus*
reticulata, Linne, 1758; *Venus*
tiara, Dillwyn, 1817; *Venus*
toreuma, Gould, 1850; *Venus*
torresiana, Smith, 1884; *Venus*
Lioconcha castrensis, Linne, 1758; *Venus*
fastigiata, Sowerby, 1851; *Cytherea*
ornata, Dillwyn, 1817; *Venus*
Granicorium indutum, Hedley, 1906
Macrocallista disrupta, Sowerby, 1853; *Cytherea*
hebraea, Lamarck, 1818; *Cytherea*
roseotincta, Smith, 1885; *Cytherea*
Chione costellifera, A. Adams, 1850; *Venus*
infans, Smith, 1885
marica, Linne, 1758; *Venus*
phoenicopterus, Romer, 1869; *Caryatis*
recognita, Smith, 1885; *Venus*
regularis, Smith, 1885; *Cytherea*
scabra, Hanley, 1845; *Venus*
semperi, Dunker, 1871
subnodulosa, Hanley, 1845; *Venus*
torresica, Reeve, 1863
undulosa, Lamarck, 1819; *Venus*
Pitaria prora, Conrad, 1837; *Cytherea*.
Paphia deshayesi, Hanley, 1856; *Venus*
gallus, Gmelin, 1791; *Venus*
hiantina, Lamarck; *Venus*
literata, Linne, 1758; *Venus*
radiata, Chemnitz
sulcosa, Philippi, 1847; *Venus*
textile, Gmelin, 1791; *Venus*
tristis, Lamarck, 1818; *Venus*
variegata, Sowerby, 1852; *Tapes*
Petricola lapicida, Gmelin, 1791; *Venus*
Isocardia moltkiana, Gmelin, 1791; *Chama*
Glaucomya rugosa, Hanley, 1828; *Glauconomya*
desmoyersii, Reeve
Tellina asperrima, Hanley, 1844
aurea, Perry, 1811
australis, Deshayes, 1855
capsoides, Lamarck, 1818
compacta, Smith, 1885
decussata, Lamarck, 1818
diluta, Smith, 1885
dispar, Conrad, 1837
donaciformis, Deshayes, 1855
emarginata, Sowerby, 1825
gargadia, Linne, 1758
inflata, Gmelin, 1791
iridescens, Benson, 1842; *Sanguinolaria*
languida, Smith, 1885
lux, Hanley, 1844
murrayi, Smith; 1885
perna, Spengler, 1798
pharaonis, Hanley, 1844
philippinarum, Hanley, 1844
philippii, Philippi, 1844
pulcherrima, Sowerby, 1825
procrita, Melvill and Standen, 1899
remies, Linne, 1758
rhomboides, Quoy and Gaimard, 1835
rugosa, Born, 1780
semen, Hanley, 1845

Tellina semitorta, Sowerby, 1867
solenella, Deshayes, 1855
staurella, Lamarck, 1818
squamulosa, A. Adams, 1850
subtruncata, Hanley, 1844
sulcata, Wood, 1815
tenuilirata, Sowerby, 1867
vernalis, Hanley, 1844
virgata, Linne, 1758
virgulata, Hanley, 1845
Macoma inequivalvis, Sowerby, 1867; *Tellina*
candida, Lamarck, 1818; *Psammotœa*
moretonensis, Deshayes, 1855; *Tellina*
Arcopagia casta, Hanley, 1844; *Tellina*
angulata, Linne, 1767; *Tellina*
carnicolor, Hanley, 1846; *Tellina*
elegantissima, Smith, 1885; *Tellina*
fabrefacta, Pilsbry, 1904; *Tellina*
lingua-felis, Linne, 1758; *Tellina*
ovata, Bolten, 1798; *Tellina*
pinguis, Hanley, 1844; *Tellina*
robusta, Hanley, 1844; *Tellina*
savignyi, H. Adams, 1870; *Tellina*
scobinata, Linne, 1758; *Tellina*
tessellata, Deshayes, 1855; *Tellina*
Metis meyeri, Philippi, 1846; *Tellina*
spectabilis, Hanley, 1844; *Tellina*
Strigilla euronia, Hedley, 1908
grossiana, Hedley, 1908
splendida, Anton, 1839; *Tellina*
Phylloda foliacea, Linne, 1758; *Tellina*
Semele amabilis, Reeve, 1853; *Amphidesma*
casta, Reeve, 1853; *Amphidesma*
crenata, Adams and Angas, 1863
crenulata, Reeve, 1853; *Amphidesma*
duplicata, Sowerby, 1830
exarata, Adams and Reeve, 1850
infans, Smith, 1885
jukesii, Reeve, 1853; *Amphidesma*
lamellosa, Sowerby, 1830
regularis, Smith, 1885
Theora fragilis, A. Adams, 1856; *Neæra*
Leptomya psittacus, Hanley, 1883
Abra truncata, Hedley, 1906
Psammobia anomala, Deshayes, 1855
castrensis, Spengler, 1794; *Solen*
gracilenta, Smith, 1884
lessoni, Blainville, 1826
marmorea, Deshayes, 1855
modesta, Deshayes, 1855
ornata, Deshayes, 1855
praestans, Deshayes, 1855
pulcherrima, Deshayes, 1855
rasilis, Melvill and Standen, 1899
zonalis, Lamarck, 1818; *Psammotœa*
Sanguinolaria virescens, Deshayes, 1855; *Capsa*
tenuis, Deshayes, 1855; *Capsa*
Asaphis deflorata, Linne, 1758; *Venus*
contraria, Deshayes, 1863; *Psammobia*
Donax deltoides, Lamarck, 1818
brazieri, Smith, 1891
faba, Gmelin, 1791
nitida, Reeve, 1854
Cultellus cultellus, Linne, 1758; *Solen*
hanleyi, Dunker, 1861

Psammosolen australis, Dunker, 1861; *Macha*
coarctatus, Gmelin, 1791; *Solen*
deshayesii, Dunker, 1861; *Macha*
minutus, Dunker, 1861; *Azor*
sulcatus, Dunker, 1861; *Macha*
Mactra achatina, Chemnitz, 1795
angulifera, Reeve, 1854
apicina, Reeve, 1854
aspersa, Sowerby, 1825
coppingeri, Smith, 1884
dissimilis, Reeve, 1854
eximia, Reeve, 1854
jacksonensis, Smith, 1885
maculata, Gmelin, 1791
obesa, Reeve, 1854
ornata, Gray, 1837
parkesiana, Hedley, 1902
plicataria, Linne, 1767
pusilla, A. Adams, 1856
tristis, Reeve, 1854
Spisula parva, Petit, 1853; *Gnathodon*
Labiosa grayi, H. Adams, 1872; *Raeta*
Lutraria arcuata, Reeve, 1854
elongata, Gray, 1837
impar, Reeve, 1854
oblonga, Gmelin, 1791; *Mya*
philippinarum, Reeve, 1854
Standella nicobarica, Gmelin, 1791; *Mactra*
Cardilia semisulcata, Lamarck, 1819; *Isocardia*
Atactodea glabrata, Gmelin, 1791; *Mactra*
intermedia, Reeve, 1854; *Mesodesma*
mitis, Reeve, 1854; *Mesodesma*
striata, Gmelin, 1791; *Mactra*
Mesodesma elongata, Reeve, 1854
Davila plana, Hanley, 1843; *Mesodesma*
Ervilia bisculpta, Gould, 1861
Cryptomya elliptica, A. Adams, 1851; *Sphaenia*
Corbula crassa, Hinds, 1843
macgillivrayi, Smith, 1885
monilis, Hinds, 1843
scaphoides, Hinds, 1843
taitensis, Lamarck, 1818
tunicata, Hinds, 1843
Saxicava arctica, Linne, 1767; *Mya*
Anisodonta caledonica, Fischer, 1886; *Eucharis*
Gastrochaena hians Gmelin, 1791; *Pholas*
gigantea, Deshayes, 1830; *Fistulana*
plicatilis, Deshayes, 1855
Roccellaria pupina, Deshayes, 1855; *Gastrochaena*
Pholas quadrizonata, Spengler, 1792
latissima, Sowerby, 1849
orientalis, Gmelin, 1791
australasiæ, Sowerby, 1849
obturamentum, Hedley, 1893
multistriata, Sowerby, 1849
Martesia obtecta, Sowerby, 1849; *Pholas*
striata, Linne, 1758; *Pholas*
Jouanetia cumingi, Sowerby, 1849
globosa, Q. and G., 1832
Fistulana mumia, Spengler, 1783; *Gastrochaena*
Solen sloanii, Hanley, 1842
vagina, Linne, 1758
Nausitoria manni, Wright, 1865
thoracites, Gould, 1856, *Calobates*

CEPHALOPODA.

Nautilus pompilius, Linne, 1758
Spirula spirula, Linne, 1758; *Nautilus*
Sepia cultrata, Hoyle, 1885
esculenta, Hoyle, 1886
pfefferi, Hoyle, 1885
Sepioteuthis lessoniana, Ferussac, 1826
Ommastrephes oualaniensis, Lesson, 1830
Polypus pictus, Brock, 1882; *Octopus*
polyzenia, Gray, 1849; *Octopus*
tenebricus, Smith, 1884; *Octopus*
Argonauta hians, Dillwyn, 1817

AMPHINEURA.

Notomenia clavigera, Thiele, 1897
Proneomenia australis, Thiele, 1897
Ischnochiton adelaidensis, Reeve, 1847; *Chiton*
australis, Sowerby, 1840; *Chiton*
Callistochiton antiquus, Reeve, 1847; *Chiton*
Acanthochites asbestoides, Smith, 1884; *Chiton*
Cryptoplax burrowi, Smith, 1884; *Chiton*
oculatus, Quoy and Gaim, 1834; *Chiton*
Chiton miles, Pilsbry, 1892
translucens, Hedley and Hull, 1909
pulcherrimus, Sowerby, 1841
Tonicia confossa, Gould, 1846; *Chiton*
fortilirata, Reeve, 1847; *Chiton*
picta, Reeve, 1847; *Chiton*
Liolophura curtisiana, Smith, 1884; *Chiton*
gaimardi, var. queenslandica, Pilsbry, 1894
Acanthopleura aculeata, Linne, 1758; *Chiton*
spinosa, Bruguière, 1792; *Chiton*
Schizochiton incisus, Sowerby, 1841; *Chiton*
Onithochiton lyellii, Sowerby, 1832; *Chiton*

GASTEROPODA.

Schismope atkinsoni, Ten-Woods, 1877; *Scissurella*
Scutus unguis, Linne, 1758; *Patella*
Subemarginula cumingii, Sowerby, 1863; *Emarginula*
clathrata, Ad. and Reeve, 1850; *Emarginula*
rugosa, Quoy and Gaim, 1833; *Emarginula*
Emarginula convexa, Hedley, 1907
dilecta, A. Adams, 1852
incisura, A. Adams, 1852
micans, A. Adams, 1852
variegata, A. Adams, 1852
Megatebennus javanicensis, Lamarck, 1822; *Fissurella*
Fissuridea corbicula, Sowerby, 1862; *Fissurella*
galeata, Helbling, 1779; *Patella*
incii, Reeve, 1850; *Fissurella*
jukesii, Reeve, 1849; *Fissurella*
proxima, Sowerby, 1862; *Fissurella*
quadriradiata, Reeve, 1850; *Fissurella*
rüppellii, Sowerby, 1835; *Fissurella*
singaporensis, Reeve, 1850; *Fissurella*
ticaonica, Reeve, 1850; *Fissurella*
Fissurella calyculata, Sowerby, 1823
elongata, Philippi, 1845
lanceolata, Sowerby, 1862
minuta, Lamarck, 1822
octagona, Reeve, 1850
Macroschisma madreporaria, Hedley, 1907
Lucapinella nigrita, Sowerby, 1834; *Fissurella*
Zeidora lodderæ, Tate and May, 1900
Rimula exquisita, A. Adams, 1853

Puncturella galerita, Hedley, 1902
Haliotis asinina, Linne, 1758
astricta, Reeve, 1846
ovina, Gmelin, 1791
squamata, Reeve, 1846
varia, Linne, 1758
Microtis tuberculata, A. Adams, 1850
Stomatella bicarinata, A. Adams, 1854; *Stomatia*
biporcata, A. Adams, 1850
cancellata, Krauss, 1848
concinna, Gould, 1845
elegans, Gray, 1847
imbricata, Lamarck, 1822
maculata, Quoy and Gaimard, 1834
orbiculata, A. Adams, 1850
rufescens, Gray, 1847
stellata, Souverbie, 1863
sulcifera, Lamarck, 1822
Stomatia angulata, A. Adams, 1850
australis, A. Adams, 1850
decussata, A. Adams, 1850
phymotis, Helbling, 1779
Gena lentricula, A. Adams, 1850
striatula, A. Adams, 1850
ungula, Hedley, 1907
varia, A. Adams, 1850
Trochus calcaratus, Souverbie, 1875
fenestratus, Gmelin, 1791
hexagonus, Philippi, 1846
maculatus, Linne, 1758
niloticus, Linne, 1767
obeliscus, Gmelin, 1791
Clanculus albinus, A. Adams, 1853
atropurpureus, Gould, 1849; *Trochus*
bicarinatus, Angas, 1880
granti, Hedley, 1907
stigmatarius, A. Adams, 1853
unedo, A. Adams, 1853
Camita rotellina, Gould, 1860; *Trochus*
Monodonta labio, Linne, 1758; *Trochus*
millelineatus, Bonnet, 1864; *Trochus*
viridis, Lamarck, 1822
Cantharidus crenelliferus, A. Adams, 1853; *Thalotia*
cingulatus, A. Adams, 1863; *Leiopyrga*
eximius, Perry, 1811; *Bulimus*
marginatus, Ten.-Woods, 1880; *Thalotia*
suturalis, A. Adams, 1853; *Thalotia*
Gibbula maccullochi, Hedley, 1907
townsendi, Sowerby, 1895
Monilea callifera, Lamarck, 1822; *Trochus*
glaphyrella, Melvill and Standen, 1895; *Minolia*
henniana, Melvill, 1891; *Minolia*
lentiginosa, A. Adams, 1852
lifuana, Fischer, 1878; *Trochus*
nuclea, Philippi, 1849; *Trochus*
pudibunda, Fischer, 1878; *Trochus*
tropicalis, Hedley, 1907
vitiliginea, Menke, 1843; *Trochus*
Calliostoma arruense, Watson, 1880; *Trochus*
bicingulatus, Lamarck, 1822; *Trochus*
deceptum, Smith, 1899
monile, Reeve, 1863; *Ziziphinus*
nobile, Philippi, 1846; *Trochus*
polychroma, A. Adams, 1853; *Ziziphinus*
scobinatum, Reeve, 1863; *Ziziphinus*

Calliostoma similare, Reeve, 1863; *Ziziphinus*
speciosum, A. Adams, 1855; *Ziziphinus*
trepidum, Hedley, 1907
Astele septenarium, Melv. Stand., 1899; *Calliostoma*
Turcia maculata, Brazier, 1877; *Thalotia*
monilifera, A. Adams, 1855
montrouzieri, Fischer, 1878; *Tectaria*
Basilissa superba, Watson, 1879
Euchelus atratus, Gmelin, 1791; *Trochus*
foveolatus, A. Adams, 1853; *Monodonta*
granosus, Brazier, 1877; *Clanculus*
roseola, Nevill, 1869; *Tallorbis*
rubus, A. Adams, 1853; *Monodonta*
Angaria delphinus, Linne, 1758; *Turbo*
formosa, Reeve, 1842; *Delphinula*
Umbonium vestiarium, Linne, 1758; *Trochus*
Ethalia guamensis, Quoy and Gaimard, 1834; *Rotella*
pulchella, A. Adams, 1855; *Isanda*
Isanda coronata, A. Adams, 1855
Chrysostoma paradoxum, Born, 1780; *Helix*
Alcyna australis, Hedley, 1907
Phasianella variegata, Lamarck, 1822
Turbo argyrostomus, Linne, 1758
concinnus, Philippi, 1847
chrysostomus, Linne, 1758
foliaceus, Philippi, 1846
gemmatus, Reeve, 1848
imperialis, Gmelin, 1791
marmoratus, Linne, 1758
nivosus, Reeve, 1848
petholatus, Linne, 1758
porphyrites, Martyn, 1784; *Helix*
sparverius, Gmelin, 1791
speciosus, Reeve, 1848
tumidulus, Reeve, 1848
undulatus, Martyn, 1784; *Limax*
Astralium petrosum, Martyn, 1787; *Trochus*
nobile, Gray, 1847
aureum, Hedley, 1907
tentoriiforme, Jonas, 1845; *Trochus*
Callomphala globosa, Hedley, 1901
lucida, Adams and Angas, 1864; *Neritula*
Teinostoma involutum, Hedley, 1902
oppletum, Hedley, 1898
orbitum, Hedley, 1900
qualum, Hedley, 1899
vestum, Hedley, 1901
Cirsonella weldii, Tenison-Woods, 1877; *Cyclostrema*
cubitale, Hedley, 1907
Liotia acidalia, Melvill and Standen, 1899; *Microtheca*
calliglypta, Melvill, 1891
crenata, Kiener, 1839; *Delphinula*
corona, Hedley, 1902
devexa, Hedley, 1901
discoidea, Reeve, 1843; *Delphinula*
incidata, Hedley, 1902
latebrosa, Hedley, 1907
micans, A. Adams, 1850; *Cyclostrema*
minima, Tenison-Woods, 1878
muricata, Reeve, 1843; *Delphinula*
peronii, Kiener, 1839; *Delphinula*
philtata, Hedley, 1900
rostrata, Hedley, 1900
scalaroides, Reeve, 1843; *Delphinula*
varicosa, Reeve, 1843; *Delphinula*
venusta, Hedley, 1901

Mecoliotia spinosa, Hedley, 1902
Moerchia introspecta, Hedley, 1907
Leptothyra laeta, Montrouzier, 1863; *Turbo*
nanina, Souverbie, 1864; *Turbo*
Nerita albicilla, Linne, 1758
chamaeleon, Linne, 1758
costata, Gmelin, 1791
grossa, Linne, 1758
insculpta, Recluz, 1841
lineata, Gmelin, 1791
melanotragus, Smith, 1884
planospira, Anton, 1839
plicata, Linne, 1758
polita, Linne, 1758
reticulata, Karsten, 1789
undata, Linne, 1758
Magadis eumerintha, Melvill and Standen, 1899
Neritina souverbiana, Montrouzier, 1863
Neritopsis radula, Linne, 1758; *Nerita*
Acmaea costata, Sowerby, 1839; *Lottia*
saccharina, Linne, 1758; *Patella*
Phenacolepas cinnamomea, Gould, 1846; *Patella*
crenulata, Broderip, 1834; *Scutella*
senta, Hedley, 1899
Helcioniscus illibrata, Verco, 1906
Litorina coccinea, Martyn, 1784; *Limax*
mauritiana, Lamarck, 1822; *Phasianella*
melanacme, Smith, 1876
nebulosa, Lamarck, 1822; *Phasianella*
pallescens, Philippi, 1846
picta, Philippi, 1846
scabra, Linne, 1758; *Helix*
undulata, Gray, 1839
Tectarius malaccanus, Philippi, 1847; *Littorina*
nodulosus, Gmelin, 1791; *Trochus*
Risella melanostoma, Gmelin, 1791; *Trochus*
tantilla, Gould, 1849
Fossarus brumalis, Hedley, 1907
cereus, Watson, 1880
Adeorbis plana, Sowerby, 1864
Planaxis sulcatus, Born, 1778; *Buccinum*
brasilianus, Lamarck, 1822; *Buccinum*
zonatus, A. Adams, 1853
Quoyia decollata, Quoy and Gaimard, 1833; *Planaxis*
Rissoa atropurpurea, Frauenfeld, 1867; *Setia*
australiæ, Frauenfeld, 1867
cheilostoma, Tenison-Woods, 1879
devecta, Tate, 1899
flammea, Frauenfeld, 1867; *Sabanaea*
frauenfeldi, Schwartz, 1869
incidata, Frauenfeld, 1867; *Sabanaea*
liddelliana, Hedley, 1907
nitens, Frauenfeld, 1867; *Setia*
novarensis, Frauenfeld, 1867; *Alvania*
olivacea, Frauenfeld, 1867; *Alvania*
Onoba glomerosa, Hedley, 1907
mercurialis, Watson, 1886; *Rissoa*
Epigrus dissimilis, Watson, 1883; *Eulima*
verconis, Tate, 1899; *Rissoa*
xanthias, Watson, 1886; *Mucronalia*
Amphithalamus capricorneus, Hedley, 1907
jacksoni, Brazier, 1895; *Rissoa*
salebrosus, Frauenfeld, 1868; *Alvania*
scrobiculatus, Watson, 1886; *Rissoa*

Anabathron ascensum, Hedley, 1907
contortum, Hedley, 1907
contabulatum, Frauenfeld, 1868
Aclis minutissima, Watson, 1886
Scaliola arenosa, A. Adams, 1862
bella, A. Adams, 1860
caledonica, Crosse, 1870
elata, Issel, 1869
Rissoina cardinalis, Brazier, 1877
clathrata, A. Adams, 1853
crassa, Angas, 1871
curtisi, Smith, 1881
efficata, Brazier, 1877
elegantula, Angas, 1880
exasperata, Souverbie, 1866
fasciata, A. Adams, 1853
hanleyi, Schwartz, 1860
inconspicua, Brazier, 1877
inermis, Brazier, 1877
kesteveni, Hedley, 1907
miranda, A. Adams, 1861
montrouzieri, Souverbie, 1862
nodicincta, A. Adams, 1853
obeliscus, Schwartz, 1860
pulchella, Brazier, 1877
reticulata, Sowerby, 1834; *Rissoa*
scalarina, A. Adams, 1853
scolopax, Souverbie, 1877
spirata, Sowerby, 1834; *Rissoa*
teres, Brazier, 1877
thaumasia, Melvill and Standen, 1898
triangularis, Watson, 1886
Alaba flammea, Pease, 1867; *Rissoa*
phasianella, Angas, 1867
goniochila, A. Adams, 1860; *Styliferina*
semistriata, Philippi, 1849
Diala martensii, Issel, 1869
Litiopa melanostoma, Rang., 1829
Obtortio fulva, Watson, 1886; *Alaba*
striata, Watson, 1886; *Alaba*
Cithna marmorata, Hedley, 1907
Stenothyra australis, Hedley, 1901
Pyrgula clathrata, A. Adams, 1855
Truncatella ferruginea, Cox, 1868
teres, Pfeiffer, 1857
yorkensis, Cox, 1868
Hipponix conica, Schumacher, 1817; *Amalthea*
barbata, Sowerby, 1835; *Hipponyx*
Cheilea equestris, Linne, 1758; *Patella*
Calyptraea pellucida, Reeve, 1859; *Trochita*
Crepidula aculeata, Gmelin, 1791; *Patella*
Capulus tricarinatus, Linne, 1767; *Patella*
calyptra, Martyn, 1784; *Patella*
Cerithium album, Hombron and Jacquinot, 1853
articulatum, A. Adams and Reeve, 1850
balteatum, Philippi, 1848
bicanaliferum, Brazier, 1877
citrinum, Sowerby, 1855
coarctatum, Sowerby, 1866
columna, Sowerby, 1834
contractum, Sowerby, 1855
eximium, Sowerby, 1855
fasciatum, Bruguière, 1792
fusiforme, Sowerby, 1855
graciliforme, Sowerby, 1865

Cerithium granosum, Kiener, 1842
kochi, Philippi, 1848
lemniscatum, Quoy and Gaimard, 1834
macrostoma, Hinds, 1844
mitraeforme, Sowerby, 1855
morus, Lamarck, 1822
nigrobalteatum, Smith, 1884
novaehiberniae, Sowerby, 1855
novaehollandiæ, Sowerby, 1855
petrosum, Wood, 1828
piperitum, Sowerby, 1855
rostratum, Sowerby, 1855
rubus, Martyn, 1784; *Clava*
salebrosum, Sowerby, 1855
taeniatum, Sowerby, 1865
tessellatum, Sowerby, 1855
torresi, Smith, 1884
turritum, Sowerby, 1855
variegatum, Quoy and Gaimard, 1834
Bittium diplax, Watson, 1886
elegantissimum, Hedley, 1899; *Cerithium*
perparvulum, Watson, 1886
porcellanum, Watson, 1886
pupiforme, Watson, 1880
xanthum, Watson, 1886
zebrum, Kiener, 1842; *Cerithium*
Ataxocerithium abbreviatum, Brazier, 1877; *Cerithium*
serotinum, A. Adams, 1855; *Cerithium*
Plesiotrochus pagodiformis, Hedley, 1907
Clava aluco, Linne, 1758; *Murex*
aspera, Linne, 1758; *Murex*
nodulosa, Bruguière, 1792
pulchra, Sowerby, 1855; *Vertagus*
recurva, Sowerby, 1855; *Cerithium*
sinensis, Gmelin, 1791; *Murex*
sowerbyi, Kiener, 1842; *Cerithium*
vertaga, Linne, 1767; *Murex*
Cerithidea kieneri, Hombr. and Jacq., 1853; *Cerithium*
largillierti, Philippi, 1848; *Cerithium*
Pyrazus australis, Quoy and Gaim., 1834; *Cerithium*
cingulatus, Gmelin, 1790; *Murex*
herculeus, Martyn, 1784; *Clava*
layardi, A. Adams, 1855; *Cerithium*
palustris, Linne, 1767; *Strombus*
sulcatus, Born, 1778; *Murex*
telescopium, Linne, 1758; *Trochus*
Mathilda oppia, Hedley, 1907
elegantula, Angas, 1871
Cerithiopsis angasi, Semper, 1874
ridicula, Watson 1886
Triphora cornuta, Hervier, 1897
corrugata, Hinds, 1843
dolicha, Watson, 1886; *Triforis*
excelsior, Melvill and Standen, 1899; *Triforis*
funebris, Jousseaume, 1884
gigas, Hinds, 1843
kesteveni, Hedley, 1903
labiata, A. Adams, 1851
rubra, Hinds, 1843
rufula, Watson, 1886; *Triforis*
violacea, Quoy and Gaimard, 1834; *Cerithium*
Turritella captiva, Hedley, 1907
cerea, Reeve, 1849
cingulifera, Sowerby, 1825
deliciosa, Watson, 1880

Turritella fascialis, Menke, 1830
fastigiata, Adams and Reeve, 1850
multilirata, Adams and Reeve, 1850
Eglisia tricarinata, Adams and Reeve, 1840
Modulus tectum, Gmelin, 1791; *Trochus*
Caecum amputatum, Hedley, 1894
angustum, de Folin, 1886
attenuatum, de Folin, 1879
chinense, de Folin, 1867
eburneum, de Folin, 1886
lilianum, Hedley, 1903
microcyclus, de Folin, 1879
subflavum, de Folin, 1879
succineum, de Folin, 1879
Strebloceras cygnicollis, Hedley, 1904
Parastrophia challengeri, de Folin, 1879
Watsonia elegans, de Folin, 1879
Ctiloceras clathratum, Hedley, 1902
cyclicum, Watson, 1886; *Vermetus*
striatum, Hedley, 1902
Crossea biconica, Hedley, 1902
gatliffi, Hedley, 1902
inverta, Hedley, 1907
striata, Watson, 1883
Lippistes blainvilleanus, Petit, 1851; *Trichotropis*
gracilentus, Brazier, 1877; *Trichotropis*
zodiacus, Hedley, 1907
Couthouyia aculeata, Hedley, 1900
Vermicularia maxima, Sowerby, 1825; *Serpula*
novaehollandiæ, Rousseau
quoyi, H. and A. Adams, 1854; *Cladopoda*
Siliquaria cumingii, Morch, 1860
ponderosa, Morch, 1860
scalariformis, Morch, 1860
trochlearis, Morch, 1860
Ianthina ianthina, Linne, 1758; *Helix*
Recluzia johnii, Chemnitz, 1795; *Helix*
Vanikoro cancellata, Hermann, 1781; *Nerita*
clathrata, Recluz, 1845; *Narica*
deshayesiana, Recluz, 1843; *Narica*
gaimardi, A. Adams, 1854
Xenophora cerea, Reeve, 1845; *Phorus*
exuta, Reeve, 1843; *Phorus*
helvacea, Philippi, 1851
pallidula, Reeve, 1843; *Phorus*
solarioides, Reeve, 1845; *Phorus*
Strombus australis, Gray, 1827
auris-dianæ, Linne, 1758
elegans, Sowerby, 1842
campbelli, Griffith and Pidgeon, 1834
canarium, Linne, 1758
dentatus, Linne, 1758
gibberulus, Linne, 1758
laciniatus, Dillwyn, 1817
lentiginosus, Linne, 1858
luhuanus, Linne, 1758
melanostomus, Swainson, 1822
papilio, Dillwyn, 1817
plicatus, Bolten, 1798; *Lambis*
sibbaldii, Sowerby, 1842
urceus, Linne, 1758
ustulatus, Schumacher, 1817; *Canarium*
variabilis, Swainson, 1821
vittatus, Linne, 1758

Pterocera bryonia, Gmelin, 1791; *Strombus*
lambis, Linne, 1758; *Strombus*
Terebellum terebellum, Linne, 1758; *Conus*
Epitonium aculeatum, Sowerby, 1844; *Scalaria*
auritum, Sowerby, 1844; *Scalaria*
bicarinatum, Sowerby, 1844; *Scalaria*
castum, Sowerby, 1873; *Scalaria*
denticulatum, Sowerby, 1844; *Scalaria*
dentiscalpium, Watson, 1883; *Scalaria*
hyalinum, Sowerby, 1844; *Scalaria*
irregulare, Sowerby, 1844; *Scalaria*
kieneri, Canefri, 1876; *Cirsotrema*
lyra, Sowerby, 1844; *Scalaria*
muricatum, Kiener, 1839; *Scalaria*
obliquum, Sowerby, 1844; *Scalaria*
philippinarum, Sowerby, 1844; *Scalaria*
replicatum Sowerby, 1844; *Scalaria*
revolutum, Hedley, 1899; *Scala.*
rubrolineatum, Sowerby, 1844; *Scalaria*
scalare, Linne, 1758; *Turbo*
subauriculatum, Souverbie, 1866; *Scalaria*
subnudatum, Sowerby, 1874; *Scalaria*
tenuicostatum, Sowerby, 1844; *Scalaria*
turriculum, Sowerby, 1844; *Scalaria*
varicosum, Lamarck, 1822; *Scalaria*
vestale, Hinds, 1843; *Scalaria*
Pyramidella auris-cati, Chemnitz, 1795; *Voluta*
concinna, A. Adams, 1860
gracilis, A. Adams, 1855
acus, Gmelin, 1791; *Voluta*
mitralis, A. Adams, 1855
pulchella, A. Adams, 1854; *Obeliscus*
terebelloides, A. Adams, 1854; *Obeliscus*
tessellata, A. Adams, 1854; *Obeliscus*
turrita, A. Adams, 1854; *Obeliscus*
Syrnola cinctella, A. Adams, 1860
pulchra, Brazier, 1877
tincta, Angas, 1871
Oscilla tasmanica, Ten.-Woods, 1877; *Parthenia*
Odostomia aciculina, Souverbie, 1865
bulbula, Hedley, 1907
canaria, Hedley, 1907
clara, Brazier, 1877
compta, Brazier, 1877
convoluta, Watson, 1886
corpulenta, Watson, 1886
kymatodes, Watson, 1886
metata, Hedley, 1907
oodes, Watson, 1886
opaca, Hedley, 1901
oxia, Watson, 1886
pupa, Watson, 1886
rubra, Pease, 1868
sigma, Hedley, 1907
Turbonilla amoebaea, Watson, 1886; *Odostomia*
aplini, Brazier, 1877
cheverti, Hedley, 1901
confusa, Brazier, 1877
darnleyensis, Brazier, 1877
homoeotata, Watson, 1886; *Odostomia*
spina, Crosse and Fischer, 1884; *Turritella*
varicifera, Tate, 1898
Pyrgulina gliriella, Melvill and Standen, 1896
henni, Brazier, 1894; *Odostomia*
senex, Hedley, 1902
umeralis, Hedley, 1902
zea, Hedley, 1902

Elusa subulata, A. Adams, 1855; *Pyramidella*
Eulima acerrima, Watson, 1886
acicula, Gould, 1849; *Stylifer*
acuta, Sowerby, 1834
amabilis, Brazier, 1877
bivittata, H. and A. Adams, 1853
brevis, Sowerby, 1834
campyla, Watson, 1883
cuspidata, A. Adams, 1854
eurychades, Watson, 1883
lactea, A. Adams, 1854
latipes, Watson, 1883
modicella, A. Adams, 1854
nitens, Brazier, 1877
Melanella grandis, A. Adams, 1854; *Eulima*
martinii, A. Adams, 1854; *Eulima*
petterdi, Beddome, 1883; *Eulima*
tortuosa, Adams and Reeve, 1850; *Eulima*
Stilifer astericola, Broderip, 1832
auricula, Hedley, 1907
orbiculata, Hedley, 1907
Mucronalia bizonula, Melvill, 1906
Scalenostoma striatum, Hedley, 1900
Eulimella acerrima, Watson, 1886
angusta, Watson, 1886
coacta, Watson, 1886
columna, Hedley, 1907
laxa, Watson, 1886
subtilis, Watson, 1886
Architectonica hybrida, Linne, 1758; *Trochus*
perdix, Hinds, 1844; *Solarium*
perspectiva, Linne, 1758; *Trochus*
straminea, Gmelin, 1791; *Trochus*
Torinia cælata, Hinds, 1844; *Solarium*
dorsuosa, Hinds, 1844; *Solarium*
variegata, Gmelin, 1791; *Trochus*
Omalaxis radiata, Hedley, 1907
Cymatium elongatum, Reeve, 1844; *Triton*
encausticum, Reeve, 1844; *Triton*
exaratum, Reeve, 1844; *Triton*
gemmatum, Reeve, 1844; *Triton*
chlorostoma, Lamarck, 1822; *Triton*
moritinctum, Reeve, 1844; *Triton*
pfeifferianum, Reeve, 1844; *Triton*
pyrum, Linne, 1758; *Murex*
rubicundum, Perry, 1811; *Septa*
spengleri, Chemnitz, 1795; *Murex*
tuberosum, Lamarck, 1822; *Triton*
vespaceum, Lamarck, 1822; *Triton*
gracile, Reeve, 1844; *Triton*
labiosum, Wood, 1828; *Murex*
lotorium, Linne, 1758; *Murex*
sacrostoma, Reeve, 1844; *Triton*
strangei, A. Adams and Angas, 1864; *Triton*
Septa tritonis, Linne, 1758; *Murex*
aquatile, Reeve, 1844; *Triton*
Distortrix decipiens, Reeve, 1844; *Triton*
Bursa bitubercularis, Lamarck, 1822; *Ranella*
gyrina, Linne, 1758; *Murex*
lampas, Linne, 1758; *Murex*
pusilla, Broderip, 1833; *Ranella*
rana, Linne, 1758; *Murex*
venustula, Reeve, 1844; *Ranella*
Argobuccinum succinctum, Linne, 1771; *Murex*

Gyrineum affine, Broderip, 1833; *Ranella*
pulchellum, Forbes, 1852; *Ranella*
pusillum, Broderip, 1833; *Ranella*
ranelloides, Reeve, 1844; *Triton*
rubicola, Perry, 1811; *Biplex*

Cassidea areola, Linne, 1758; *Buccinum*
coronulata, Sowerby, 1825; *Cassis*
glauca, Linne, 1758; *Buccinum*
nodulosa, Gmel., var. torquata, Rv.
pila, Reeve, 1848; *Cassis*
vibex, Linne, 1758; *Buccinum*

Cassis cornuta, Linne, 1758; *Buccinum*
nana, Ten.-Woods, 1879

Tonna chinensis, Dillwyn, 1817; *Buccinum*
cumingii, Reeve, 1849; *Dolium*
perdix, Linne, 1758; *Buccinum*
pomum, Linne, 1758; *Buccinum*
variegata, Lamarck, 1822; *Dolium*

Ficus communis, Bolten, 1798

Natica areolata, Recluz, 1844
alapapilionis, Bolten, 1798; *Cochlis*
buriasensis, Recluz, 1844
chinensis, Lamarck, 1822
colliei, Recluz, 1844
deidosa, Reeve, 1855
gualteriana, Recluz, 1844
helvacea, Lamarck, 1822
limpida, Smith, 1884
lineata, Bolten, 1798; *Cochlis*
raynoldiana, Recluz, 1844
seychellium, Watson, 1886
stellata, Martyn, 1786; *Nerita*
subcostata, Ten.-Woods, 1878
variabilis, Reeve, 1855

Polinices alba, Gray, 1827; *Natica*
albumen, Linne, 1758; *Nerita*
aurantium, Bolten, 1798; *Albula*
columnaris, Recluz, 1850; *Natica*
conicus, Lamarck, 1822; *Natica*
didyma, Bolten, 1798; *Albula*
filosa, Reeve, 1855; *Natica*
flemingiana, Recluz, 1843; *Natica*
incei, Philippi, 1853; *Natica*
mamilla, Linne, 1758; *Nerita*
melanostoma, Lamarck, 1822; *Natica*
melanostomoides, Quoy and Gaim., 1832; *Natica*
nux-castanea, Martyn, 1786; *Nerita*
plumbeus, Lamarck, 1822; *Natica*
vitellus, Linne, 1758; *Nerita*

Sigaretus australis, Dunker, 1871
eximius, Reeve, 1864
planulatus, Recluz

Lamellaria ophione, Gray, 1847

Cypraea angustata, Gmelin, 1791
annulus, Linne, 1758
arabica, Linne, 1758
argus, Linne, 1758
asellus, Linne, 1758
caput-serpentis, Linne, 1758
carneola, Linne, 1758
caurica, Linne, 1758
clandestina, Linne, 1767
cylindrica, Born, 1778
eburna, Barnes, 1824
erosa, Linne, 1758

Cypraea errones, Linne, 1758
felina, Gmelin, 1791
fimbriata, Gmelin, 1791
flaveola, Linne, 1758
helvola, Linne, 1758
hirundo, Linne, 1758
isabella, Linne, 1758
limacina, Lamarck, 1810
lutea, Gronovius, 1781
lynx, Linne, 1758
mauritiana, Linne, 1758
miliaris, Gmelin, 1791
moneta, Linne, 1758
notata, Gill, 1858
punctata, Linne, 1771
quadrimaculata, Gray, 1824
saulæ, Gaskoin, 1843
sophiæ, Brazier, 1875
subviridis, Reeve, 1835
tigris, Linne, 1758
valentia, Perry, 1811
vitellus, Linne, 1758
walkeri, Gray, 1832
xanthodon, Gray, 1832
ziczac, Linne, 1758
Trivia globosa, Gray, 1832; *Cypraea*
grando, Gaskoin, 1848
pellucida, Gaskoin, 1846
producta, Gaskoin, 1835; *Cypraea*
scabriuscula, Gray, 1828; *Cypraea*
staphylaea, Linne, 1758; *Cypraea*
sulcata, Gaskoin, 1848; *Cypraea*
vitrea, Gaskoin, 1848; *Cypraea*
Erato angiostoma, Sowerby, 1841
gallinacea, Hinds, 1844; *Ovulum*
lachryma, Gray, 1832
nana, Reeve, 1865
Ovula brevis, Sowerby, 1830
margarita, Sowerby, 1849
ovum, Linne, 1758; *Bulla*
punctata, Duclos, 1830
tortilis, Martyn, 1784, *Cypraea*
volva, Linne, 1758; *Bulla*
Radius angasi, Reeve, 1865; *Ovulum*
Scaphella canaliculata, McCoy, 1869; *Voluta*
flavicans, Gmelin, 1791; *Voluta*
maculata, Swainson, 1822
magnifica, Chemnitz, 1795; *Voluta*
marmorata, Swainson, 1822; *Voluta*
nivosa, Lamarck, 1804; *Voluta*
perplicata, Hedley, 1902; *Voluta*
pulchra, Sowerby, 1825; *Voluta*
punctata, Swainson, 1823; *Voluta*
ruckeri, Crosse, 1867; *Voluta*
rutila, Broderip, 1825; *Voluta*
spenceriana, Gatliff, 1908; *Voluta*
studeri, Martens, 1897; *Voluta*
volva, Gmelin, 1791; *Voluta*
zebra, Leach, 1814; *Voluta*
Cymbium flammeum, Bolten, 1798
Lyria deliciosa, Montrouzier, 1859; *Voluta*
nucleus, Lamarck, 1811; *Voluta*
Oliva annulata, Gmelin, 1791; *Voluta*
australis, Duclos
caerulea, Bolten, 1798; *Porphyria*
gibbosa, Born, 1778; *Voluta*

Oliva guttata, Lamarck, 1810
ispidula, Linne, 1758; *Voluta*
miniacea, Bolten, 1798; *Porphyria*
multiplicata, Reeve, 1852
oliva, Linne, 1758; *Voluta*
ornata, Marrat, 1867
tigrina, Meuschen, 1787; *Cylindrus*
Olivella nympha, Adams and Angas, 1863
Ancilla cingulata, Sowerby, 1830; *Ancillaria*
elongata, Gray, 1847; *Ancillaria*
oblonga, Sowerby, 1830; *Ancillaria*
similis, Sowerby, 1859; *Ancillaria*
tricolor, Gray, 1847; *Ancillaria*
Marginella alta, Watson, 1886
brachia, Watson, 1886
fusiformis, Hinds, 1844
guttula, Reeve, 1865
laevigata, Brazier, 1877
mustelina, Angas, 1871; *Hyalina*
ochracea, Angas, 1871
ovulum, Sowerby, 1846
pachia, Watson, 1886
Cancellaria antiquata, Hinds, 1844
australis, Sowerby, 1841
bicolor, Hinds, 1843
costifera, Sowerby, 1849
lamellosa, Hinds, 1843
macrospira, Adams and Reeve, 1850
obliquata, Lamarck, 1822
Terebra affinis, Gray, 1834
australis, Smith, 1873
bernardi, Deshayes, 1857
caelata, Adams and Reeve, 1850
cancellata, Quoy and Gaimard, 1833
chlorata, Lamarck, 1822
circumcincta, Deshayes, 1857
columellaris, Hinds, 1844
crenulata, Linne, 1758; *Buccinum*
dimidiata, Linne, 1758; *Buccinum*
exigua, Deshayes, 1859
feldmanni, Bolten, 1798; *Epitonium*
jukesi, Deshayes, 1857
maculata, Linne, 1758; *Buccinum*
marmorata, Deshayes, 1859
muscaria, Lamarck, 1822
ornatum, Martyn, 1786; *Buccinum*
pertusa, Born, 1778; *Buccinum*
polygyrata, Deshayes, 1859
triseriata, Gray, 1834
spectabilis, Hinds, 1844
straminea, Gray, 1834
subulata, Linne, 1767; *Buccinum*
taylori, Reeve, 1860
tenera, Hinds, 1844
turrita, Smith, 1873
undulata, Gray, 1834
Conus aculeiformis, Reeve, 1844
arenatus, Hwass, 1792
atramentosus, Reeve, 1849
lizardensis, Crosse, 1865
capitaneus, Linne, 1758
ceylanensis, Hwass, 1792
deshayesi, Reeve, 1844
cinctus, Swainson, 1833
coccineus, Gmelin, 1791

Conus coxeni, Brazier, 1875
emaciatus, Reeve, 1849
eximius, Reeve, 1849
figulinus, Linne, 1758
flavidus, Lamarck, 1810
geographus, Linne, 1758
glans, Hwass, 1792
ebraeus, Linne, 1758
lineatus, Bruguière, 1792
litteratus, L. v. millepunctatus, Lamk.
lividus, Bruguière, 1792
magus, Linne, 1758
marmoreus, Linne, 1758
musicus, Hwass, 1792
mustelinus, Hwass, 1792
nanus, Broderip, 1833
nussatella, Linne, 1758
peasei, Brazier, 1877; *Lithoconus*
praecellens, A. Adams, 1854
radiatus, Gmelin, 1791
spectrum, Linne, 1758
stercus-muscarum, Linne, 1758
striatus, Linne, 1758
sugillatus, Reeve, 1844
suturatus, Reeve, 1844
tenellus, Chemnitz
tenuistriatus, Sowerby, 1858
terebra, Born, 1778
tessellatus, Born, 1778
textile, Linne, 1758
tiaratus, Broderip, 1833
trigonus, Reeve, 1848
varius, Linne, 1758
vitulinus, Hwass, 1792

Glyphostoma polynesiense, Reeve, 1846
aliceæ, Melvill and Standen, 1893
spurca, Hinds, 1844; *Clavatula*
strombillum, Hervier, 1895
tricolor, Brazier, 1876; *Clathurella*
vultuosum, Reeve, 1846
huberti, Sowerby, 1893

Pleurotoma gemmata, Hinds, 1843
jubata, Hinds, 1843

Columbarium distephanotis, Melvill, 1891
spinicinctum, Martens, 1881; *Pleurotoma*

Clathurella amabilis, Hinds, 1843; *Clavatula*
arctata, Reeve, 1846; *Pleurotoma*
daedala, Reeve, 1846; *Pleurotoma*
darnleyi, Brazier, 1876; *Mangilia*
debilis, Hinds, 1843; *Clavatula*
macleayi, Brazier, 1876
moretonica, Smith, 1882; *Pleurotoma*
quisqualis, Hinds, 1843; *Clavatula*
tessellata, Hinds, 1843; *Clavatula*
thespesia, Melvill and Standen, 1896; *Daphnella*
tincta, Reeve, 1846; *Pleurotoma*

Daphnella aulacoessa, Watson, 1881; *Clathurella*
axis, Reeve, 1846; *Pleurotoma*
cassandra, Hedley, 1904
excavata, Gatliff, 1906
marmorata, Hinds, 1844
ornata, Hinds, 1844
pluricarinata, Reeve, 1845; *Pleurotoma*
souverbiei, Smith, 1882
subula, Reeve, 1845; *Pleurotoma*

Mangilia abyssicola, Reeve, 1846
angulata, Reeve, 1846
argillacea, Hinds, 1843; *Clavatula*
balteata, Reeve, 1846
bicolor, Reeve, 1846
capillacea, Reeve, 1846
chionea, Melvill and Standen, 1899
crassilabrum, Reeve, 1843; *Pleurotoma*
cylindrica, Reeve, 1846
exquisita, Smith, 1882
goodalli, Reeve, 1846
gracilenta, Reeve, 1843; *Pleurotoma*
gracilis, Reeve, 1846
hexagonalis, Reeve, 1845; *Pleurotoma*
languida, Reeve, 1845; *Pleurotoma*
maculata, Reeve, 1846
pellucida, Reeve, 1846
pessulata, Reeve, 1846
ponderosa, Reeve, 1846
pulchella, Reeve, 1846
undaticosta, Reeve, 1845; *Pleurotoma*

Drillia alabaster, Reeve, 1843; *Pleurotoma*
essingtonensis, Smith, 1888; *Pleurotoma*
exigua, Hombron and Jacq., 1853; *Pleurotoma*
laterculata, Sowerby, 1870; *Pleurotoma*
nitens, Hinds, 1843; *Clavatula*
putilla, Reeve, 1845; *Pleurotoma*
radula, Hinds, 1843; *Pleurotoma*
sinensis, Hinds, 1843; *Clavatula*
spaldingi, Brazier, 1876
sterrha, Watson, 1881; *Pleurotoma*
tayloriana, Reeve, 1846; *Pleurotoma*
varicosa, Reeve, 1843; *Pleurotoma*
ventricosa, Smith, 1888; *Pleurotoma*
violacea, Hinds, 1843; *Pleurotoma*
bijubata, Reeve, 1843; *Pleurotoma*
brevicaudata, Reeve, 1843; *Pleurotoma*
fusca, Hombron and Jacq., 1853; *Pleurotoma*
punctata, Reeve, 1845; *Pleurotoma*

Pleurotomella vepratica, Hedley, 1903; *Pleurotoma*

Turris acuta, Perry, 1811; *Pleurotoma*
armillata, Reeve, 1845; *Pleurotoma*
crispa, Lamarck, 1822; *Pleurotoma*
granosa, Helbling, 1779; *Murex*
indica, Bolten, 1798
spectabilis, Reeve, 1843; *Pleurotoma*
undosa, Lamarck, 1822; *Pleurotoma*

Vasum turbinellum, Linne, 1767; *Voluta*
ceramicum, Linne, 1758; *Murex*

Turbinella iricolor, Hombr. and Jacquinot, 1853
subnassatula, Souverbie, 1872

Tudicla armigera, A. Adams, 1856
spinosa, H. and A. Adams, 1863

Galeodes cochlidium, Linne, 1758; *Murex*
pricei, Smith, 1887; *Fusus*

Megalatractus aruanus, Linne, 1758; *Murex*

Siphonalia gracillima, Adams and Reeve, 1850; *Fusus*

Fasciolaria filamentosa, Bolten, 1798; *Fusus*

Latirus angustus, Smith, 1884
australiensis, Reeve, 1847; *Turbinella*
craticulatus, Linne, 1758; *Murex*
recurvirostris, Schub. Wagn., 1829; *Turbinella*
gibbulus, Gmelin, 1791; *Murex*
polygonus, Gmelin, 1791; *Murex*

Peristernia incarnata, Deshayes, 1830; *Turbinella*
lyrata, Reeve, 1847; *Turbinella*
wagneri, Anton, 1839; *Turbinella*
Leucozonia smaragdula, Linne, 1758; *Buccinum*
Imbricaria conica, Schumacher, 1817
Cylindra crenulata, Gmelin, 1791; *Voluta*
Mitra amanda, Reeve, 1845
amabilis, Reeve, 1845
antonelli, Dohrn, 1860
arenosa, Lamarck, 1811
armillata, Reeve, 1845
aurantia, Gmelin, 1791; *Voluta*
avenacea, Reeve, 1845
bernhardina, Bolten, 1798
caffra, Linne, 1758; *Voluta*
capricornea, Hedley, 1907
circula, Kiener, 1839
crassa, Swainson, 1822
crenifera, Lamarck, 1811
cruentata, Gmelin, 1791; *Voluta*
cucumerina, Lamarck, 1811
curvilirata, Sowerby, 1874
deshayesii, Reeve, 1844
delicata, A. Adams, 1853
dichroa, A. Adams, 1853
duplilirata, Reeve, 1845
filaris, Linne, 1771; *Voluta*
formosa, A. Adams, 1853
fragra, Quoy and Gaimard, 1833
granatina, Lamarck, 1811
hastata, Sowerby, 1874
hebes, Reeve, 1845
interlirata, Reeve, 1844
jukesii, A. Adams, 1853
leucodesma, Reeve, 1844
limosa, Martyn, 1786
longispira, Sowerby, 1874
lubens, Reeve, 1845
lucida, Reeve, 1845
lugubris, Swainson, 1821
michaui, Crosse and Fischer, 1864
mitra, Linne, 1758; *Voluta*
modesta, Reeve, 1845
obeliscus, Reeve, 1844
patriarchalis, Gmelin, 1791; *Voluta*
peasei, Dohrn, 1860
plicaria, Linne, 1758; *Voluta*
porphyritica, Reeve, 1844
procissa, Reeve, 1844
pura, A. Adams, 1853
reticulata, A. Adams, 1853
retusa, Lamarck, 1811
rotundilirata, Reeve, 1844
rubritincta, Reeve, 1844
rufescens, A. Adams, 1853
rugosa, Gmelin, 1791; *Voluta*
suturata, Reeve, 1845
sanguisuga, Linne, 1758; *Voluta*
scabricula, Linne, 1767; *Voluta*
sculptilis, Reeve, 1845
scutulata, Gmelin, 1791, *Voluta*
subdivisa, Bolten, 1798; *Vexillum*
solida, Reeve, 1844
tabanula, Lamarck, 1811
taeniata, Lamarck, 1811

Mitra variabilis, Reeve, 1844
variegata, Gmelin, 1791; *Voluta*
vermiculata, Martyn, 1786
vulpecula, Linne, 1758; *Voluta*
zephyrina, Sowerby, 1874
Cantharus balteatus, Reeve, 1846; *Buccinum*
curtisianus, Smith, 1884; *Tritonidea*
mollis, Gould, 1860; *Pisania*
semitextus, Hedley, 1899; *Nassa*
undosus, Linne, 1758; *Buccinum*
Pisania crenilarum, A. Adams, 1855
Cyllene lactea, Adams and Angas, 1863
pulchella, Adams and Reeve, 1850
Phos roseatus, Hinds, 1844
rufocinctus, A. Adams, 1850
scalaroides, A. Adams, 1851
sculptilis, Watson, 1886
senticosus, Linne, 1758; *Murex*
spinicostatus, A. Adams, 1851
textum, Gmelin, 1791; *Buccinum*
Engina anaxeres, Kiener, 1836; *Purpura*
concinna, Reeve, 1846; *Ricinula*
lauta, Reeve, 1846; *Ricinula*
lineata, Reeve, 1846; *Ricinula*
mendicaria, Linne, 1758; *Voluta*
reevei, Tryon, 1883
siderea, Reeve, 1846; *Ricinula*
trifasciata, Reeve, 1846; *Ricinula*
Nassaria bituberculavis. A. Adams, 1855; *Hindsia*
Colubraria antiquata, Hinds, 1844; *Triton*
tessellata, Reeve, 1844; *Triton*
Maculotriton bracteatus, Hinds, 1844; *Triton*
Arcularia albescens, Dunker, 1849; *Buccinum*
algida, Reeve, 1853; *Nassa*
arcularia, Linne, 1758; *Buccinum*
callosa, A. Adams, 1852; *Nassa*
coronata, Bruguière, 1789; *Buccinum*
crebrelineata, Hombr. Jacq., 1853
cremata, Hinds, 1844
crenulata, Bruguière, 1789; *Buccinum*
delicata, A. Adams, 1852; *Nassa*
densigranata, Reeve, 1854; *Nassa*
dorsata, Bolten, 1798; *Buccinum*
fretorum, Melv. Stand., 1899; *Nassa*
gemmulata, Lamarck, 1822; *Buccinum*
glans, Linne, 1758; *Buccinum*
lachrymosa, Reeve, 1853; *Nassa*
lurida, Gould, 1850; *Nassa*
marginulata, Lamarck, 1822; *Buccinum*
melanioides, Reeve, 1853; *Nassa*
mirostoma, Pease, 1867; *Nassa*
mucronata, A. Adams, 1852; *Nassa*
nana, A. Adams, 1852; *Nassa*
paupera, Gould, 1850; *Nassa*
picta, Dunker, 1846; *Buccinum*
plebicula, Gould, 1860; *Nassa*
psila, Watson, 1882; *Nassa*
pullus, Linne, 1758; *Buccinum*
ravida, A. Adams, 1852; *Nassa*
rotunda, Melv. Stand., 1896; *Nassa*
semiplicata, A. Adams, 1852; *Nassa*
suturalis, Lamarck, 1822; *Buccinum*
Pyrene abyssicola, Brazier, 1877; *Columbella*
atkinsoni, Ten.-Woods, 1876; *Mangelia*
contaminata, Gaskoin, 1852; *Columbella*

Pyreno darwini, Angas, 1877; *Columbella*
digglesi, Brazier, 1875; *Columbella*
essingtonensis, Reeve, 1859; *Columbella*
flava, Bruguière, 1789; *Buccinum*
fulgurans, Lamarck, 1822; *Columbella*
galaxias, Reeve, 1859; *Columbella*
gemmulifera, Hedley, 1907
gowllandi, Brazier, 1875; *Columbella*
intexta, Gaskoin, 1852; *Columbella*
clathrata, Brazier, 1877; *Columbella*
conspersa, Gaskoin, 1852; *Columbella*
cumingii, Reeve, 1859; *Columbella*
duclosiana, Sowerby, 1844; *Columbella*
peasei, v. Mart. and Langk., 1871; *Columbella*
læta, Brazier, 1877; *Columbella*
lurida, Hedley, 1907
melvilli, Hedley, 1899; *Columbella*
merita, Brazier, 1877; *Columbella*
moleculina, Duclos, 1840; *Columbella*
nivosa, Reeve, 1859; *Columbella*
pardalina, Lamarck, 1822; *Buccinum*
plicaria, Montrouzier, 1862; *Columbella*
pudica, Brazier, 1877; *Columbella*
roseotincta, Hervier, 1899; *Columbella*
russelli, Brazier, 1875; *Columbella*
semiconvexa, Lamarck, 1822; *Buccinum*
troglodytes, Souverbie, 1866; *Columbella*
varians, Sowerby, 1832; *Columbella*
versicolor, Sowerby, 1832; *Columbella*

Murex acanthodes, Watson, 1883
acanthopterus, Schroeter, 1783
aduncospinosus, Reeve, 1845
denudatus, Perry, 1811; *Triplex*
axicornis, Lamarck, 1822
brevispina, Lamarck, 1822
capucinus, Lamarck, 1822
cervicornis, Lamarck, 1822
confusa, Brazier, 1877
coppingeri, Smith, 1884
cornucervi, Bolten, 1798; *Purpura*
corrugatus, Sowerby, 1840
macgillivrayi, Dohrn, 1862
maurus, Broderip, 1833
microphyllus, Lamarck, 1822
miliaris, Gmelin, 1791
multiplicatus, Sowerby, 1895
mundus, Reeve, 1846
pellucidus, Reeve, 1845
pholidotus, Watson, 1883
ramosus, Linne, 1758
recticornis, von Martens, 1880
salmoneus, Melvill and Standen, 1899
sauliæ, Sowerby, 1840
scaber, Martyn, 1789; *Purpura*
ternispina, Lamarck, 1822
territus, Reeve, 1845
tetragonus, Broderip, 1833
trapa, Bolten, 1798
triremis, Perry, 1811; *Aranea*

Aspella anceps, Lamarck, 1822; *Ranella*

Trophon contractus, Reeve, 1846; *Buccinum*
paivae, Crosse, 1864

Thais alveolata, Reeve, 1846; *Purpura*
bitubercularis, Lamarck, 1822; *Purpura*
echinata, Blainville, 1832; *Purpura*

Thais gemmulata, Lamarck, 1822; *Purpura*
hippocastanea, Linne, 1758; *Murex*
succinctus, Martyn, 1784; *Buccinum*
persica, Linne, 1758; *Buccinum*
pseudamygdala, Hedley, 1903; *Purpura*
rustica, Lamarck, 1822; *Purpura*
Vexilla vexillum, Gmelin, 1791; *Strombus*
Nassa sertum, Bruguiere, 1789; *Buccinum*
Galeropsis monodonta, Quoy and Gaim, 1833; *Purpura*
Rapa rapiformis, Born, 1778; *Murex*
rapa, Linne, 1767; *Bulla*
Drupa cavernosa, Reeve, 1846; *Ricinula*
chaidea, Duclos, 1832; *Purpura*
concatenata, Blainville, 1832; *Purpura*
heptagonalis, Reeve, 1846; *Ricinula*
mancinella, Linne, 1758; *Murex*
margariticola, Broderip, 1832; *Murex*
marginalba, Blainville, 1832; *Purpura*
muricata, Reeve; 1846; *Ricinula*
ochrostoma, Blainville, 1832; *Purpura*
ozenneana, Crosse, 1861; *Ricinula*
porphyrostoma, Reeve, 1846; *Ricinula*
ricinus, Linne, 1758; *Murex*
rubusidæa, Bolten, 1798
spinosa, H. and A. Adams, 1853; *Pentadactylus*
Coralliophila squamulosa, Reeve, 1846; *Purpura*
imbricata, Smith, 1876; *Fusus*
Ellobium auris-judæ, Linne, 1758; *Bulla*
helvaceum, Pfeiffer, 1876; *Auriculus*
semisculptum, H. and A. Adams, 1854
Pythia argenvillei, Pfeiffer, 1853
nux, Reeve, 1860; *Scarabus*
Cassidula angulifera, Petit, 1841; *Auricula*
auris-felis, Bruguière, 1789; *Bulimus*
rugata, Menke, 1843; *Auricula*
sowerbyana, Pfeiffer, 1853; *Auricula*
zonata, H. and A. Adams, 1855
Marinula patula, Lowe, 1835; *Melampus*
Laimodonta conica, Pease, 1862
Ophicardelus quoyi, H. and A. Adams, 1855
sulcatus, H. and A. Adams, 1855; *Laimodonta*
Plecotrema moniliferum, H. and A. Adams, 1854
typicum, H. and A. Adams, 1854
Melampus adamsianus, Pfeiffer, 1855
cristatus, Pfeiffer, 1855
parvulus, Pfeiffer, 1856
pulchellus, Petit, 1843; *Auricula*
granosa, Hombr. and Jacq., 1853; *Auricula*
trifasciatus, Kuster, 1844
variabilis, Gassies, 1863
Blauneria leonardi, Crosse, 1872
Onchidium punctatum, Quoy and Gaimard, 1832
tumidum, Semper, 1880
verruculatum, Cuvier, 1804
meriakrii, Stantschinsky, 1907
fungiforme, Stantschinsky, 1907
buetschlii, Stantschinsky, 1907
coriaceum, Semper, 1882
Onchidina australis, Semper, 1882
Siphonaria atra, Quoy and Gaimard, 1833
denticulata, Quoy and Gaimard, 1833
sipho, Sowerby, 1828
siquijorensis, Reeve, 1856
Actaeon flammeus, Gmelin, 1791; *Voluta*
insculptus, Reeve, 1842; *Tornatella*

Pupa affinis, A. Adams, 1855; *Solidula*
coccinata, Reeve, 1842; *Tornatella*
nitidula, Lamarck, 1822; *Tornatella*
solidula, Linne, 1758; *Bulla*
sulcata, Gmelin, 1791; *Voluta*
suturalis, A. Adams, 1855; *Solidula*
Leucotina casta, A. Adams, 1853; *Monoptgyma*
helva, Hedley, 1900
Tornatina acrobeles, Watson, 1883; *Utriculus*
biplex, A. Adams, 1850; *Bulla*
gracilis, A. Adams, 1850
leptekes, Watson, 1883; *Utriculus*
planospira, A. Adams, 1850; *Bulla*
voluta, Quoy and Gaimard, 1833; *Bulla*
Volvula sulcata, Watson, 1883; *Cylichna*
Ringicula abyssicola, Brazier, 1877
arctata, Gould, 1860
assularum, Watson, 1883
caron, Hinds, 1844
pusilla, Watson, 1883
Retusa amphizosta, Watson, 1883; *Utriculus*
complanata, Watson, 1883; *Utriculus*
nitida, A. Adams, 1850; *Bulla*
simillima, Watson, 1883; *Utriculus*
Cylichna arachis, Quoy and Gaimard, 1835; *Bulla*
bizona, A. Adams, 1850; *Bulla*
concentrica, A. Adams, 1850; *Bulla*
crispula, Watson, 1883
decussata, A. Adams, 1850; *Bulla*
doliaria, Hedley, 1907
dubiosa, Brazier, 1877; *Atys*
granosa, Brazier, 1877; *Mnestia*
pulchra, Brazier, 1877; *Atys*
strigella, A. Adams, 1850; *Bulla*
Atys cheverti, Brazier, 1877
cylindrica, Helbling, 1779; *Bulla*
darnleyensis, Brazier, 1877
debilis, Pease, 1860
decora, Brazier, 1877; *Haminea*
densa, Brazier, 1877
dentifera, A. Adams, 1850; *Bulla*
elongata, A. Adams, 1850; *Bulla*
monodonta, A. Adams, 1850; *Bulla*
naucum, Linne, 1758; *Bulla*
solida, Bruguière, 1792; *Bulla*
tortuosa, A. Adams, 1850; *Bulla*
Scaphander multistriatus, Brazier, 1877
Bullaria adamsi, Menke, 1850; *Bulla*
punctulata, A. Adams, 1850; *Bulla*
Cylindrobulla fischeri, A. Adams and Angas, 1864
pusilla, Nevill, 1869
Volvatella pyriformis, Pease, 1860
Haminea brevis, Quoy and Gaimard, 1883; *Bulla*
crocata, Pease, 1860
papyrus, A. Adams, 1850; *Bulla*
vitrea, A. Adams, 1850; *Bulla*
Aplustrum aplustre, Linne, 1758; *Bulla*
Hydatina physis, Linne, 1758; *Bulla*
Philine angasi, Crosse and Fischer, 1845; *Bullæa*
schroeteri, Philippi, 1844; *Bullæa*
Aglaja marmorata, Smith, 1884; *Doridium*
Tethys denisoni, Smith, 1884; *Aplysia*
sparsinotata, Smith, 1884; *Aplysia*
tigrina, Rang., 1828; *Aplysia*
Paraplysia piperata, Smith, 1884; *Aplysia*

Dolabella ecaudata, Rang., 1828; *Aplysia*
scapula, Martyn, 1786; *Patella*
Salinator fragilis, Lamarck, 1822; *Ampullaria*
Cavolina gibbosa, D'Orbigny, 1836; *Hyalœa*
inflexa, Lesueur, 1813; *Hyalœa*
longirostris, Lesueur, 1821; *Hyalœa*
quadridentata, Lesueur, 1821; *Hyalœa*
trispinosa, Lesueur, 1821; *Hyalœa*
uncinata, D'Orbigny, 1836; *Hyalœa*
Limacina bulimoides, D'Orbigny, 1836; *Atlanta*
inflata, D'Orbigny, 1836; *Atlanta*
leseuri, D'Orbigny, 1836; *Atlanta*
Clio acicula, Rang., 1828; *Creseis*
pyramidata, Linne, 1767
striata, Rang., 1828; *Creseis*
subula, Quoy and Gaimard, 1827; *Cleodora*
virgula, Rang., 1828; *Creseis*
Cuvierina columnella, Rang., 1827; *Cuvieria*
Euselenops luniceps, Cuvier, 1830; *Pleurobranchus*
Umbraculum umbrella, Martyn, 1786; *Patella*
Glaucus atlanticus, Forster, 1777
Bornella digitata, Adams and Reeve, 1850
Hexabranchus flammulatus, Q. and Gaim., 1833; *Doris*
Thordisa clandestina, Bergh., 1884
Platydoris coriacea, Abraham, 1777; *Doris*
cruenta, Gray, 1850; *Asteronotus*
infrapicta, Smith, 1884; *Doris*
Hypselodoris lineolata, van Hasselt, 1824; *Doris*
Ceratosoma gibbosum, Rochebrune, 1894
lixi, Rochebrune, 1894
tenue, Abraham, 1876
Miamira sinuata, van Hasselt, 1824; *Doris*
Sphaerodoris incii, Gray, 1850; *Doris*
Placomopherus insignis, Smith, 1884

Scaphopoda.

Dentalium annulosum, Brazier, 1877
bisexangulatum, Sowerby, 1860
cheverti, Sharp and Pilsbry, 1897
clathratum, Martens, 1881
dispar, Sowerby, 1860
duodecimcostatum, Brazier, 1877
hexagonum, Gould, 1859
javanum, Sowerby, 1860
longitrorsum, Reeve, 1842
octangulatum, Donovan, 1803
pseudosexagonum, Deshayes, 1825
quadricostatum, Brazier, 1877
Siphonodentalium eboracense, Watson, 1879
Cadulus laevis, Brazier, 1877; *Dentalium*
prionotus, Watson, 1879; *Siphonodentalium*
simillimus, Watson, 1879

Brachiopoda.

Lingula anatina, Lamarck, 1801
Crania suessi, Reeve, 1862
Cryptopora brazieri, Crane, 1886; *Atretia*
Megerlia sanguinolenta, Gmelin, 1791; *Anomia*

TORRES STRAIT.

[*Abstract of Lecture by C. HEDLEY, F.L.S., Assistant Curator, Australian Museum, Sydney.*]

The subject of Torres Straits is equally fascinating whether considered from the standpoint of geologist, biologist, or anthropologist. From the latter aspect it forms the boundary between the Australian and the Papuan races. Though much farther advanced in civilisation, the Papuan was unable to gain a footing in Australia. As an agriculturist, a trader, a navigator, or a mechanic, the Papuan gained, held, and improved the islands of the Strait. But as a fighter he was the inferior of the fierce tribe which held the strong strategic point of Cape York. This inferiority was partly the inferiority of the agriculturist to the hunter, and partly the inferiority of the bow and arrow to the womerah and javelin. The Australian propelled a heavier missile farther. The prompt way in which the Cape York men turned out to fight Captain Cook in 1770, shows how subject they were to the head-hunting forays of the Papuans.

Standing on the end of Cape York, the geologist notes, to the northward, a cluster of lofty granitic islands, from the latter may be seen more islands extending northwards, and so on right across the Strait. These islands are the peaks of a drowned mountain range, the continuation of the Australian cordillera. In past ages this range, standing at a higher level, bridged the Strait by an isthmus which linked Australia to New Guinea. At that time the shore of the continent extended to where the Barrier Reef now is.

Geologically the Strait falls into three divisions, the continental islands just described, the low coral islands to the east of them, and, on the extreme north-east, a group of volcanic islands. The largest of these is Mer or Murray Island, on which the rim of a large ash crater is still distinct. The two monsoons have piled the ash into a tall hill and a low one, the work respectively of the N.E. and the N.W. monsoons. Numerous blocks of dolomitised coral among the ash show the crater pipe to have burst through a deep-seated stratum of coral.

To a biologist the Strait would always be a happy hunting ground. South from Cape York, and diminishing as we recede, are a number of New Guinea plants and animals. Contrasted and supported by another series of Australian plants and animals occurring in New Guinea, these add force to the geological argument for a former isthmus across Torres Strait. By that route the cassowary and the palms travelled south, while the marsupials and eucalypts went north.

In marine zoology the Strait is famous for the extensive beds of pearl-shell (*Meleagrina maxima*) that occur there. Over a large area the water is maintained at an unusually high temperature. This fosters a rich growth of corals and associated organisms. The dugong has not yet been extirpated, and affords, to the natives, an important food supply.

PAPERS READ IN SECTION D.

1.—RECORDS OF QUEENSLAND BOTANISTS.

By J. H. MAIDEN, Government Botanist of New South Wales, and Director of the Botanic Gardens, Sydney.

I have used the term "botanist" in a somewhat wide sense, having included collectors of note whether they described their finds or not, notable horticulturists, and, in my general list (**6**) botanists who have described Australian plants whether they visited this land or not. I have included no living man, so far as I am aware. It will be seen how imperfect is the record of some who have worked amongst us and who have not been removed by the hand of death very long.

Records of departed botanists form a branch of Australian history of practical value to working botanists. They afford a guide to their published works, and indicate where their observations were made.

The lists of species named after the various botanists and collectors are valuable (so I have often found) for tracing particulars of botanical journeys, biographical notes, and other useful information.

Select Bibliography.

Bailey, F. M. "A Concise History of Australian Botany." (Proc. Roy. Soc., Queensland, viii., p. xvii., 1891.) Quoted as (**1**).

Hooker, J. D. "Introductory Essay to the Flora of Tasmania," cxii.-cxxviii. ("Outlines of the Progress of Botanical Discovery in Australia.") Quoted as (**2**).

Britten and Boulger. "British and Irish Botanists." Quoted as (**3**).

Mennell, Philip. "The Dictionary of Australian Biography . . . from the inauguration of Responsible Government down to the present time (1855-1892)," London, 1892. Quoted as (**4**).

Maiden, J. H. Address of the President, Section D, Biology, of this Association, Adelaide Meeting, 1907. Contains Biographical Notices of South Australian and some other botanists. Quoted as (**5**).

Maiden, J. H. "Records of Australian Botanists—(*a*) General, (*b*) New South Wales" (Proc. Roy. Soc., N.S.W., xlii., 1908). Quoted as (**6**).

Maiden, J. H. "Records of Victorian Botanists." (Vict. Nat., xxv., 97-117, 1908.) Quoted as (**7**).

Maiden, J. H. "Records of Western Australian Botanists." (Journ. W.A. Nat. Hist. Soc., 1909.) Quoted as (**8**).

Maiden, J. H. "Records of Tasmanian Botanists." (Proc. Roy. Soc., Tas., 1909.) Quoted as (**9**).

The veteran Queensland botanist, Mr. F. M. Bailey, in his "Concise History of Australian Botany," already referred to (**1**), included notices of living workers, and I hope that the information which follows will usefully supplement Mr. Bailey's references. In some cases one must read the State-name broadly, as I have included in it a few men engaged in Polynesian botanical exploration.

Armit, William E. D. M.—

An extract from a letter of the Secretary, Commissioner of Police, to Mr. W. C. Brennan, Secretary, Public Service Board, Brisbane, says:—

Mr. Armit's name appears as William E. D. M. Armit, but the full christian name cannot be given, nor is it known where and when he was born and died; the last communication from him is dated April, 1883. He was appointed a sub-inspector on 5th June, 1872, and served at Murray River, Waterview, Cashmere, Georgetown, Dunrobin, Brisbane, Bynoe, and Carl Creek. He left the service on the 14th April, 1882.

He was an officer of the Queensland Mounted Police. He became a New Guinea official.

He collected largely in Northern Queensland for Mueller—*e.g.*, on the Gilbert River, Lynd River, Herbert River, head of Burdekin, &c. His botanical papers include "Notes on certain Plants of North-Western Queensland possessing valuable Medicinal Properties," which was published in abstract in Journ. Linn. Soc., xx., 69. He read a paper, "List of Plants noticed on Moresby, Basilisk, O'Neill, and Margaret Islands, S. Eastern New Guinea," on 19th March, 1885, Proc. Linnean Society (1883-86), p. 74; but it was not published.

His ethnological papers include—"Notes on the Philology of the Islands adjacent to the South-eastern Extremity of New Guinea" (Proc. Roy. Soc., Queensland, ii., 2); "The Papuans: Comparative Notes on Various Authors, with Original Observations" (*ib.*, 78).

He is commemorated by the following plants:—*Bossiaea Armitii*, F.v.M. (Fragm. ix. 44); *Goodenia Armitiana*, F.v.M.; *Eriachne Armitii*, F.v.M.; *Sarcochilus Armitii*, F.v.M.

Backhouse, James (1794-1869). *See* **(6)**—

He was a Quaker missionary who visited Australia on a philanthropic mission. He arrived at "Brisbane Town" 29th March, 1836; and in chapters xxxii. and xxxiii. of his "Narrative of a Visit to the Australian Colonies" are interesting notes on the botany of Moreton Bay.

Bancroft, Joseph (1836-1894)—

Born at Stretford, near Manchester, England, February 21st, 1836. Arrived in Brisbane, 1864. Died at Brisbane, June 16th, 1894. M.R.C.S. Eng., M.D. St. Andrews', 1859.

He worked at the pharmacology of some Queensland plants—*e.g.*, *Duboisia myoporoides* and *D. Hopwoodii*. He also worked at the hybridisation of plants; produced new varieties of the grape, castor oil plant, strawberry, &c. He discovered a rust-proof wheat. He proved that wheat, barley, and rice could be grown in Southern Queensland on poor coast country. Was interested in diseases of plants—*e.g.*, Banana (Tylenchus), Sugar-cane, &c.

Following are some of his papers:—"*Pituri* and *Duboisia*," Brisbane, 1877, 8vo. "Further remarks on the Pituri group of plants, &c." (*Ib.* 1878), 8vo. "Contribution to Pharmacy from Queensland" (1886). "*Duboisia Pituri*" (Wing's Southern Science Record, ii. 221). "Food of the Aborigines of Central Australia" (Proc. Roy. Soc., Q.,

Joseph Bancroft (1836 1894).

i., 104). "Experiments with Indian wheats in Queensland" (*ib.* i., 176). Presidential Address before the Royal Society of Queensland (*ib.* ii., 67). "An Inquiry into the Maize Diseases of the Caboolture District" (*ib.* iii., 108).

See a notice of his work by the then President of the Linnean Society, Rev. J. E. Tenison-Woods, in Proc. Linn. Soc., N.S.W., iv., 482, 1880.

See a biographical notice of him in (**4**). For obituary notices *see* "The Telegraph," 18th June, 1894; "The Queenslander" (Brisbane), 23rd June, 1894; "Australasian Medical Gazette," 15th July, 1894 (with portrait). See also "Obituary notice of Dr. Joseph Bancroft" by Eugen Hirschfeld (Proc. Roy. Soc., Q., x., 102).

He is commemorated by the following plants:—*Strychnos Bancroftiana*, Bail.; *Dendrobium speciosum var. Hillii*, forma *Bancroftianum*, H. G. Reichb.f.

A portrait of Dr. Bancroft will be found in this volume.

BERNAYS, LEWIS ADOLPHUS (1831-1908)—

Born in London, 3rd May, 1831, died in Brisbane, 22nd August, 1908. He was the son of Dr. Bernays, Professor of the German Language and Literature at King's College, London, and arrived in New Zealand, 1850. When Queensland became a separate colony, with her own Parliament, Mr. Bernays, in 1859, was appointed Clerk of the Legislative Assembly. He was made C.M.G. in 1892. He was the first honorary secretary of the Queensland Acclimatisation Society, and was its leading spirit for very many years. He was a Fellow of the Linnean Society of London, and a prominent member of the Royal Society of Queensland.

He was an assiduous collector of our native plants, and was specially interested in the introduction of economic plants into Queensland. He was a successful cultivator of many useful and ornamental plants.

He was author of the following works:—"The Olive and its Products . . . the Habits, Cultivation and Propagation of the Tree, &c." Brisbane, 1872. 8vo. "Cultural Industries of Queensland.—Papers on . . . useful plants suited to the climate." 1st series. Brisbane, 1883. 8vo.

He is commemorated by:—*Phaius Bernaysii*, Rowl.; *Nepenthes Bernaysii*, Bail.

BIDWILL, JOHN CARNE (1815-1853)—

Government Botanist and Director of the Botanic Gardens, Sydney (the first on whom these two titles were conferred), Commissioner of Crown Lands at Wide Bay. He botanised much in the Wide Bay and Brisbane River districts. *See* (**6**).

BOWMAN, EDWARD MACARTHUR (1826-1872)—

Born at Sydney, died 30th June, 1872, at Clermont, Peak Downs, Queensland.

Eldest son of Dr. James Bowman, who was Colonial Surgeon in Sydney for some years.

Owed his botanical training to Sir William Macarthur, of Camden Park, N.S.W., whose nephew he was. He occupied his time chiefly on Queensland stations, and collected for Mueller and for others. A number of plants collected by him are referred to in the "Flora Australiensis" and the "Fragmenta."

There is an account of some of his botanical discoveries, from the pen of the late Rev. Dr. Woolls, in Hort. Mag., Sydney, v. 127 (1868), and the following account is given of a man concerning whom little is known, and who did much to advance a knowledge of Queensland botany four decades ago. Specimens are extant from him from Herbert Creek (Broadsound).

Amongst those who have contributed to the advancement of botanical science in Australia, the name of Mr. Edward Macarthur Bowman should be remembered with gratitude, for (says the "Sydney Mail") the specimens which he collected in North-east Australia have proved highly serviceable to the learned authors of the "Flora Australiensis." In the introduction to the first volume of that work Mr. Bentham expresses his obligation to Mr. Bowman for his collections in Queensland; and Baron F. von Mueller, in a recent letter, characterises him as a most disinterested collector, who will be much missed. This indefatigable naturalist was the discoverer of *Ptychosperma Alexandræ*, one of the most splendid palms in Australia, a figure and description of which will be found in the fifth volume of Baron Mueller's "Fragmenta." He was also the first to collect *Ricinocarpus Bowmanii*, *Pimelea Bowmanii*, and many other interesting plants; and it was principally through his exertions that the properties of *Gastrolobium grandiflorum*, the Poison Pea of the Flinders, were investigated. . . . For some years past he resided in various parts of North-east Australia, devoting much of his leisure time to the collection of new and rare plants, and corresponding with Baron von Mueller and other scientific gentlemen in the Australian colonies. ("Gardeners' Chronicle," 1873, p. 177, based on an article in the "Sydney Mail," by Rev. Dr. Woolls.)

He is commemorated by the following species:—*Eucalyptus Bowmanii*, F.v.M.; *Eremophila Bowmani*, F.v.M.; *Dendrobium Bowmanii*, Benth; *Pimelea Bowmani*, F.v.M.; *Ricinocarpus Bowmani*, F.v.M.; *Cyperus Bowmani*, F.v.M.

Brown, Robert (1773-1858)—

Travelled much along coastal Queensland, 1800-4, and described many Queensland plants. "Botanicorum facile princeps." *See* (**6**).

Cunningham, Allan (1791-1839)—

King's Botanist and Superintendent, Botanic Gardens, Sydney. *See* (**6**). Discoverer of the Darling Downs. *See* Hon. Arthur Morgan's paper (Proc. Roy. Geog. Soc. Austral. Q.). An eminent botanist who botanised much in the Moreton Bay district and South Queensland generally.

Dietrich, Amalie—

This lady collected largely between 1863 and 1873 for the Museum Godeffroy, of Hamburg, Germany. Specimens collected by her are extant from Rockhampton, Port Mackay, Lake Elphinstone, Gladstone, Brisbane River, Curtis Island, and other places.

See a paper "Zur Flora von Queensland, Verzeichniss der von Frau Amalie Dietrich, in den Jahren, 1863 bis 1873, an der Nordostküste von Neuholland gesammelten Pflanzen" von Dr. Chr. Luerssen, in "Journal des Museum Godeffroy," Heft viii., pp. 101-122, Taf. 12-18. There is another paper based on material from the same collector in pp. 1-22 of the same Journal (Heft ?) There is also an account of Mrs. Dietrich's travels in Catalog. iv. of the same Museum, pp. xviii., xix. (1869), but the notes are almost entirely zooloogical.

She is commemorated by the following plants:—*Carex Dietrichiæ*, Bœckel = ?; *Cyperus Dietrichiæ*, Bœckel = ?; *Heleocharis Dietrichiana* Bœckel = ?; *Scirpus Dietrichiæ*, Bœckel = *S. squarrosus*, Linn.; *Scleria Dietrichiæ*, Bœckel = *S. hebecarpa*, Nees.

No biographical details appear to be available in regard to this admirable collector.

GILBERT, JOHN (-1846)—

Explored both in Queensland and Western Australia; killed by the blacks in Queensland, near the Gulf of Carpentaria. *See* (**8**). He was in the employment of John Gould, the celebrated ornithologist, and although he mainly gave attention to birds, he did good botanical collecting.

HILL, WALTER (1820-1904)—

Born at Scotsdyke, Dumfriesshire, Scotland, 31st December, 1820. Died at Canonbie Lea, Eight Mile Plains, Brisbane, 4th February, 1904.

Having received a thorough training as a gardener, he was two years in the Royal Botanic Gardens, Edinburgh, under Mr. W. McNab, and then was nine years at Kew (1843-51). There is a notice of him in the "Journal of the Kew Guild," 1904, based on the "Queenslander" notices of 13th February and 9th July of the same year, which contain portraits.

He came to Sydney in February, 1852, by the ship "Maitland," bearing a letter of introduction to Mr. William Sharp Macleay. He went to the gold diggings at Bendigo, Beechworth, the Turon, and other places with the late P. L. C. Shepherd, of Sydney. (*See* **6**.)

Mr. Macleay introduced him to Mr. Frederick Strange (*see* **6**), with whom he entered into partnership for the purpose of collecting natural history specimens, on the occasion of the unfortunate expedition when Mr. Strange was speared by the blacks on Percy Island No. 2. They had purchased the ketch "Vision" for the purposes of this expedition, and Mr. Hill returned to Sydney in this vessel.

He was appointed first superintendent of the Botanic Gardens, Brisbane, on 21st February, 1855, by the Imperial Government (soon after Separation, in 1859, he was also appointed Colonial Botanist), and retired from his post on a pension on 1st March, 1881. The garden originally consisted of 6 acres, a considerable portion of it swampy, and it did not extend to the river.

From the "Queenslander" of 13th February and 9th July, 1904, some of the following notes have been abstracted:—

For four years previous to his retirement Mr. Hill also had charge of the forest reserves. He has always been considered by those in a position to judge of his work as a highly competent gardener, and to him is due the credit for the introduction of and acclimatisation of many valuable trees and plants formerly quite unknown to Queensland. It was he who introduced the mango and other fruits now common objects in every garden. He also initiated a useful system of exchange with other botanic gardens, especially in the East. The work of acclimatisation was for many years carried on by him, even after the present acclimatisation gardens were established, as the work of the latter was at first mainly the acclimatisation of animals.

In 1862 Mr. Hill accompanied the Governor, Sir George Bowen, in an expedition to Cape York, in H.M.S. "Pioneer," Commodore Burnett, with the object of reporting on the feasibility of establishing a settlement there, Somerset being established as the result.

In the work of exploration Mr. Hill also did good work. In 1873, he went with an expedition to explore the North-east coast in company with Mr. G. Elphinstone Dalrymple (who was in command) and Inspector Johnstone. During this trip the following places were visited, namely:—Cardwell, Mourilyan Harbour, Moresby River, Gladys Inlet and Johnstone River, Trinity Harbour, Endeavour River, Mulgrave and Russell Rivers, and the Mossman and Daintree Rivers. When starting on this expedition Mr. Hill took with him a useful collection of seeds and growing plants, which he sowed and planted in suitable positions on the mainland and islands. Included in the list of these plants and seeds were rice plants, guinea corn, millet, buck wheat, guinea grass, Angola grass, prairie grass, ground nuts, loquats, custard apples, mangoes, Chinese date plums, bread fruit, jack fruit, coffee, cocoa, nutmeg, cinnamon, clove, black pepper, ginger, vanilla, arrowroot, tapicoa, pineapples (6 varieties), mulberry (6 varieties), sweet potatoes, American vines (12 varieties), and many other plants. Not the least interesting part of this exploring party was the ascent of Bellenden-Ker. A party consisting of Inspector Johnstone, Mr. Walter Hill, and eight troopers started on 25th November, 1873, from Expedition Bend on the Mulgrave. On the following day they reached a height of 2,100 feet and on 27th November, at noon, the highest point of Bellenden-Ker was attained.

Mr. Hill did not write much. His works include:—"Catalogue of specimens of woods indigenous to Queensland" (London International Exhibition, 1862). "Narrative and reports of the Queensland north-east coast expedition (under command of G. Elphinstone Dalrymple), 1873" (Parl. Paper, 1874). (Botanical Report by Walter Hill at pp. 48-52.) "Catalogue of the plants in the Queensland Botanic Gardens," 8vo., 1875. "Botanic Gardens, Brisbane. Collection of Economic and other plants, &c." (Brisbane, 1880.) 8vo. "Collection of Queensland Timbers. Botanic Gardens, Brisbane" (Brisbane, 1880). 8vo.

The following species commemorate him:—*Acronychia Hillii*, F.v.M. = *A. Baueri*, Schott; *Akania Hillii*, Hook.f.; *Harpullia Hillii*, F.v.M.; *Keraudrenia Hillii*, F.v.M.; *Rubus Hillii*, F.v.M. = *R. moluccanus*, Linn.; *Myrtus Hillii*, Benth.; *Grevillea Hilliana*, F.v.M.; *Claoxylon Hillii*, Benth.; *Musa Hillii*, F.v.M.; *Dendrobium Hillii*, F.v.M. = *Thrixspermum Hillii*, Reichb. = *Sarcochilus Hillii*, F.v.M.; *Saccolabium Hillii*, F.v.M.; *Polypodium Hillii*, Bak.

I am indebted for some of the above information to his niece, Miss Mary Hill, and to Mr. W. C. Brennan, Secretary of the Queensland Public Service Board.

LINDLEY, JOHN—

The describer of Mitchell's Queensland and other Australian plants. *See* (**6**).

MACGILLIVRAY, JOHN (-1867). Usually spelled McGillivray in error—

Son of William, Prof. of Botany at Aberdeen. Dr. P. H. Gillivray, of Bendigo (the well-known authority on zoophytes), was a brother.

He died at Sydney 6th June, 1867. The notice of him in (**3**) confuses father and son through a slip of the pen.

Mr. John MacGillivray, late naturalist of H.M.S. "Rattlesnake," died at Sydney on the 6th June. He had just returned from an expedition to the Richmond River, and was preparing to leave for the islands of the South Pacific, when his career of usefulness was cut short by death. John MacGillivray was the eldest son of the late William MacGillivray, Regius Professor of Natural History, Marischal College, Aberdeen. He spent his early years in Edinburgh, and exhibited from boyhood a taste for those branches of natural science which his father cultivated with so much success. He was intended for the medical profession, and had all but completed his studies when the late Lord Derby offered him the appointment of naturalist on board H.M.S. "Fly," which was about to make the voyage round the world. On his return to England he was appointed naturalist to H.M.S. "Rattlesnake," employed on the Government survey, and recorded the results of a three years' cruise in two interesting volumes, which were favourably received by the public and the leading literary journals of the day. His next appointment was to H.M.S. "Herald," and brought him to Polynesia and Australia. Owing to his intemperate habits this appointment was cancelled. He spent nearly five years among the savage inhabitants of the South Sea Islands, where he had many strange adventures and hairbreadth escapes. He had a wonderful power of gaining the confidence and adapting himself to the manners of the cannibal tribes among whom he lived. (Seemann, Journ. Bot. v. 316, [1867].)

See also (**5**), under Armstrong, J.

In 1842, Captain Blackwood was sent out in H.M.S. "Fly" and "Bramble" to make a further survey of the tropical coasts of Australia.

The narrative of the expedition was written by Mr. Jukes (Geologist to the expedition), and contains no botanical matter. The coasts and islands visited by the "Fly" and "Bramble" had been previously explored by Cunningham, and subsequently by Mr. MacGillivray, a skilful naturalist, in H.M.S. "Rattlesnake." . . . .

In 1847, H.M.S. "Rattlesnake" was fitted out by Captain Owen Stanley, to discover openings through the Barrier Reefs in Torres Strait, to the northward of Raine Island passage, to examine Harvey Bay as a site for a new settlement, and to make a general survey of the Lousiade Archipelago.

Many places were visited between Sydney, Cape York, and Port Essington, and excellent collections made at Port Curtis, Rockingham Bay, Port Molle, Cape York, Goold, Lizard, and Moreton Islands. The expedition was accompanied by Mr. MacGillivray, upon whom the task of editing the narrative of the voyage devolved, owing to the death of its commander in Sydney. Mr. MacGillivray's narrative abounds in interesting observations on the vegetation of Australia. Among the most noticeable discoveries are—that of a clump of cocoanuts on Frankland Islands, whence, no doubt, the nuts and husks were washed to the mainland, where they had excited the curiosity of Cook, King, &c., of *Caryota urens* and a native Musa, on the peninsula of Cape York, and of the *Balanophora fungosa* in Rockingham Bay. The author also mentions the existence of the Pomegranate on Fitzroy Island, where (if no error exists) it has no doubt been planted. . . . (**2**.)

In 1853 Captain Denham surveyed the Pacific Islands in H.M.S. "Herald." He was accompanied by Mr. MacGillivray and a botanical collector, and sent some interesting collections from Lord Howe's Island, between Australia and New Zealand, and from Dirk Hartog's Island and Shark Bay.

See the Lord Howe Island bibliography, by Maiden, in Proc. Linn. Soc., N.S.W., xxiii., 119 (1898).

Then we have:—

Captain Denham has, fortunately for science, two naturalists on board H.M.S. "Herald," now employed surveying that group of islands in the South Pacific Ocean, of which those of Feejee may be considered the centre—Mr. MacGillivray and Mr. William Milne, assistant naturalist. These gentlemen have not been idle, as we can testify by the arrival of the collections of plants which they have formed at the several places they have touched at on their way to Sydney, and as is shown by the following extract from Mr. MacGillivray's latter addressed to us from that Colony, dated 23rd February, 1853.

* * * * * * *

Milne has been actively employed collecting at all the places he has visited, and improves much in his way of preparing specimens. (Hook. Journ. Bot. v. 279 [1853].)

In 1852, the British Admiralty determined to recommission H.M.S. "Herald" (Captain Denham, R.N.) for the purpose of surveying some of the little known groups of islands in the South Polynesian Ocean. Mr. John MacGillivray and Mr. William Milne were appointed to her as naturalists, the latter as assistant to the former. No connected narrative of this voyage has been published, but a sketch of an excursion made (14th August to 24th September, 1856) in Fiji has been described by Mr. Milne (Hooker's Journ. Bot. ix., p. 106 [1857].) (Seemann's Fl. Vitiensis VII.)

Both MacGillivray and Milne were excellent collectors. The former was a man of great promise, but for some weighty reason he was dismissed the service, and after returning to New South Wales and accepting engagements there for exploring the flora and fauna of several Polynesian islands, he joined some sandalwood traders and died, still a young man, 6th June, 1867. (Seemann Fl. Vitiensis VII.); (Seem. Journ. Bot. 1867, 163.)

Mr. MacGillivray's herbarium was given to Sir W. Hooker, and contains several hundred species in excellent preservation. (2.)

The following MS. Catalogue at Kew refers to these:—

"MacGillivray, John. Voyage of H.M.S. 'Rattlesnake. Catalogue of botanical specimens, collected in 1846-9. sm. 8vo." *See* also:

"MacGillivray, John. Narrative of the voyage of H.M.S. 'Rattlesnake,' commanded by . . . Captain O. Stanley . . . 1846-50 . . . to which is added . . . E. B. Kennedy's Expedition for the exploration of the Cape York Peninsula. London, 1852. 2 vols. 8vo."

Seemann only took up MacGillivray's plants, of which there is also a set in the British Museum. He did not touch Milne's plants.

While in private employment he wrote:—"Some remarks on the Sandalwood of the South Sea Islands." Read before the Horticultural Improvement Society of N.S. Wales. (Syd. Mag. Sci. and Art., 11, 196.)

He collected for many years for Mr. M. Guilfoyle, of Double Bay, Sydney. There is an account of MacGillivray under the title of "A Martyr to Science," by the Rev. P. C. Beaton, in "Good Words" for 1868, p. 425, with a portrait.

John MacGillivray

O'SHANESY, JOHN (1834-1899)—

Born July, 1834, at Ballybunnion, Co. Kerry, Ireland, died at Rockhampton, July, 1899. Was a trained Irish and Scotch gardener. Landed in Brisbane, April, 1861. He obtained work in the Botanic Gardens, under Mr. Hill. Here he remained until the discovery of gold at Gympie, but he soon returned to the Botanic Gardens and left again in 1864 to take a place with Mr. John McGregor, of Rockhampton, laying out a large pleasure garden near where the Rockhampton Cemetery now is.

In 1866 he started a nursery of his own in Rockhampton and, in 1870, removed to Kangaroo Park (Kabra), where he had selected a large area of land. Here he entered into fruit growing as well as establishing a nurseryman's business. In 1876 he started farming, and continued the three businesses together up till his death.

He assisted in the collection of grasses, woods, &c., and specimens of them were sent on to Baron von Mueller, Melbourne, with whom he kept up a regular correspondence.

He wrote many articles on the growing of lucerne and cereal crops in the Central District for the "Morning Bulletin," Rockhampton.

O'SHANESY, PATRICK ADAMS (1837-1884)—

Born at Ratto, Co. Kerry, Ireland. Died at Rockhampton, December, 1884. He was trained as a gardener in Scotland. Left for Australia in 1864, and landed in Brisbane. Coming to his brother John he was employed by him in his nursery both at Rockhampton and Kangaroo Park, Kabra, till 1876. He then entered into business for himself.

He was an earnest student of the botany of the Central District, and gave considerable attention to the collection and arrangement of specimens of grasses and other plants.

He was a constant correspondent of Mueller. He made a fine collection of timbers for the Philadelphia Exhibition of 1876. In or about 1880 he was elected a Fellow of the Linnean Society.

He was the author of:—"Contributions to the Flora of Queensland, with an Epitome of Botany for Beginners," pp. 82, Rockhampton, 1880;" also "The Botany of the Springsure District." (Proc. Linn. Soc., N.S.W., vi., 730.)

Solanum Shanesii, F.v.M., commemorates him.

THOZET, ANTHELME (?1826-1878)—

Born in France (Departement d'Ain, near Lyons); died at Rockhampton, 31st May, 1878, aged 52 years.

He was F.L.S. and Officier de l'Académie, Paris. He was a most assiduous collector of the botany of his district, most of his specimens going to Baron von Mueller. His end was hastened through his botanical exploration of Expedition Range. He also cultivated many economic plants, and prepared them for commercial use. His private garden was an experimental garden of great value, in which he introduced many plants to Central Queensland, and even to the colony. He did much in extending a knowledge of Queensland in France.

He was author of the following:—

(1) "Notes on some of the Roots, Tubers, Bulbs, and Fruits used as Vegetable Food by the Aboriginals of North Queensland." ("Bulletin" office, Rockhampton, 1866, pp. 16.)

These notes have the botanical and aboriginal names, and were incorporated by Brough Smyth, in his "Aborigines of Victoria," i. 227.

(2) "In the Catalogue of the Natural and Industrial Products of Queensland," exhibited in the Local Exposition by the Commissioners, 29th October, 1861, Mons. Thozet exhibited tobacco in the leaf, cigars, cotton, wheat, various native tree barks possessing medicinal properties, fibres.

(3) "Sketch of the Residence of James Morrill among the Aboriginals of Northern Queensland for Seventeen Years, being a Narrative of his Life, Shipwreck, Landing on the Coast, and Residence among the Aboriginals; also an Account of the Natural Productions of Northern Queensland, and Manners, Customs, Language, and Superstitions of its Inhabitants," by Edmund Gregory. "Courier" office, Brisbane, 2nd Edn., pp. 23, 1865.

This remarkable man, whose name was really James Murrells, as pointed out by Mr. Gregory, gave an account of the seeds, roots, &c., he fed upon while he lived like an aborigine, and, in the "Rockhampton Bulletin" of 14th March, 1863, M. Thozet gives a valuable account of Murrell's food-plants, and it is copied in Mr. Gregory's pamphlet.

He is commemorated by the following species:—*Acacia Thozetiana*, F. v. M.=*Albizzia Thozetiana*, F. Muell.; *Terminalia Thozetii*, Benth.; *Ixora Thozetiana*, F. v. M.=*Randia densiflora*, Benth.; *Jambosa Thozetiana*, F. v. M.=*Eugenia myrtifolia*, Sims; *Aristolochia Thozetii*, F. v. M.; *Cladodes Thozetiana*, Baill.=*Alchornea Thozetiana*, Baill.; *Eucalyptus Thozetiana*, F. v. M.

I am indebted to Madame Thozet and also to Mr. Thomas V. Nobbs, the town clerk of Rockhampton (M. Thozet's son-in-law) for some of the above information.

TENISON-WOODS, JULIAN E. (1832-1889)—

See (**5** and **6**). See also a paper "On a Fossil-plant Formation in Central Queensland." (Wing's "Southern Science Record," iii., 77.)

He devoted much attention to the botany of Queensland.

2.—NOTES ON THE CERATODUS.

By D. O'CONNOR.

1. A remarkable power of the Ceratodus.
2. A problem solved.

(1.) On my sixth journey in transferring ceratodus to new habitats, more specimens having been collected than my three tanks could conveniently accommodate, I resolved to make the experiment of conveying the surplus without immersing them in water. At the bottom of a wooden box a series of partitions were fixed, made of deal 6 in. wide, $\frac{1}{2}$ in. thick and 6 in. apart. These compartments were liberally supplied with damp water-weed, in which the fish were enveloped. Above these a similar frame, which was movable, was placed, at the bottom of this a piece of "scrim" (a coarse open fabric) was tacked, this to allow of the free percolation of water. The fish were all placed with their heads in one direction. When the train stopped for a supply of water for the engine, I filled my can and sprinkled the fish, more especially their heads. On arrival at Toowoomba, 235 miles from Miva, Mary River, I found that one of the fish lay with its head in the opposite direction to its mates. I placed it in its proper position, but when inspecting them on their arrival at Warwick, their destination, a further distance of 68 miles, I noticed one turn sideways and reverse its position with marvellous celerity. This was rendered possible through the frame of ceratodus being of cartilage and not of bone. The fish were altogether thirty-three hours out of the water. The new method of transport proved more satisfactory than the old, and was subsequently adopted, as not a single fish died during transport, a result never previously obtained.

(2.) The problem "What becomes of ceradotus during its early existence?" has been solved. To Mr. Harold H. Wilson, of Coranga Station, on the River Burnett, is due its solution. Mr. Wilson, aided by an aboriginal, made diligent search in the mud of the river, the water being unusually low at the time, and after a good deal of perseverance succeeded in unearthing a fine specimen about 14 in. in length. This he sent to the museum, but it arrived in a decomposed state, and was found to be useless. On being informed of this, Mr. Wilson resumed his search, and found another, and this he sent to the museum in a bottle of spirits (now on view). I have since seen a third specimen, about a foot long, which was also dug out of the mud.

It was previously supposed that the young ceratodus spent its early years in the mud, but this is the first record of the young fish actually being taken from the mud and preserved.

3.—LIST OF BIRDS OCCURRING WITHIN A TWELVE-MILE RADIUS OF BRISBANE.

By W. E. WEATHERILL, Brisbane Museum.

4.—LIST OF FROGS OF THE BRISBANE DISTRICT.

By JOSEPH LAMB, Brisbane Museum.

5.—LIST OF FISHES OF THE BRISBANE WATERSHED.

By J. D. OGILBY.

6.—THE PRINCIPLES OF SCIENTIFIC CLASSIFICATION IN NATURAL HISTORY.

By REVD. THOMAS BLACKBURN, B.A.

7.—COLEOPTERA OF FIG-TREE POCKET AND NEIGHBOURHOOD.

By RICHARD E. SWAN.

Section E.

GEOGRAPHY.

ADDRESS BY THE PRESIDENT,

A. H. S. LUCAS, M.A., B.Sc.,

Grammar School, Sydney.

THE FUTURE OF THE PACIFIC.

I have shown a certain audacity in accepting the honourable position of President of this Section, and a, perhaps, commensurate audacity in the selection of a subject for my address. "De l'audace, et encore de l'audace, et toujours de l'audace" is, it seems, my motto. The Pacific is a prodigious entity. The history of its Past, physical and political, is too comprehensive for any one man to master. Its Future in the story of the world must be of magnificent importance, but it lies on the knees of the gods, and who can foretell that which shall be as the centuries sweep over it? Still, it lies at our doors, our future is closely wrapped up in its future, and it behoves us to try to discern the streams of its destiny. We know something of the Past, something of the Present, and out of these will the Future evolve. When we are supplied with the data of a physical problem we may trace out a curve which shall accurately represent the phenomena within certain limits, and the shape of the curve will suggest the character of the phenomena outside these limits. Still extrapolation is always risky even in the case of similar physical phenomena, and the more so the further we depart from the region of our data. We cannot, then, hope to be correct in prognostications of the future far ahead, but we may hope to be suggestive of the present trend of things. And certain principles are as unchangeable as the ether. And, if I am altogether wrong, and Heaven knows that I claim no special sagacity or knowledge, it may still be of some service to attract the attention of others wiser than I to a great subject in which we all have so lively and direct an interest.

Could we but rise at noon of an equinox to a height of some 12,000 miles above a point near the centre of the ocean, we should be able to survey the whole of the Pacific. With certain conditions provided for our comfort, and with sufficiently powerful telescopes, we could make out some of the detail on a scale about twenty times as great as that presented by the features of the moon. At so great a height we could see in its entirety the great ocean, which occupies the greatest depression in the solid globe. And, our comfort still attended to, we might be induced in our exaltation to speculate on the cosmic origin of the depression, and be able to foresee more clearly the great ocean become a great lake, furrowed by the keels of fleets of peace and war, and serving as a royal means of communication between great nations on the East and on the West.

Did the Pacific originate in a catastrophe? Is it the great healed-over scar of the wound made in Mother Earth in the days when the moon was torn from her? Or was it formed gradually as the planetisimal meteorites accumulated and settled down into the coherent globe? However formed, there it is, a monumental basin differing in type from the beds of all the other oceans. We have evidence that its surface was in the past less extensive and more broken by land. Long ago we have a dim vision of a greatly-extended Antarctica, continent or archipelago, forming a bridge of connection between Australia and New Zealand and South America. Later, there is evidence of a long peninsula stretching down from Papua to New Zealand. And this is important, because along the line of the peninsula lay the old border of the ocean. For, around the borders of the ocean runs a curved line of disquietude, of strain, of rupture in the earth's crust. Along this line the coasts are shaken by earthquakes, and breached by volcanoes. In general, the signs point to subsidence of the whole ocean bed. The submergence of the old Antarctica, of the Papua to New Zealand peninsula, the numerous atolls kept just above water, the Great Barrier Reef, the drowning of the estuaries, which gave us the deep harbours of Eastern Australia, the continuation of the Andes in a chain of islands to the south, finally sinking below the ocean level, indicate widespread subsidence on a grand scale. In antagonism to this secular sinking, and to the great agencies of sub-aerial denudation, which are striving to drag our lands under the sea, we have the upheaving activities of the vulcano-seismic girdle. This is the great fighting line, where the mighty struggle of the opposing forces of Nature is taking place. Along this we hear the alarums and drums of cosmic war.

From Japan to New Zealand, from San Francisco to Valparaiso, the earthquake is known and dreaded. So serious is the phenomenon to Japan that, in addition to establishing stations in Formosa, Saghalien, China, and Korea, she has already more than 1,000 observing stations at home, and spends large sums each year in seismological investigation. In 1901 at Gifu Ken the losses by one earthquake were equal to those in a great battle. There were nearly 5,000 killed, 12,000 wounded, and 90,000 houses were wholly or partially destroyed. [Alas! as I am writing, the newspapers bring the cables, announcing the fearful destruction in the Straits of Messina, where the losses are those of a great war, and not of a single battle.] Surely such possibilities should make the Government of New Zealand take warning to study carefully the seismic movements, and to learn the best forms of protected building. On the opposite shore, in April, 1906, we were appalled by the fearful display of seismic energy in California. In sixty-five seconds a rupture was produced along the line of an old fault, a crack which extended obliquely across the Coast Ranges for some 400 miles, and along this the shock was felt in its violence over a width of 50 miles of country. The horizontal displacement of the ground at the line of fracture was on the average 8 to 10 ft., and the vertical, at its greatest, reached 4 ft. It takes the pull of a ton weight to snap a bar of granite 1 in. square. What must have been the force required to snap a mass 400 miles long, and, probably 10 or more miles deep? Fortunately, the number of lives lost did not exceed 1,000, but the damage to property, by the earthquake and subsequent fire, was estimated at £60,000,000. At all events, the British insurance companies were called on to meet claims amounting to £12,000,000. That California must expect frequent repetitions of shock is fully recognised by the American men of science.

If you elect, or are compelled by circumstances, to live in the fighting line, you must expect and prepare for inconveniences, as the rough and tumble of the shift will go on regardless of the presence of non-combatants. The American scientists give a striking picture of the issue of the conflict:—

*"The earthquakes of California have been studied for some years (1906) by Messrs. Holden and Perrine, of the Lick Observatory, and the geology of the State is being revealed through the labours of Messrs. Russell, Diller, and Lawson. Between the Rocky Mountains and the Pacific are the parallel chains of the Sierra Nevada and the Coast Range. Among the Rocky Mountains earthquakes are few and slight; on the eastern slopes of the Sierra Nevada they are more frequent, and, sometimes, as in the Owen's Valley earthquake of 1872, of considerable severity. The Western portion of the Sierra Nevada, the Cascade Range, is remarkably free from earthquakes, though it is worth noting by those who see an intimate relation between volcanic and seismic actions, that it contains the recently extinct cones of Shasta, Mount Hood, and Mount Rainier. Again, the Coast Range, and especially the districts surrounding San Francisco and Los Angeles, is one of the great seismic regions of the globe. Lastly, to the west of California, the sea-bed deepens rapidly, the contour of 4,000 metres lying only a short distance from the land, and from this region many of the strong Californian earthquakes are known to proceed.

"Recent studies have established a close connection between these earthquakes and the geological structure of the district. Whether the earthquakes take place under the Coast Range or beneath the adjoining ocean, the longer axis of the isoseismal lines are either parallel or perpendicular to the sub-oceanic contour-lines, the crust folds of the Coast Range and the long lines of fault of the Pacific sea-board. It is difficult to resist the conclusion that in the Western United States we are presented with mountains in four successive stages of growth. In the Rockies we have ranges so ancient that they have almost ceased to grow; in the Sierra Nevada, to the west, another which is approaching old age; the Coast Ranges are in the stage of youthful, vigorous growth, with the possibility of a long and active life before them; while still further to the west, and not yet risen above the ocean, there seems to be an embryonic range, of which the San Francisco and other earthquakes are the birth-throes."

The geology of Central and South America has not been so carefully studied, but we may anticipate very similar effects in the many regions of seismic activity.

On our side of the ocean volcanic eruptions constitute a safety valve and are the main agents in the upheaval or up-building of land. The mighty pile of Fusijama shows us the scale of magnitude of such operations. The pumice-strewn seas of the New Hebrides, the masses of lava poured out unceasingly by the volcano still erupting in Savaii, the terrific blow-out of Tarawera in 1886, which buried 1,800 square miles of country more or less deeply under sand, ash, and tuff, and fragments of the country rock, are examples nearer home. Fortunately for Australia, it is situated well behind the fighting line, and,

* "Nature," April 26, 1906.

though mild shocks are felt from time to time over the continent from Perth to Sydney, they are of small consequence. Probably no part of the earth can be beyond the influence of earthquake shock, and probably no part is much more secure than Australia. The extinct volcanoes of South-west Victoria, Mount Gambier, and Kangaroo Island, however, show us that at no very distant geological time, later Pliocene or Pleistocene, there was a long line of strain along the south coast, and it is along this line, if anywhere, that we may expect seismic and volcanic trouble.

Perhaps even more interesting and striking as phenomena than the eruptions on land are those which are submarine, especially if they result in the permanent uplift of land. Submarine disturbances are frequent in the Pacific. It is not often that a vessel contrives to be in the centre of one, but this seems to have happened to the "Hesper," an American bark, Captain Sodergren. His ship was lying at anchor at Kobe during the earthquake shock at Gifu Ken, and it received a sudden bump which threw all on deck off their legs. Two days after the shock, "when about 75 miles off the Japan coast, the bark was almost thrown on her beam-ends," writes the captain, "by the sudden eruption of a submarine volcano. The water became so hot that when a sea was shipped on deck the crew took to the rigging. The heat became so intense that the pitch in the deck was melted, and the seams opened. Great blasts of hot air with a strong sulphurous smell came up from the breaking surface of the ocean, and almost suffocated us for the moment. This phenomenon lasted for several hours. I have had all I want of sailing in Japanese waters."

The Rev. Dr. Brown witnessed an eruption in Blanche Bay, New Britain. The water of the whole of the Bay literally boiled, and cooked fish were plentifully thrown up. An island arose in the bay, on which, when, 20 years after, he revisited the spot, a young grove of Casuarina trees was flourishing. Several islands, as Niu Force, have been thrown up in the Tongan group, and it is probable that the volcanic islands of the Pacific all originated, and that others will originate, in this way.

We may conclude that the general subsidence of the Pacific bed will continue where not interfered with by the forces of upheaval, accompanied or not, by volcanic eruptions. Minor oscillations in recent times have taken place around our Australian coasts, upward as well as downward, but the general level seems to be stable, and we do not anticipate the drowning of our ports and submergence of strips of our coast in the same way as that in which the ports and littoral of the Adriatic are threatened. While the Pacific may be expected generally to grow deeper, we may also expect that the number and extent of the islands will be increased. New volcanic islands will be raised, and those denuded to water level will be converted into coral islands. Perhaps others of these may be built up from the submarine plateaux. There is little likelihood of this upward counter movement occurring to any extent in the East Pacific, and since the cyclones originate over the open sea to the east, and travel westward, we must make up our minds that hurricanes and typhoons will still be a menace in the seas and lands to the west. So we can only recommend Queensland to establish communications with meteorological stations to the East, that she may have warnings in time.

As the art of navigation has advanced, men of the littoral have pushed out further and further into the surrounding waters. The Levant, the Red Sea, and the Persian Gulf were the areas of the first sea-commerce, and furnished the adventures of the first sea traders. We know but little of the doings of the Chinese and Malay sailors in the typhoon-swept seas of South-east Asia. Emboldened by familiarity with the use of their sails, and armed with experience of the tricks of wind and wave, daring mariners sought commercial advantage over the extent of the Great Sea, the Mediterranean, on the one side, and made their toilsome and dangerous way to India on the other. The adventures of Sinbad give us a vivid picture of some of the later phases of these enterprises. We would all be glad to believe in the circumnavigation of Africa by Necho's captain, but at least we know of the gradual conquest of the Atlantic, the daring voyages of the Northmen and the Portuguese, and, the compass known, the grand venture of Columbus. Curiously abandoning the Mediterranean to the infidel pirates, the Spaniards hastened to carry the sword and the gospel to the New World. The raiders and the traders of Western Europe then opened up the Atlantic, and rounding the Cape and the Horn, entered on the unknown vastnesses of the Indian and Pacific Oceans. With the settlement of white races in America regular trade routes were established in the Atlantic, and presently battle fleets encountered on its waters. With settlement in India came a regular interchange of commodities across the Indian Ocean and round the Cape. Lastly, the colonisation of Australia and New Zealand, the growth of British Columbia, and the Western United States, the opening up of trade with China, and the marvellous awakening of Japan, have brought it about that the last of the great oceans is brought into service for intercontinental traffic and trade. Two great cables cross it; the one, All Red, from Vancouver to Fanning Island, Fiji, Norfolk Island, and Southport, in this State; the other from San Francisco to Hawaii, Midway Island, Guam, and Japan. A Russian war fleet traversed the Atlantic and Indian Oceans, and passed round the coasts of China to be annihilated in the Straits of Corea. And, but a few months back, an American battle fleet has sailed down the Atlantic, rounded the Horn, half circumnavigating the Americas, and then completely circumnavigating the Pacific, has been uproariously welcomed everywhere, from Australia to Japan. It is apparent that civilisation has won its hold on the Pacific.

What is the situation? The whole of one border of the Pacific is occupied by European races, Anglo-Saxon in the North and Latin in the South. The other border is held by Russia in the North and Australia and New Zealand in the South, while between the two lie the great Eastern nations of Japan and China. The islands occupied by natives of neither East nor West are now in the hands of Britain, America, Germany, and France. What will be the relations of the white races to one another, to the yellow races, to the natives of the islands?

What is to be the future of the native races of the islands of the Pacific? The days of piracy and plunder are practically over. Traders can no longer palm off old German newspapers as calico (Moseley), or carry off natives by violence. The islands are now under the protection of one or other of the Great Powers. Still the outlook is dark for the native races.

Had they reached their climax and begun to dwindle in numbers before the white man appeared? There seems to be evidence of this in Fiji (Fison) and in New Britain (Bromilow), where the natives pointed out sites of older and more populous villages. They seem to have become adapted to their environment almost as completely as the other members of the fauna, and to show no signs of invention or progress. They live as their fathers lived until they come into contact with the whites. Since the white man came, there is no doubt about the physical deterioration and diminution of the native populations.

A notable feature in producing this result is the introduction of the white man's diseases among peoples not rendered immune. The first fleet which brought the white man to Australia brought with it the germs of smallpox. "An epidemic starting from Sydney in 1789 spread during the succeeding years over the whole of the continent," writes Dr. Tidswell; "it was maintained till 1845, shortly after which it appears to have died out There is abundant evidence that during its prevalence it produced an enormous mortality amongst the blacks, about one-half of the native inhabitants of the southern part of Australia having been killed by it. Notwithstanding the great loss of life amongst the blacks, the whites escaped." At present there is no law of compulsory vaccination in New South Wales. We trust to quarantine, instead of being individually armed against the disease, just as we trust to the British Navy and do not arm ourselves against invasion. There is a danger then of the disease slipping in, and in that case the mortality of the epidemic is not likely to be confined to the few remaining blacks. Further, the disease might spread to the other States, and to the islands. Is it not time to use sure prevention rather than to trust to an uncertain cure?

Measles, whooping cough, influenza are under rein amongst races long salted; but cause devastation when introduced amongst the natives. There seems to be no prophylactic known to medical science, and thus there is always danger of the outbreak of epidemics of these diseases. They can only be mitigated by proper treatment and nursing. Quarantine in the islands should be as rigidly enforced in the case of these diseases as against the smallpox and scarlet fever more deadly to the whites.

On the other hand, there is hope of mitigating if not of eradicating the indigenous tropical diseases. We have been astonished and overjoyed at the medical triumphs of the last few years. It is not so long since a citizen of Brisbane, Dr. Bancroft, was one of the first to draw attention to the dissemination of disease by stinging flies. The clue, followed up by Ross and others, has led to wonderful results. Ismailia has been cleared of malarial fever, Yellow Jack has been driven from Havana and New Orleans. Malta fever was traced to the drinking of goats' milk, and disuse of the milk resulted in the extermination of the fevers. Samarai, the entrance port to New Guinea, occupies an island of 60 acres. The Anopheles mosquito has been exterminated in the island, and Samarai is free from fevers, black water, remittent and intermittent. What has been done for this port may be accomplished for all others, and the natives, be it remembered, suffer from fever as well as the whites. Lung diseases are a serious element of mortality in the islands, but the missionaries are wise in keeping the natives to simple and natural clothing, and whatever improvements may be discovered in the prevention and treatment of phthisis will be adopted in the islands.

Other indigenous affections, such as elephantiasis and the native ulcers and skin diseases, have not yet been sufficiently studied. It behoves us, Governments and peoples, to support our School of Tropical Medicine, and to endeavour by strenuous and purposeful scientific research to understand and to stamp out these scourges.

But upon their direct relations to the whites depend mainly the future of these races. In North America the Indians, hunters and warriors, have nearly died out. In the West Indies, cruelly overworked by the Spaniards, they have entirely vanished. In South America, where they were more settled and cultivated their lands to some extent, they have survived. Treatment by the whites was less harsh, especially in Brazil, and there seems to have been established an order of things under which the peons live in some comfort. In Java, a vast native population survives under Dutch rule, and the land is tilled more completely than in any other part of the world. The African negro and the Indian coolie increase and multiply under adverse conditions. How will the Polynesian fare under white control?

The policy of the British, German, and American Governments has been mainly directed to reserve the lands for the natives, and this policy seems to be wise as well as fair. Settled in villages, and, if necessary, compelled to work *for themselves*, the natives will have the best chance of surviving, and of developing their lands for the general benefit. To rob the villages of their able-bodied men, to draw them away to work on distant plantations, is to sap the very life of the village communities. These will sooner or later, and not so much later, be wiped out.

Let us suppose this done. Apparently, white men cannot work at manual labour in the tropics. Failing the natives, the planters must import negroes or coolies, Hindoos, Chinese, Japanese. Is the presence of the Hindoo coolie in Fiji an unmixed blessing? Are we prepared to replace the mild natives—and all the natives have become mild who have been handled by the missionaries, who consider their interests and win their confidence—by large settlements of negroes or Hindoos, or men of the yellow races. I hardly think that Queensland will allow this immigration on a large scale. I hardly think that Australia will countenance such immigration into New Guinea. In Queensland, since the aboriginals are unavailable, the problem of cultivation of the tropical lands has become an extremely difficult one, and I have no pronouncement to make. The care of New Guinea is different, and there, I think, we cannot too strongly urge the maintenance of the village system as completely as possible, that there be no necessity or opportunity for a large immigration of undesirable aliens.

It remains, lastly, to consider the relations of the white nations to one another and to the yellow races. In 1892 it seemed as if war was inevitable between Germany and the United States over Samoan affairs. War ships in equal numbers anchored opposite to one another off Apia. The dogs of war faced each other snarling. But a bolt from the blue smote them. In a few hours all were sunk or on the reef hopelessly wrecked. Robert Louis Stephenson described the catastrophe with his vivid pen and foretold the issue with the insight of the seer. Let me give you his concluding words: "Thus in what seemed the very article of war, and within the duration of a single day, the sword arm of each of the two angry Powers was broken; their formidable ships reduced to junk; their disciplined hundreds to a horde of castaways, fed with difficulty, the fear of whose misconduct marred the sleep of their commanders. Both paused aghast; both had time to recognise that not the whole Samoan Archipelago was worth the loss in men and costly ships already suffered. The so-called hurricane of 16th March made this a marking epoch in world history; directly, and at once, it brought about the Congress and Treaty of Berlin; indirectly, and by a process still continuing, it founded the modern navy of the States. Coming years and other historians will declare the influence of that."

The prophecy has been abundantly justified. The method of agreement and not the chance of war has been accepted by the Great Powers. The American Fleet is a substantial reality. In a few years the Panama Canal will be open to ships of all classes, and Atlantic traffic will have an easy and direct ingress into the Pacific. This will plainly strengthen America's position in our ocean, and render more unlikely than ever her withdrawal from Hawaii and the Philippines. In fact, we may expect that the opening of the Canal will give to the United States preponderance for years to come. And America has continued the policy initiated in the Berlin Treaty. Quite recently she has concluded an agreement with Japan, almost in the identical terms of the Anglo-Japanese Alliance. "The first paragraph, covering 'a common aim, policy, and intention,' deals with the expressed wish of the two Governments 'to encourage the free and peaceful development of their commerce on the Pacific Ocean.' The next is the determination to maintain the existing *status quo*, and to defend the principle 'of equal opportunity for commerce and industry in China'; and the third asserts the need for preserving the independence and integrity of China. Finally, in the event of trouble the two Governments are to communicate with each other. To all intents and purposes," continues the "Sydney Morning Herald," "another Pacific Triple Alliance has been established, and the concise terms in which its existence is now advertised make the latest development the more significant. Great Britain, Japan, and the United States are practically hand in hand to guard the world's peace in the Pacific, and to discuss frankly the various causes of possible friction as they arise. The rest may be left to the course of events."

"East is East, and West is West, and never the twain shall meet," writes Kipling. In the Pacific, East and West face with the ocean common and free to each. Will there be tremendous conflict or will mutual understanding allow both to work out their several destinies in peace and amity? As reasonable men, surely we may hope for the latter. The great Eastern nations cannot be destroyed. Nor is it likely that the united Westerns can be overpowered. For instance, could America and Germany afford to allow Australia to be overrun and occupied by an Eastern Power? What chance would they then have of retaining their own outposts? That Japan and China, and especially China, will be great world Powers no one can doubt. And why should they not? The East is everywhere moving. Surely the most wondrous cablegram ever despatched was this: "The elections are proceeding quietly at Jerusalem." Turkey is rejuvenescent, and in spite of complications we may hope that the principles of freedom and toleration taught to Europe by the French Revolution and advanced by Anglo-Saxon example are being grasped by the peoples of the Turkish Empire. The Persian people, aided by Russia and Britain, are throwing off their despotism. The peoples of India are travelling under the fostering care of our Motherland to more and more of freedom and self-government. Japan has not only sprung at a bound into the ranks of civilisation, but has also shown a wise restraint in the hour of success. China, with its immense population and resources, the good qualities of patience in her peasants, and probity in her merchants, has a future before her the greatness of which we can but dimly foresee. There is no reason to adduce that these nations will be unworthy of respect, of reciprocity, of alliance. And we see that this respect is already accorded to Japan by the two great Anglo-Saxon Governments.

The black and sad pages of past history, the ever-recurring disappointment in the achievement for which the struggle was so keen and the hope so high, may at times make us lose heart and faith in an even nobler evolution. But there are the bright pages, and the shining examples of self-sacrifice and patience and of heroic deed, which show us that the cause of humanity is not lost, but only that there is need for us all to play our part and not to be weary in well-doing. Two qualities are of enduring value. We must be scientific in our lives, in our conduct, in our Government. We must be unselfish as nations and as individuals. Ignorance is doomed to destruction. Selfishness ends in catastrophe. Let us hope, then, and work for a strenuous and an equable development of this great Pacific. The way may be long and the stumblings many; but the goal is assured, even if we as individuals and as nations are not worthy to attain to it. Let me conclude by quoting to you the idealistic poem of John Addington Symonds, who after a lifetime devoted to the study of the evolution of Italy, that land which has suffered more set-backs and more miseries than perhaps any other, could still write—

These things shall be! A loftier race
  Than e'er the world hath known shall rise,
With flame of freedom in their souls
  And light of knowledge in their eyes.
They shall be gentle, brave, and strong
  To spill no drop of blood, but dare
All that may plant man's lordship firm
  On earth, and fire, and sea, and air.
Nation with nation, land with land,
  Unarmed shall live as comrades free;
In loving heart and brain shall throb
  The pulse of one fraternity.
Man shall love man with heart as pure
  And fervent as the young-eyed joys
Who chant their heavenly songs before
  God's face with undiscordant noise.
New arts shall bloom of loftier mould,
  And mightier music thrill the skies,
And every lip shall be a song,
  When all the earth is paradise.

ABSTRACT OF LECTURE DELIVERED IN THE ALBERT HALL, BRISBANE, JANUARY, 1909, ON SIR JOSEPH BANKS, THE FATHER OF AUSTRALIA.

By J. H. MAIDEN, Government Botanist and Director of the Botanic Gardens, Sydney

Joseph Banks was born at Revesby, Lincolnshire, in 1743, and inherited considerable wealth. After leaving Oxford, he became imbued with the desire for foreign travel, and, in 1766, made a botanical tour in Newfoundland and Labrador, then but little known. In 1768, Lieutenant James Cook having been appointed to the command of H.M.S. "Endeavour," 269 tons, Banks decided to accompany him, and, at his own expense, took with him his naturalist-librarian (Dr. Solander, a pupil of Linnæus), three accomplished artists, and a number of attendants and servants, besides supplying equipment for collecting natural history specimens on a scale which was unprecedented, and which was destined not to be repeated for many years.

The "Endeavour" left England in August, 1768, and the east coast of New Holland having been sighted, and, indeed, discovered by Cook, the "Endeavour" put into Botany Bay (called by Cook Stingray Harbour) from 28th April to 6th May, 1770. This is, of course, now a suburb of Sydney.

A number of interesting observations were made by Banks, who wrote a journal of the voyage, and duplicates of the identical plants collected by him at Botany Bay were presented by the trustees of the British Museum to the Botanic Gardens in Sydney in 1905.

The ship then headed north, and Cook named the principal features of the coast. She struck on the Barrier Reef, and was with difficulty brought into the Endeavour River, near Cooktown, but this delay was a blessing in disguise, in that it gave Banks an opportunity of recording valuable information in regard to the botany, zoology, and aborigines of Northern Queensland. This stay in modern Queensland was far longer than in Botany Bay.

Cook and Banks left Australian shores on 27th August, and went home *viâ* New Guinea, Java, Cape of Good Hope, St. Helena, and Ascension, arriving at Deal, England, on 12th July, 1771.

Banks employed engravers to depict the Australian plants which his artists had drawn, and it is a remarkable fact that these fine engraved plates were not printed until eight or nine years ago.

One cannot read Banks' journal without being impressed with the fact that he was a most observant naturalist and a broad-minded man. The heir to wealth and luxury, he underwent the hardships and perils of the tiny "Endeavour" for the pure love of knowledge. In 1772 he went to Iceland with Solander, a far more formidable undertaking than it is at present, and this voyage also resulted fruitfully, while he secured the affection of the islanders.

The matter of transportation of convicts being suggested, he attended a Committee of the House of Commons, gave evidence in regard to this great southern land, and, doubtless as a result of his advocacy, the colonisation of this country was decided upon. What followed is a matter of history.

Banks was practically the founder of New South Wales, and, therefore, of Australia. He was president of the Royal Society for forty-two years, an intimate friend of King George the Third, a *persona grata* with Ministers. He held a unique position in these early days, being habitually consulted on Australian affairs.

He was a sort of general adviser of everybody on everything concerning the welfare of the young colony, and the early Governors wrote to him frequently, and deferentially asked his advice in regard to matters of importance.

In the dark days Banks' refreshing optimism in regard to the future of the colony was like a ray of sunshine, and was the more remarkable since his opportunities in the "Endeavour" of penetrating the country had been very limited. He consistently advocated the exploration of Australia.

His researches in regard to the botany of Australia would take too long to do justice to on this occasion. His purse was ever open for the advancement of botanical science, and thus he successively employed Solander, Dryander, the great Robert Brown (the most eminent botanist of his age), who was in Australia for four years, from 1801 to 1805, botanically exploring coastal Australia (but little of the interior had been explored then); also the Bauers, whose skill as botanical artists has never been excelled. Peter Good, George Caley, and many others were also botanical and horticultural protéges of Sir Joseph Banks. He died in 1820.

His Australian collections formed the nucleus of the celebrated Banksian herbarium, practically a public institution, and freely open to scientific men, yet maintained by the purse of Banks, which, with the Banksian Library (chiefly botanical, and valued, for insurance purposes in 1827, at £7,300), is in the British Museum at the present day. As the years roll on Australian botanists will visit England to study it with increasing zeal.

Banks virtually acted as director of the scientific operations of Kew, and appointed collectors of plants for that establishment on behalf of the King (George III.), whose personal property it was at that time. He appointed Allan Cunningham, afterwards in charge of the Sydney Botanic Gardens, and whose reputation as a botanist and an Australian explorer (he discovered the Darling Downs) will never die.

In fact, Banks had the knack of making good appointments. He appointed Bligh and Flinders to important offices, and when they got into trouble he was a good friend to their disconsolate wives. Banks was indeed the most loyal of friends.

Banks is very definitely associated with Queensland. Reference to his journal shows what a careful observer he was in regard to the aborigines, the botany and natural history generally, of the Endeavour River, and thence to Cape York.

Altogether, his personality was a unique one. His wealth, his great influence, his unbounded zeal, were ever called into requisition for the development of the struggling colony of Botany Bay. He was the only man of rank and wealth who, to use a homely expression, "stuck to" the place, and this at a time when the conduct of some of the colony's responsible officers did not tend to lighten his labours, or to make Botany Bay a fashionable subject.

Australia was fortunate in having such an unselfish, noble-minded patriot to look after her interests in the early days, and I am sure that, when the situation is properly explained, she will not allow the man to whom she owes so much to be uncommemorated, especially as she has so honoured men of inferior calibre and achievement.

[The lecturer here announced that a committee had been formed with the object (*a*) of erecting a replica of the Chantrey statue of Banks in the Mitchell Library, Sydney, where so many of the Banksian manuscripts have found a home, and (*b*) of founding a Banksian University Prize in Botany.]

A trait of Banks' character which always charms me is the kindness and patience with which he deals with such of his friends as were in humble walks of life. He writes at greater length to a working man than to the Secretary to the Admiralty. He had the knack of getting the best services out of a man for the benefit of Australia. His, indeed, was a fine character, and I am confident that my fellow-Australians admire a good man.

He was corresponding member of the Institute of France, at a time when England and France were engaged in the fiercest struggles, but, throughout those stormy times, he retained the respect and affection of French scientific men. The eulogium of him by the eminent Cuvier was one of the noblest discourses ever pronounced by one scientific man upon another. He pointed out that on ten occasions Banks caused specimens collected by French scientific men, and which had been captured by British cruisers, to be transmitted to Paris unopened. Napoleon declared that the name of Banks was spoken of with affection throughout France. We will let him rest with Cuvier's beautiful tribute, the force of which is understood by every scientific man.

(The lecture was illustrated by 51 lantern slides.)

PAPERS READ IN SECTION E.

1.—THE GEOGRAPHICAL DISTRIBUTION OF MINERALS ON THE PACIFIC LITTORAL, AND ITS INFLUENCE ON COMMERCE.

(A Lecture to the Australasian Association for the Advancement of Science—Brisbane Meeting—13th January, 1909.)

By R. LOGAN JACK, LL.D., formerly Government Geologist, Queensland.

Food is the primary need of mankind, as of all animals. For civilised man clothing comes next; but to primitive man, in his struggle to procure food, while at the same time protecting himself from his enemies, implements must have been even more essential than clothing. There is plenty of evidence that considerable progress had been made in the arts in which metals are of service long before the want of clothing made itself acutely felt.

Many great cities—London, for instance—owed their existence and progress to being favourably situated for the collection and distribution of food stuffs. Others, such as Glasgow, rose into importance by reason of the proximity of iron and coal, a combination resulting in the manufacture, on easy terms, of the thousands of articles, great and small, comprehended in the term "implements."

I propose to call your attention to the distribution, over the area which concerns us most nearly, the Pacific littoral, of the principal items of raw material—fuel and metallic ores—required in the manufacturing industries, and to endeavour to estimate the influence of their actual geographical distribution on the various centres of population.

The more valuable a commodity is in proportion to its bulk, the less influence has it on the commerce of the producing country. Thus gold, of which the whole world's annual production could easily be carried in a single ship of moderate tonnage, does little for the producing country's export trade, although that country benefits to the extent of the purchasing power of the surplus remaining after the supply of its own requirements, and by the indirect advantages resulting from the ultimate settlement of the producers and their diversion to other industries. The same is true of silver in a less degree.

I propose, therefore, rapidly to review the distribution and movements of the bulkier products—coal, iron, copper, and tin—in the region under consideration, as a preliminary to the discussion of the present and future effects of such a distribution on the commerce of the Pacific.

COAL.

In 1868 the United Kingdom was the leading coal producer of the world, with an output of 115,518,096 short tons, as against

Germany's 36,249,233 and the United States' 32,861,960. In 1871 the United States produced 46,885,000 tons, as against Germany's 41,736,361 tons, and the United Kingdom's 131,434,271 tons. In 1899 the United States overtook and passed the United Kingdom, the figures being: United States, 253,741,192; United Kingdom, 246,506,155; and Germany, 149,719,766. In 1906, the figures were: United States, 414,157,278; United Kingdom, 281,195,743; and Germany, 222,350,526. For the same year (1906) the production of Japan was 12,980,103 tons, that of China 9,032,660 tons, that of the Australian Commonwealth 8,921,011 tons, and that of New Zealand 1,757,291 tons. In 1907, the coal production of the United States was 480,363,424 tons

Against the overwhelming predominance of the United States, as producers of coal, there must be set their capacity for consumption. The geographical position of the principal coalfields, all situated in the eastern third of the country, limits the distribution of the surplus in a great measure to exports overland to the interior of Canada, and by the Atlantic seaboard to the east coast of South America. The only States that appreciably contribute to the commerce of the Pacific are Alaska, Washington, Oregon, and California.

ALASKA produced in 1906, 5,541 short tons of coal. The coal-fields are both Tertiary and Cretaceous, but are of very limited extent. A large proportion of the coal is lignitic, but there are bituminous and semi-anthracitic coals on Controller Bay. The uses of the coal are chiefly local and for coasting steamers. Alaska imports more coal than it produces. In 1900 the import from the State of Washington was about 13,000 tons, and that from British Columbia was undoubtedly larger. In 1906 the import of coal from Australia was 7,716 long tons.

The State of WASHINGTON produced in 1906, 3,276,184 tons. The coalfields, which are for the most part situated in the western and central districts, are small—probably not over 1,000 square miles. The coal is lignitic, locally converted into bituminous. The local uses of the coal, and therefore the output, are greatly interfered with by the accessibility and cheapness of petroleum, but a considerable coast-ward trade is done north and south along the Pacific Coast.

OREGON produced in 1906, 79,731 short tons, almost entirely from the one field, which is actively worked—viz., that of Coos Bay, in the south-western part of the State. The conditions affecting export are similar to those of Washington.

CALIFORNIA is not a large producer of coal, and the area of its Tertiary coalfields is limited. The output of lignitic or sub-bituminous coal for 1906 amounted to 50,497 short tons. On the other hand, San Francisco and other large cities are consumers on a great scale, and not only absorb the local product but import coal and coke from other States and countries. In 1907, according to Commonwealth statistics, the export of coal from Australia to the United States amounted to 539,880 long tons. There is understood to be little or no traffic in coal from the Commonwealth to the United States except that to Pacific ports. British Columbia is a still larger contributor. Japan contributed 11,966 tons in 1906.

The coal production of British Columbia for 1906 was 1,541,652 metric tons, besides 202,424 tons of coke. On the Crow's Nest branch of the Canadian Pacific Railway, the coal is all used up locally, chiefly in smelting, but further west, the products of the Cascade field, near Banff, begin to find their way to the Pacific. The coal of this field is of Cretaceous age and semi-anthracitic or anthracitic. There is bituminous coal on the eastern side of Vancouver Island. British Columbia is the most important source of coal for consumption in California, its contribution for 1900 being 766,917 short tons. It also exports a considerable amount to Alaska.

In the Pacific States of Mexico—viz., Oajaca, Michoacan, and Guerrero—coal is known to exist in considerable quantities, but the difficulty of transport to the coast has hitherto prevented the mines being seriously worked, and it is unlikely that in the near future, Mexican coal mines will become serious factors in the trade of the Pacific. In 1906, this country imported 74,737 long tons of coal and 3,245 of coke from Australia. In 1907, the coal import was only 50,316 tons.

Guatemala figures in 1906 as an importer of 3,383 long tons of coal from Australia, but is not a producer.

Nicaragua possesses some coal deposits, but difficulties of labour and transport prevent their being worked. The import from Australia in 1906 amounted to 1,350 tons.

Ecuador produces no coal. In 1906 it imported 15,487 long tons from Australia, but in 1907 the import had fallen to 7,519.

Peru produced in 1906, 77,209 metric tons of coal. The production is unable to meet local requirements, chiefly for smelting works. In 1906 the import from Australia amounted to 109,278 long tons. In 1907 it was 101,131 tons.

Bolivia is not a producer of coal, and does not appear in the list of importers from Australia. Its great mining industries, however, make it almost certain that it must import coal or coke. Probably it is supplied from British Columbia.

Chile produced in 1905, 793,927 metric tons of coal, the coalfields occurring in a narrow strip of country between the Pacific and the Andes, extending from the city of Concepçion to the Straits of Magellan. The greater part of the production was absorbed in local (chiefly mining) requirements, and 881,062 long tons were imported from Australia in 1907. Yet Chile sent a considerable amount of coal to the San Francisco market, and the competition of Chilian coal and oil in the market of Peru is recognised as a formidable detriment to the importation of Australian coal.

On the Western shores of the Pacific, coal occurs in the island of Saghalien. Some mines were worked by Russian convict labour, the output (which is not large) going to the bunkering of steamers.

Japan has extensive coalfields, and produced in 1906, 12,980,103 metric tons, or 48 per cent. more than Australia. In 1907 the production had advanced to 15,362,467 tons. The coal, however, is of Tertiary and Cretaceous age, and for the most part is of a bituminous type of inferior quality. The exports amounted to 2,500,000 tons in 1905. The bulk of the coal exported goes to Chinese ports and Singapore. The export to China (including Hongkong) for 1896 is stated to have been 994,000 tons. In 1904 the export to California was 45,429 short tons, but in 1905 it had fallen to 11,996. Figures are not accessible for 1906 and 1907, but it is understood that the exports to California have greatly increased during these years. Australian coal has lately been able to compete to some extent successfully against Japanese in the Singapore market. In 1907 Japan actually imported 5,300 tons of coal from Australia. The local fuel requirements of Japan are very great, including coal and coke for copper smelting, as well as for manufacturing and household purposes. The coal mines are worked by convict labour.

Korea is a small producer of coal. The amount for 1906 is given as 5,895 metric tons.

Siberia has extensive coal deposits along the line of the Russian railway, but the coal is said to be of comparatively poor quality, and it cannot hope to compete in Pacific traffic with the better coal of Manchuria, which has fallen under Japanese control, as it would actually have to pass over the Manchurian fields on its way to markets in the Pacific, with the added drawback of long land carriage. Japan has now the coalfields of Fu Shan, near Mukden, and these can find ready access to the Pacific by rail to Korea Bay or the Gulf of Pechi-Li. These workings are of immense antiquity; supposed to be older than Chinese occupation, and since the Japanese took them over their importance has been triumphantly demonstrated.

China is destined to be the leading coal producer of the future. Our knowledge of this vast country is limited, but no reader of the literature of travel, from Marco Polo downward to Richthofen, Schechenyi, Hosie, Parker, Gill, and Little, can entertain any doubt of the value and wide distribution of its coal deposits. A recent writer speaks of China as "one vast coalfield," which is an exaggeration. A British blue book ("Mines and Quarries"), little prone to enthusiasm, as a rule, refers to the coalfields of China as "incomparable," and this is the right note. I have myself travelled slowly by river and road over an 800-mile stretch, and seldom been a whole day without seeing the outcrops of seams of coal. The "one vast coalfield" theory may indeed receive support, in time to come, by the discovery of seams of coal beneath the vast alluvial flats which form the eastern portion of the country. Where river navigation is possible, as on the Yangtse, the coal is distributed to great distances, but the difficulties of inland transport must be seen to be appreciated. An experience of my own may be related in illustration.

At Takwan, 48 miles up the river from Cheng tu, the capital of Szechuan, a nearly vertical bed of shale, about 2 ft. in thickness, contained scattered through it films of coal up to the thickness of a knife blade, and aggregating at the most a thickness of 2 in. This seam was mined by a tunnel driven into the hillside. Air was supplied by a fan worked by hand. The miners picked the face, and sent out the whole in baskets carried by boys. The product was washed at the pit-mouth, and the coal having been separated from the clay was partly briquetted and partly coked—a splendid coke it was—placed on rafts and floated down the river to the city. When we saw for ourselves that really magnificent coal occurred along a main road within 300 miles of the city, and that the cost of coolie labour to carry it turned the scale in favour of perhaps the poorest coal seam ever worked by man, we could grasp the importance of carriage as a factor in mining.

China is a densely populated country, and all its cultivable soil has long ago been denuded of timber, so that coal is a necessity for industrial and domestic purposes. Such large quantities are obviously required for copper and iron smelting and brine evaporation that I am inclined seriously to doubt the correctness of the British official estimate of the coal production of China (9,032,660 metric tons for 1906). Be this as it may, the needs of the indigenous population will be the only limit of Chinese coal production until the—perhaps not far distant—time when a network of railways brings the interior into communication with the Pacific.

A few foreign concessions are held, such as the coal mines of the Pekin Syndicate in Shan si, and those of the Chinese Engineering and Mining Co. at Kai ping, near Tien t'sin. The latter has six or eight seams of bituminous coal of workable thickness, one of them 35 ft. This colliery produced from 1881 to 1889 inclusive 6,552,570 tons. The German province of Shantung contains coal seams up to 2½ metres in thickness.

Although bituminous coal is plentiful, anthracite is still more widely distributed throughout China. I have seen immense deposits of lignite in the province of Yünnan extensively employed in the evaporation of brine.

Our knowledge of the geology of China is naturally imperfect, but coalfields of Carboniferous and Triassic age have been recognised, and doubtless Cretaceous and Tertiary coals are represented.

China, owing to difficulties of inland transport, is an importer of coal from Japan and Australia. The contribution of the latter, through Hong Kong, in 1906, was 70,708 tons. In 1907, Hong Kong only took 63,623 of Australian coal, but Chinese ports took 41,058.

French Indo-China is a considerable producer of coal. In 1906 the output of the Hongay Colliery (employing 3,000 men) was 230,980 tons, of which 106,289 tons were briquetted, some of the briquettes being sent to Hong Kong. The Kebao Colliery produced about 6,000, and the Schoebelin Colliery about 5,000 tons. The total output of the province is given at 315,000 tons, including 19,000 of lignite.

The Dutch possessions of Netherlands-India produced a total of 389,000 metric tons of coal in 1906; 277,097 of this came from the Government Colliery, at Ombilien, in Sumatra, which is connected by rail with Padang. Coal is also worked in the Sedan district of Java. Apparently the output does not supply home requirements, since Java was an importer of 66,542 long tons from Australia in 1906, and of 37,734 in 1907.

British Borneo produced 62,974 metric tons of coal in 1906, and South-east Borneo (Dutch) 111,909 tons. A large proportion of the output is used for bunkering.

The Philippine Islands (belonging to the United States) have large deposits of a black pitchy lignite south of Southern Luzón, supposed to be of Eocene age. Brown lignites, believed to be late Tertiary, are also known. The seams best developed (up to 18 ft. thick) are in Zebu Island. In Batan Island there is bituminous coal of Tertiary age. The group has scarcely taken rank as yet as a producer. The Philippines imported from Australia, in 1907, 313,100 long tons of coal and 713 of coke.

Formosa (Japanese) produced 85,348 metric tons of coal in 1906.

New Caledonia is not quoted as a producer of coal, although the Nondou coalfield is only fifteen miles from Noumea, and is connected with the capital by rail. The position of this coalfield is of considerable strategic importance.

New Caledonia imported 12,294 long tons of coal from Australia in 1906, and 12,816 in 1907.

Australia produced, in 1906, 8,731,965 metric tons of coal. This was made up as follows:—

New South Wales ...	7,748,747	(In 1907, 10,510,961.)
Queensland ...	616,509	
Victoria	163,209	(All bituminous; *no* brown coal; 51 tons the previous year.)
Western Australia ...	149,755	
Tasmania ...	53,745	
	8,731,965	

Strange to say, Australia imported coke (for smelting) from the United Kingdom to the extent of 4,683 long tons, and from Germany 1,368 tons.

Australia exported coal (in quantities of over 3,000 tons) to the following countries:—

	1906. Long Tons.		1907. Long Tons.
To Ceylon	...	...	13,070
Fiji	19,519	...	33,114
Hong Kong ...	70,708	...	63,623
China ...	...	...	41,058
India ...	...	...	52,835
New Zealand ...	216,213	...	221,114
Straits ...	215,970	...	142,795
Celebes ...	3,009	...	4,560
Philippines ...	313,100	...	314,235
Hawaiian Islands	90,635	...	98,531
South Sea Islands	5,893	...	4,172
New Caledonia	12,294	...	12,816

	1906. Long Tons.	1907. Long Tons.
Java	66,542	... 37,734
Japan ...	...	... 5,300
Chile	603,491	... 881,062
Peru	109,278	... 101,131
Ecuador ...	15,487	... 7,519
Panama ...	11,906	... 6,402
Guatemala ...	3,383	... ...
Mexico ...	74,737	... 50,316
U.S.A. (Pacific Ports) ...	171,212	... 539,880
Alaska ...	7,616	... ...

The exports of coke from Australia in long tons were:—

	1906. Long Tons.	1907. Long Tons.
To New Zealand ...	...	... 3,210
Mexico ...	3,245	... ...
U.S.A. (Pacific Ports) ...	3,955	... 24,651
British Columbia	...	... 4,016

New Zealand's coal production for 1906 was 1,757,291 metric tons, and for 1907, 1,937,080. The most important coalfield is that of Westport, on the west coast of South Island. It produced, in 1907, 610,759 tons. The State Collieries at Seddonville and Point Elizabeth gave 240,773 tons, and the Taupiri Collieries in North Island 161,046 tons. The West Coast mines turn out a high-class bituminous coal, and new mines are being opened in the Buller and Grey fields. About a third of the total coal production of the colony is brown coal, chiefly from the southern portion of South Island. The remainder is bituminous and semi-bituminous. New Zealand imported 216,213 long tons of coal from Australia in 1906, and 221,114 in 1907, and exported in the same years 141,641 and 128,950 tons respectively.

IRON.

No country on the Pacific coast of North or South America has yet taken rank as an important producer of iron ores, with the exception of Colombia, where extensive deposits are known to occur, but they are only used for local requirements owing to transport difficulties, and Lower California (Mexico), where it has recently been reported that a contract has been made for the delivery of 500,000 tons from San Isdrio, on the coast 50 miles south of Ensenado, to the Japanese Government. No information as to the outcome of this experiment is to hand. Other Mexican provinces, Guerrero and Durango, possess very large deposits of iron ore, which may rise into importance in the future.

The Philippines contain several good deposits of iron ore, notably a belt of magnetite 12 to 15 miles south of Luzón. A high quality of steel is made from this ore, and is made into ploughshares, which locally command a high price. Probably the industry will disappear in consequence of the facility with which manufactured iron can be landed from the United States.

In the eastern part of CELEBES iron ores are worked, and on the south coast of JAVA there are extensive deposits of iron sand.

In BORNEO a deposit of iron ore 35 miles from Maruda Bay has been estimated to be capable of furnishing 26,500,000 tons.

In NEW CALEDONIA there are superficial deposits of pisolitic ironstone containing chrome oxide.

KOREA is estimated in British statistical tables to have produced 4,524 metric tons of metallic iron in 1906. This amount may, for practical purposes, be added to the product of Japan.

JAPAN is credited in American estimates with the production of 27,431 metric tons of iron ore in 1896. In 1905 British estimates put the Japanese production of pig iron at 53,210 tons, and in 1906 at 42,679 tons. The deposits of magnetite and micaceous iron ores are extensive, but a large proportion of Japanese pig iron is manufactured from imported Chinese ores. China exported, chiefly to Japanese ports, 95,339 metric tons of iron ore in 1905, and 111,460 in 1906. Figures for 1907-8 are not available, but are no doubt greatly reduced by the international boycott.

CHINA has for many centuries been entirely self-supporting in the matter of iron manufacture. Her achievements in the way of wrought iron, as exemplified in her bold suspension bridges, are the admiration of all who have seen them. Her cutlery ranges from razors to swords and ploughshares, and from the best to the worst. It is chiefly in art castings, however, that she excels. An extensive acquaintance with the interior of her temples leads me to the conclusion that in this branch of art she has no rival.

China is credited in British statistics with an estimated output of 43,950 metric tons of iron—presumably pig—in 1906. Another table gives the export of iron ore (mainly to Japan) as 95,339 metric tons in 1905, and 111,460 tons in 1906, and the export of pig iron as 25,115 and 34,305 tons respectively for the same year. The difference between the 1906 figures for production (43,950 tons) and those (34,305) for export leaves only 9,645 tons for local consumption, which, considering that at least 200,000,000 of people must depend on locally manufactured iron for all their needs, is obviously an under-estimate.

The Provinces of Foh Kien, Kuang Si, Kwei Chow, and Shan-tung are the chief producers, and are dotted with furnaces of a primitive type, which, however, do good work on a small scale. China appears to have convinced herself, some time before she thought of applying the same reasoning to other matters, that her iron industry must be carried on by modern methods, and has established many furnaces replete with every modern equipment.

British China is said to have a valuable deposit of magnetite, free of the deleterious addition of sulphur and phosphorus, on the mainland opposite Hong Kong. Large smelting works are being erected.

NEW ZEALAND has a good many occurrences of iron ore. The most promising appears to be a brown hematite at Parapara. An attempt was made last year to float a company to work this deposit and to build a light railway, but was unsuccessful.

In AUSTRALIA the chief use to which iron ores have hitherto been applied is for fluxing copper and other ores. In 1905 and 1906, the production is officially given thus:—

	1905. Metric Tons.		1906. Metric Tons.
South Australia—Flux	85,839	...	76,433
Queensland ,, ...	4,412	...	31,903
Tasmania ,, ...	6,401	...	2,642
New South Wales ,, ...	6,910	...	950
New South Wales, Oxide exported	551	...	593
Victoria and Western Australia...	Nil	...	Nil

The iron manufactured in Australia must have been made chiefly from imported raw material She imported, in 1906-7, in the form of pig, ingots, slab, bloom, and scrap iron:—

—	1906.		1907.	
	Long Tons.	Per Cent.	Long Tons.	Per Cent.
From United Kingdom	58,543	91	56,672	85
,, Norway	...	...	1,567	2·3
,, India	...	...	4,319	6·5
,, Belgium	3,445	5	2,782	4
,, Germany	1,632	2½	973	1½
,, United States	470	0·73	538	0·8
,, Other small imports ...	67	...	22	...
Total	64,157	...	66,873	...

Granting that the whole of this raw material was manufactured in Australia (with an inevitable loss in amount), it comes far short of her requirements. Consequently, she imported, in the form of manufactured iron and steel:—

—	1906.		1907.	
	Long Tons.	Per Cent.	Long Tons.	Per Cent.
From United Kingdom	124,460	58	157,673	64
,, Germany	43,062	21	44,181	18
,, United States	29,276	13	26,447	11
,, Belgium	17,845	8	17,300	7
,, Other small imports	59	...	940	...
Total	214,702	...	246,541	...

The Commonwealth's imports of railway iron (under the head of "Rails, Fish Plates, Fish Bolts, Tie Plates, Switches, Points, Crossings and Intersections for Railways and Tramways"), for which I am indebted to Mr. G. H. Knibbs, Commonwealth Statistician, were as follow:—

Country of Origin.	1906.	1907.
	£	£
United Kingdom	132,522	562,610
Belgium	95,939	19,599
France	...	240
Germany	36,575	37,969
Netherlands	255	808
U.S.A.	75,144	7,705
Total	340,435	628,931

These figures would certainly not convey to a stranger the idea that Australia ought to rank among the greatest of iron-producing countries, and yet such is literally the case.

COPPER.

ALASKA only produced 3,592 metric tons of blister copper in 1905, and 4,342 in 1906, chiefly from Prince of Wales Island. The principal fields are situated on Prince of Wales Island and Prince William Sound. These mines are favourably situated with regard to shipping facilities to smelting works on Puget Sound, Washington.

In the whole of the coastal districts of BRITISH COLUMBIA, and specially on Vancouver Island, copper mines are numerous. Again, the Boundary district (adjoining the State of Washington) is of great importance. British Columbia possesses some of the largest and best equipped copper smelters in the world. Its products could come to the Pacific if the demand lay in that direction, but as it is a large proportion of them goes east. The production in 1898 was 4,247 tons; in 1905, 17,097; and in 1906, 19,500 tons.

WASHINGTON (United States).—The Monte Christo Copper Mines (lat. 48 degrees 40 minutes east of the City of Everett, connected by E. and M.C. Railway) is in the heart of the Cascade Range, just below the snow line. There are many other mines of considerable promise in the State. The production of blister copper from Washington in 1905 was 111 short tons, and in 1906 145 tons.

OREGON produced, in 1905, 420 metric tons of blister copper, and in 1906, 272 tons.

CALIFORNIA is rich in copper mines. The first was opened in 1860. The local production of copper was 1,000 short tons in 1864, besides considerable shipments of ore to Swansea, Baltimore, and New York. The industry was closed from 1868 to 1896, when the "Iron Mountain" Copper Mine rose into importance. The high-water mark of production was reached in 1901, when it amounted to 17,000 short tons of fine copper. In 1905, the production of blister copper was 8,326 tons, and in 1906, 14,076.

In 1906, MEXICO produced 51,000 tons of fine copper, but it is doubtful whether any great proportion of this reached or affected the Pacific.

NICARAGUA has copper mines, but nothing has been done with them owing to adverse labour and transport conditions.

In COLOMBIA, copper was worked by the Spaniards for centuries, but the mines appear to be of no great importance, and are not now in activity.

ECUADOR has a little copper in conjunction with auriferous ores.

PERU has been a small producer of copper for centuries, but the output dwindled almost to vanishing point in the middle of last century, beginning to recover in 1895. In 1890, it was 150 long tons; in 1899, 5,165; in 1906, 13,474 metric tons of fine copper. The chief drawback is the difficulty of transport, and this will no doubt be overcome, as over £3,000,000 of United States capital have lately been invested in the industry.

In BOLIVIA, copper is associated with the silver and tin mines of Chlorolque (Potosi). The copper production of Bolivia advanced from 1,200 long tons in 1889 to 2,500 in 1899. It was 3,228 metric tons in 1906. At present the mines of Coro Coro are the most important. Copper was worked in Bolivia by the Incas, but the occurrence of the mines in the high cordillera and the want of railway facilities were disabilities which interfered with their competition in the markets with mines better situated. In 1906 an arrangement was completed between the Peruvian and Bolivian Governments for the construction of a railway from Arica (Peru) to La Paz (Bolivia), with a branch to Coro Coro. Most of the Bolivian copper is now shipped from the Peruvian port of Mollendo. Some goes to the Chilian port of Antofogasta. The total weight of ingots, precipitate, matte, and ore shipped from these two ports was 6,708 metric tons in 1905, and 4,347 in 1906.

CHILE produced in 1891, 19,875 long tons of copper; in 1899, 25,000 tons; in 1904, 32,926 tons; and in 1906, 29,626 tons. It was the largest copper producer in the world in 1875, but it now ranks after the United States, Mexico, Spain, Japan, and Australia. There are rich mines near the coast, Copiapo being the principal producing district, as well as in the Atacama Desert, 140 miles by rail from the port of Antofagasta.

The copper production of JAPAN has more than doubled since 1889. In 1906 it amounted to 38,515 long tons, and 245 tons of ingots were imported from Australia. The requirements of the country in the way of machinery and art probably absorb nearly the whole production and import, with, no doubt, a margin of manufactured copper for China.

KOREA has for many centuries been noted for its artistic work in copper and brass. In the matter of bell-founding the Koreans of the middle ages had attained a degree of perfection unsurpassed in Europe. At present Korea is only a small producer, the output of 1906 being 186 tons, but its undoubted copper resources may be expected to be vigorously developed by the Japanese.

There are many copper deposits in SIBERIA, but notwithstanding the facilities afforded by the Trans-Siberian Railway, nothing west of the Irkutsk and Trans-Baikal provinces is likely to find its way into the commerce of the Pacific. The entire production of Russia is estimated at 10,600 metric tons in 1906, and no great proportion of this amount can have been mined east of Lake Baikal. Several of the copper mines of the Trans-Baikal are understood to be promising.

The copper production of CHINA for 1906 has been estimated at 2,500 short tons, the most notable producer being the province of Yünnan, which is credited with one-half. Other producing provinces are Kiang Si, Kuang Si, Kwei Chow, Hu-peh, and Szechuan. The whole of the output, in addition to heavy imports, is required for domestic consumption. Australia contributed 373 tons of copper ingots direct to Chinese ports in 1906, besides 500 tons to Hong Kong; and in 1907, 2,030 tons of ingots to Chinese ports. From personal observation, I am inclined to believe that the copper production of China is seriously under-estimated abroad.

Shan-tung (German) and French Indo-China are known to possess copper mines, but their value has yet to be ascertained.

In FORMOSA (Japanese) the exploitation of copper may be said to have only commenced in 1906, and not much is yet known about its success. Ores of copper are associated with the gold mines in the Keelung district.

In the PHILIPPINES, the best known copper deposits are in Luzón, the northmost island. Here tetrahedrite was worked by the natives before the discovery of the islands by Spain, and almost continuously since by a Spanish company. Between 1864 and 1874, 1,116 metric tons were produced. Copper ores are also known in Mindanao Island, at the southern end of the group.

There are some undeveloped copper mines in the north of BORNEO.

NEW GUINEA may one day figure among copper-producing countries. An experimental shipment of 17 tons from a mine only 15 miles from Port Moresby, in 1906, gave 26·8=32 per cent. of copper; and in 1907, 135 tons of ore were shipped to Australia.

NEW ZEALAND has, so far, produced no appreciable amount of copper, but there are signs of development in the Northern Island. She imported in ingots from Australia, in 1906, 52 long tons; and in 1907, 115.

The AUSTRALIAN COMMONWEALTH (including Tasmania) ranks fifth among the copper producers of the world, being distanced, in the order named, by the United States, Mexico, Spain, and Japan.

According to British statistics ("Mines and Quarries"), the production of the various States in metric tons was as follows:—

	1905.	1906.
Queensland (copper)	7,337	10,239
South Australia (copper and matte) ...	6,814	8,539
,, (ore)	3,019	535
New South Wales (ingots)	8,090	9,108
,, (ore and matte) ...	640	804
Western Australia	2,427	7,549
Tasmania (copper and copper ore) ...	3,019	535

Given in the above form it is impossible to estimate the copper contents of the ore. In the reports of the Mining Departments of the various States, the following information is given, but it is regrettable that the statistics, not having been compiled on a uniform plan, cannot be compared or totalled.

Queensland gives the quantity of copper ore under the head of "Ore and Minerals won" as follows:—

1905.		1906.		1907.	
Long tons cwt.	Value. £	Long tons.	Value. £	Long tons cwt.	Value. £
7,220 15	503,547	10,077	916,546	12,756 5	1,028,179

South Australia gives the output of copper (including an estimate of copper contained in ore) for 1906 as 8,208 long tons, of the value of £718,609.

New South Wales gives the estimated production of copper as follows:—

Year.	Ingots, Matte, and Regulus.		Ore.		Total Value.
	Tons cwt.	Value. £	Tons cwt.	Value. £	£
1905	7,962 4	522,276	629 15	5,127	527,403
1906	8,964 0	781,645	791 0	7,882	789,527

Western Australia reports the amount of copper ore produced:—1906: 7,429·66 long tons; value, £50,337. 1907: 18,978·42 long tons; value, £180,387.

Tasmania gives the following information:—

Blister copper produced:—1906: 8,708 long tons; value, £862,444. 1907: 8,247 long tons; value, £832,691.

Copper matte exported:—1906-7: Nil.

Copper ore produced:—1906: 2,234½ long tons; value, £72,480. 1907: 788¼ long tons; value, £36,975.

The exports are given in the Commonwealth Statistics, without distinction of States, as follows:—

	1906. Long Tons.	1907. Long Tons.
Copper Ingots to—		
United Kingdom	10,207	9,304
Hong Kong	500	251
China	373	2,030
India	1,450	1,140
New Zealand	52	115
Belgium	2,579	3,145
France	1,275	1,239
Germany	1,449	1,224
Italy	192	296
Japan	245	1
Java	15	10
United States	40	4,384
Copper contained in matte to—		
United Kingdom	12,767	14,870
United States	6,453	4,141
France	26	14
Germany	32	62
Italy	48	...
Belgium	...	437

Copper ore to—	1906. Long Tons.	1907. Long Tons.
United Kingdom	1,628	6,842
Germany	34	555
Japan	10	28
Belgium	...	25
Italy	...	302

TIN.

The oxide of tin is distributed very unequally over the earth's surface, and its occurrence on the Pacific littoral is limited to a few localities.

The world's principal source of tin is what is loosely referred to as the Straits, comprising the Federated Malay States, Penang, and Netherlands-India.

The Federated Malay States produced, in 1905, 50,991 long tons of ore, estimated to contain 35,693 tons of metal; and in 1906, 48,616 tons of ore, equal to 33,131 of metal.

The imports (chiefly from Siam and Netherlands-India, but partly from Australia) amounted to 7,628 tons in 1905, and 8,078 in 1906.

The exports, omitting insignificant amounts, in long tons, were:—

	1905.	1906.
To England	31,512	34,434
Continent of Europe	8,492	7,437
United States	16,879	15,008
Netherlands-India	95	160
India	1,014	856
Japan	661	561
China	483	433

British Statistics ("Mines and Quarries") estimate the production of the British Straits Settlements for 1906 at 51 metric tons. In the Netherlands-India, Banca and Billiton produced ores containing:—

Banca Island.—1905, 8,979 metric tons; 1906, 11,744 metric tons.

Billiton Island.—1905, 4,164 metric tons; 1906, 3,851 metric tons.

Sinkep, a small island between Banca and the Malay Peninsula, produced—1905, 453 metric tons; 1906, 389 metric tons.

The *Straits* (by which may be understood the Malay States) sent—

	1906. Long Tons.	1907. Long Tons.
To Europe and America	57,143	52,520
India and China	1,292	3,140
Banca sold in Holland	9,286	11,264
Billiton sold in Java and Holland	1,968	2,229

Siam exported, in 1905 and 1906, 7,800 and 7,807 metric tons of tin ore estimated to contain 68 per cent. of metal.

French Indo-China sent 24 long tons of tin ore to Hong Kong in 1906.

Tin is mentioned as occurring in the Philippine Island of Negros.

China sent, in 1905, 4,462 long tons of metallic tin to Hong Kong, the product of the Ko Chiu mines in Yünnan.

Australia (including Tasmania) is the greatest producer of tin on the western side of the Pacific.

Tasmania, according to the Report of the Department of Mines, produced tin ore—1906; 4,473 long tons, valued at £557,266. 1907: 4,323 long tons, valued at £501,681.

Queensland produced tin ore—1906: 4,823 long tons, valued at £480,283. 1907: 5,140 long tons, valued at £496,766.

New South Wales produced ingots and ore—1906: 1,671* long tons, valued at £255,744. 1907: 1,914 long tons, valued at £293,305.

South Australia (Northern Territory) is credited with a production of tin ore of the value of £36,907, but the weight is not stated.

Western Australia produced, in 1907, 1,624 long tons of tin ore, valued at £158,648.

Victoria produced 108 tons of tin ore in 1906.

The exports of tin ingots from Australia is given in Commonwealth Statistics, without distinction of States, as follows:—

	1906. Long Tons.	1907. Long Tons.
To United Kingdom	5,086	5,629
Canada	122	...
New Zealand	118	...
Belgium	490	...
France	149	155
Germany	38	46
U.S.A.	498	176
Canada	...	86
New Zealand	...	151
Belgium	...	315
Italy	...	60

On the same authority, the export of ore is given as follows:—

	1906. Long Tons.	1907. Long Tons.
To United Kingdom	571	708
Straits	918	1,685
Germany	1,110	856

On the eastern shore of the Pacific, Alaska has deposits of stream and lode tin, but has not yet become a producer on any scale. The total output of the United States for 1906 was 1¼ ton (short) from Dakota.

British Columbia possesses deposits of both stream and lode tin, but does not rank as a producer of importance.

Bolivia comes next to the Malay States as a producer of tin. The Chlorolque mine, Potosi, is 18,000 ft. above the sea, and has both stream and lode tin associated with silver, copper, zinc, and lead. The whole tin mines of the country produced and exported from Antofagasta and Mollendo, tin ingots and ore (the ore reduced to estimated metallic contents):—

Metallic tin, 1905, 26,424 metric tons; 1906, 29,374 metric tons.

Bolivia sent 16,394 tons to England in 1906 and 15,500 in 1907. The bulk of the product goes to England and Germany for reduction.

* British Statistics give "Ingots, 1,180, and ore, 518 metric tons."

The aim of every nation is to produce by its own efforts those commodities with which Nature has endowed it in sufficient quantities to supply its own wants, and to leave a surplus which can be exchanged for such commodities as are only obtainable, or are obtainable at less cost, from abroad.

In the production of coal, it has been seen that the United States far excels all other nations. Her principal coalfields, however, are so situated that they chiefly serve to supply the internal demands of the country, and to a great extent those of Canada, besides a considerable surplus to spare for the Atlantic ports of South America. They do not, however, send any great amount of coal into the Pacific, except along the American coast line, and none at all across the Pacific. It would be easier for the States to send coal to Europe or Africa than to Australia, Japan, China, or India, and, as we know, none goes in that direction. On the contrary, the Pacific States import coal from Australia, and even from Japan. Crossing an ocean with a cargo is less costly than crossing a continent, and this is more and more the case the less the intrinsic value of the article.

British Columbia, from her proximity to San Francisco, will always be able to enter that market and to supply Alaska with as much of her coal as she can spare; but the quality of her coal will prevent her becoming a formidable opponent of Australia and other Trans-Pacific producers. Coal mined in the interior of British Columbia finds a sufficient demand among the neighbouring smelters to prevent any great surplus reaching the Pacific coast for export purposes.

Mexico, Nicaragua, Columbia, Peru, and Chile have coalfields which supply local requirements to some extent, although they have in most cases to be supplemented by imports from Australia. Chile sends some coal to San Francisco.

Japan produces at present a tonnage of coal amounting to nearly half as much again as all Australia, and exports 16 per cent. of its output, China, Singapore, and California being her best customers. Considering the manifest destiny of Japan to become a manufacturing country, and the inferiority of her coal, I am inclined to believe that at no distant date she will not only consume all her own coal, but will be a great importer, at first from Australia, where the best of the coalfields are situated near the coast, and ultimately from China, when the coalfields of that country have obtained free access to the seaboard.

Australia and China are the only serious competitors for the coal trade of such Pacific countries as cannot meet their own requirements. Australia can easily supply her own needs, and the surplus she can export is limited only by the producing capacity of her population, on the one hand, and the demands of foreign countries on the other. China produces coal enough for the requirements of the interior, but owing to the expense of land carriage finds it an economy to import coal from Japan and Australia to its own seaboard. This will not long be the case, as the extension of railways is rapidly setting in. The circumstance of the almost entire denudation of timber in China ensures a demand for coal for every purpose for which wood is employed as fuel elsewhere, and the demands of her teeming population, however economically inclined, must be enormous. An inexhaustible supply of hands will enable China to produce a large surplus of coal for exportation as soon as railway communication has enabled her to overtake the supply of her own coast. When the day of equal opportunity arrives, China will be as favourably situated as Australia for access to Californian markets, and Australia will only have a slightly better position with reference to the markets of Pacific South America

The low value of iron ore precludes the possibility of exporting it to great distances, and brings about the anomaly that even countries possessing immense deposits of it must rest content for a time to purchase and import from abroad the greater portion of their requirements in the more valuable form of manufactured iron and steel.

The possibility of any country ever becoming a great manufacturer of iron and steel goods depends upon the mutual accessibility of unlimited coal and iron ores to one another. These conditions are almost, though not quite, fulfilled in Australia. As for China, the important factor of the supply of the iron ore is by no means certain. It is true that she has hitherto mainly supplied herself, at least as far as the interior is concerned, and the fact that she has even exported iron ore in considerable quantities to Japan, in spite of the low value of the article and the great expense of land carriage, argues that she is endowed with large supplies. But, when she takes to manufacturing her own railway and ship-building steel, there is no information available to the outside world to show whether her resources are equal to the task. If they are, all that can be said is that the opportunities of a country with 400,000,000 inhabitants immensely outclass those of a country with 4,000,000. If they are not, then Australia will have an opportunity of supplying China with her own surplus production as soon as she can muster hands enough to produce a surplus over her own requirements.

There is little chance of either Australia or China exporting manufactured iron or steel to America or Europe, unless in the far distant future some almost unimaginable alteration in conditions should enable either immensely to undersell the manufacturing countries of to-day, but whichever of them can produce cheaper will send its surplus to the other.

At present there is little interchange of copper or copper ores across the Pacific. A few years ago a considerable amount of rough copper went from Australia to America to be electrolytically refined, but this is coming to an end. The great bulk of the copper produced in Australia goes direct to Europe in the form of blister or fine metal, and the remainder is high-grade ore. The large output of Mexico finds its outlet mainly by the Atlantic or into the United States. That of Peru will probably go in the future chiefly to San Francisco. That of Chile finds its way to Europe or the western States of North America, without affecting the commerce of the Pacific. Japan for the most part consumes her own production, with a small surplus for export to China. China consumes all her own and a good deal of imported copper.

When Australia, Japan, and China, or one or other of them, manufacture their own iron and steel, the industries depending on copper will follow the same course.

The greatest of all tin producers, the Straits, does little business in the Pacific beyond a comparatively small export to China.

Bolivia, the tin-producer next in importance to the Straits, gets its product out of the Pacific by the shortest available route, chiefly to England and Germany.

With the exception of about 10 per cent. to the United States, Australia sends the whole of her product to Europe in the form of ingots or "black ore," and only uses the Pacific coast as the shortest way out. The prospect of Australia becoming a manufacturer of tin goods depends, as in the case of copper, upon the future course of the iron and steel industry.

The facts and figures cited lead me to conclude that, apart from outside disturbance, the industrial future of the Pacific littoral will fall to be divided among Australia, China, and Japan. Australia and China will take their share by virtue of the natural resources with which they have been endowed. Japan will share, partly for the same reason, but still more because of the energy of her people and her advantageous geographical situation. In the last-named respect she presents a remarkable analogy to Great Britain, in the easy command of foreign raw material and in facilities for the distribution of manufactured goods among the markets.

The present state of China is one of transition. Hitherto the Chinese have "honoured their father and their mother" to such a degree that the observance, by a process of reasoning in which the Western fails to follow the working of the Eastern mind, has degenerated into what we call ancestor worship. Their peculiar system of logic has convinced them that one who seeks to know more than his father knew dishonours that father. Hence, they have, for centuries past, stood still, or even retrograded, for there is always the chance of omitting to learn, or of forgetting, something that one's father knew—while other nations learned new lessons and left them far behind. In short, their ancestor worship is a virtue run to seed.

Much has been said and written about the cerebral difference between East and West. It is true enough that the East and West do not always reason along the same lines. The difference is even more marked than that which distinguishes the mental processes of the Celtic and Saxon races, but it is a difference in degree rather than in kind, and increased communication between races invariably leads to mutual understanding.

It may be pointed out that it is barely the life of a generation of men since Japan seemed every whit as unlikely to forsake her policy of isolation as China seems to-day, or seemed a few years ago. But now, as we know, Japan has learned nearly all that the West has to teach, and has in many instances even bettered her instruction. It is unquestionable that what Japan has done China can do, whenever she chooses to adopt a progressive policy. No unprejudiced observer would contend that the Chinese individual is mentally the inferior of the Japanese.

Under the conditions of modern civilisation it is impossible for every man to "go on the land," and "on his proper patch of soil to grow his own plantation." If he did, he would relapse into barbarism or still more likely perish for want of the thousand and one requirements which civilisation has made as necessary to him as food itself.

The tilling of the soil must be left to specialists, while others fabricate for the husbandman the tools of his trade, others carry the food to the millions of empty stomachs, and still others make and others carry the further requirements of the complex life of civilisation.

Under such conditions, it will be said, the Chinese will have an unanswerable advantage in competition in the Pacific. It is a common saying that a Chinaman can "live on the smell of an oil rag," and, therefore, can afford to work for wages on which a white man would starve. This is a popular fallacy. The truth is that in China "going on the land" is overdone, the result being a widespread dead level of poverty, and that here in Australia the Chinese of whom we see most are those who take up industries which white men avoid as unremunerative, and who must of necessity practise severe economy. In fact, the Chinaman who lives on the smell of an oil rag does so because necessity compels him. The Chinese thoroughly understand the philosophy of the proverb that the man

". . . will never go bare,
Who knows when to spend and when to spare."

Whenever a Chinese can afford it he spends liberally, and even lavishly, on comforts and luxuries.

When there comes to be a brisk demand in China for workmen for those industrial arts which depend on the use of metals, there is no doubt in my mind that wages will speedily rise to the level they have reached in other countries. The West has nothing to teach the East in the tactics of trades unionism, and the Chinese craftsman, as soon as his services are sufficiently in demand, will insist on being taken at his own valuation, like his brothers abroad. For this reason, I venture to predict that in a short time wages in the industrial arts throughout the world will be so levelled up that competition between nations will, so far as wages are concerned, be carried on on fairly equal terms.

I believe that China is the last country in the world to desire to occupy by force any territory belonging to others; but a natural law will bring her surplus products into the markets of the world, and especially of the Pacific. She will not need to go abroad, but will sit at home, as others must, and offer what she can produce beyond her own needs in exchange for exotic commodities.

When this free trade ideal has been universally attained, the necessity for a greater population in Australia will be brought home to Australians with a force transcending that of academic argument. Face to face, on equal terms as regards wages, with a competitor whose industrial army has a hundred possible recruits to draw upon to her one, economies—in other directions than wages—denied to her are within the reach of the competitor with the larger population, while they are unattainable to the one with the smaller. It is devoutly to be hoped that before the foreshadowed changes have taken place Autralia will have a population approximately adequate to the exploitation of her natural resources.

I have intentionally confined my attention to the countries forming the shores of the Pacific. But the Pacific is no *mare clausum* either for peace or war. We have seen that the introduction of manufactured articles—even when the raw material originally came from the Pacific—is not only a possibility but an undeniable fact. This is made possible by the superior facilities for manufacture enjoyed by American and European countries, and by the comparatively cheap rates which shippers on a large scale can command in the freight market. In many lines freight costs less from Europe to Australia than from one Australian port to another— a further illustration of the luxury of economy being beyond the reach of those who need it most.

The completion and opening of the Panama Canal (in six years, it is said—let us say twelve at most) will profoundly modify existing commercial conditions, by giving the manufactures of the western States of America access to the Pacific. Before then, however, the industries of Australia, China, and Japan will have had the chance to establish themselves on a firmer basis.

The disturbing influences of war are simply incalculable, and they are beyond the scope of the present inquiry. It used to be held as an axiom that "trade follows the flag," a euphemistic method of stating that if any country can succeed in planting her flag on alien soil new markets will be opened up for the aggressor. In recent times it appears as if the axiom might have to be reversed, and that the modern tendency is for the flag to follow trade. The next and last phase will be, let us hope, a frank recognition of the fact that all men and all nations may live in peace and brotherhood, and vindicate their right to exist by performing services for one another. If, however, Australia is to bear a part in this give-and-take commensurate with her natural advantages, she must look, and that speedily, to the peopling of her vast void spaces.

2.—SOUTH AUSTRALIAN EARTHQUAKES.

By D. F. DODWELL, B.A.

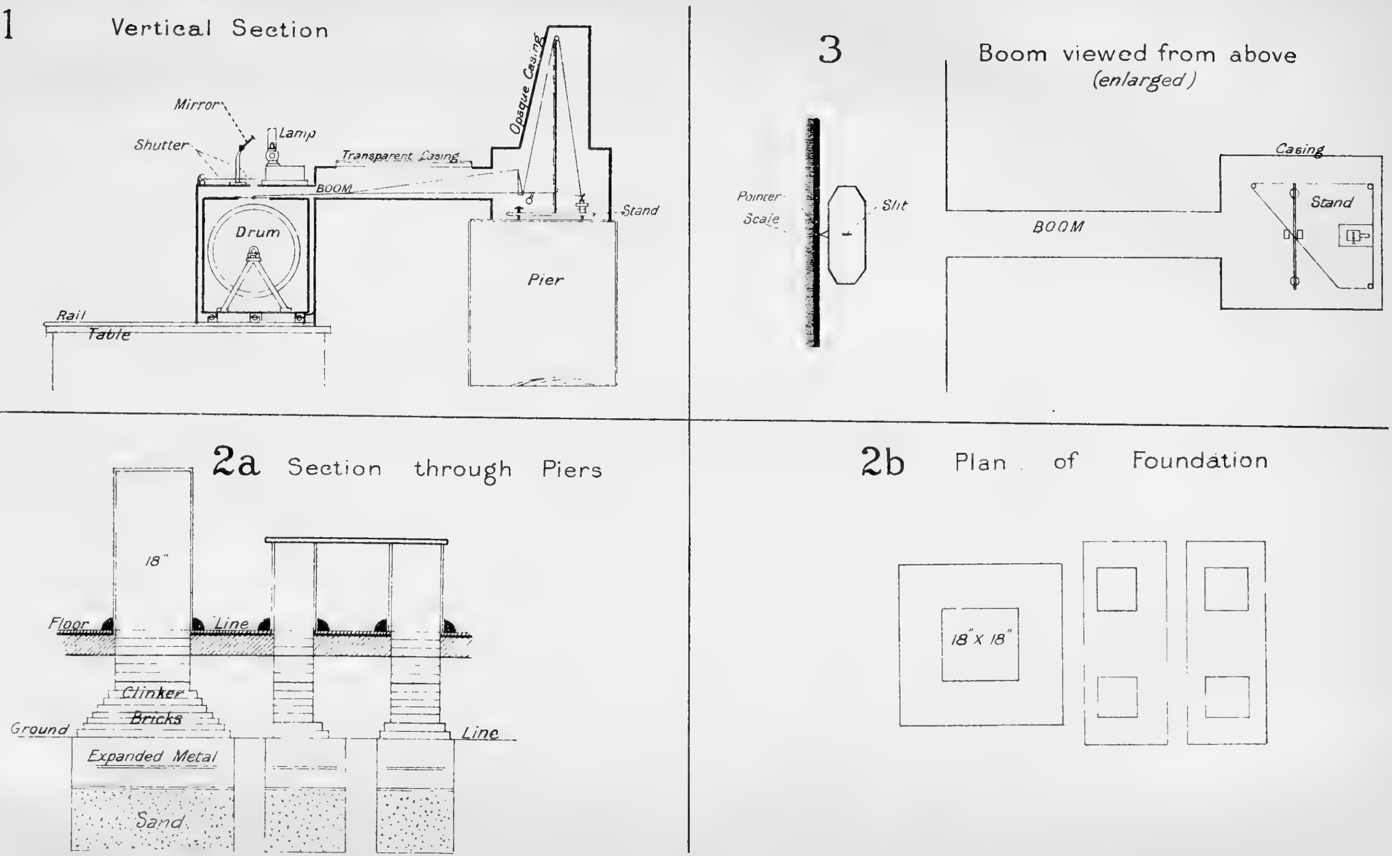
Until 1908 South Australia possessed no instrument for recording earthquakes. As long ago as 1897, however, Professor Milne had communicated with Sir Charles Todd, the Government Astronomer, and in the following year the Seismological Committee of the British Association for the Advancement of Science urged our Government, through Mr. Chamberlain, then Colonial Secretary, to instal Milne seismographs at Adelaide, Port Darwin, and Alice Springs.

This request was further supported from time to time by the resolutions of the Australasian Association, but it was not until 1908 that one of these instruments was actually purchased and installed at the Adelaide Observatory.

It will be gratifying indeed if the recommendations of the British Association for the instalment of seismographs at Port Darwin and Alice Springs can also be carried into effect, and it is hoped that the Australasian Association will continue to use their influence to bring this about.

The Adelaide seismograph is a horizontal pendulum instrument, made by Mr. R. W. Munro, of London, after Professor Milne's latest pattern. It was examined personally by the inventor, and tested under working conditions in London.

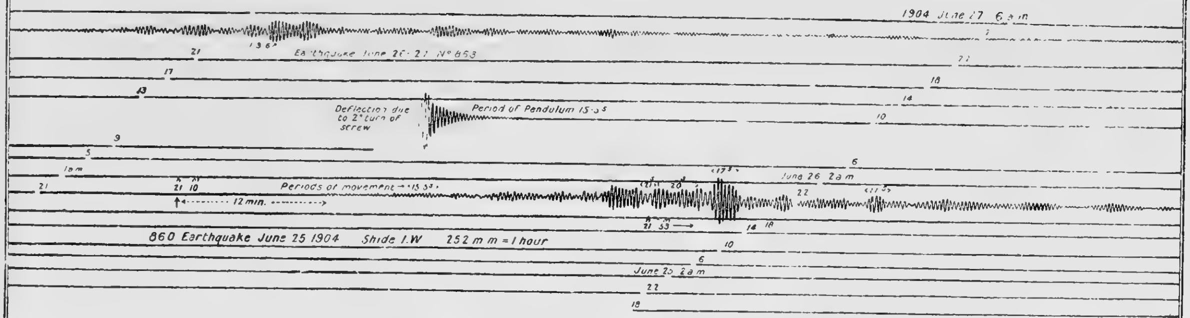
SEISMOGRAPH AT ADELAIDE



A Seismograph Record (Reproduced)

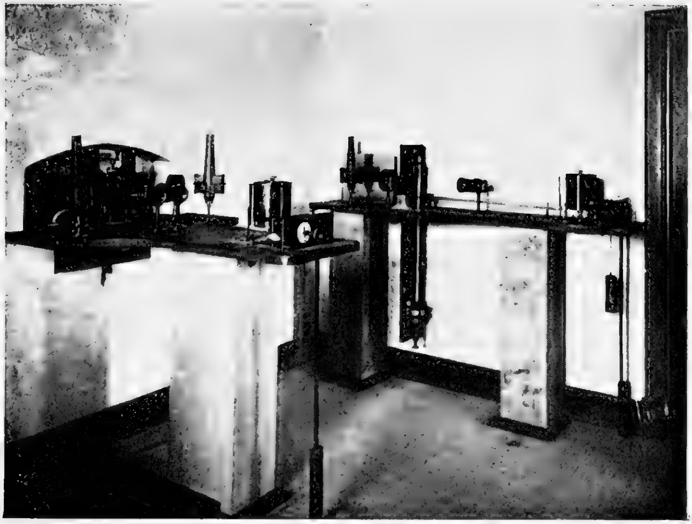
British Association 74th Report, Cambridge 1904.]

[Plate I



860 Earthquakes June 25 1904

Illustrating the Report on Seismological Investigation.



Thermograph. Barograph.

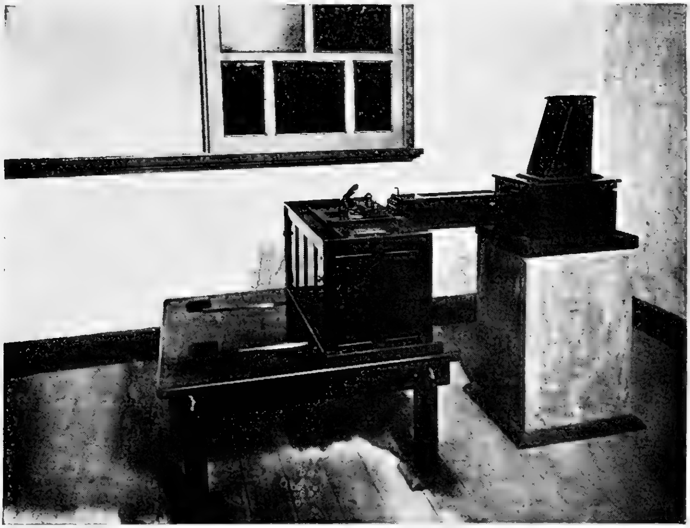
PHOTOGRAPHIC THERMOGRAPH AND BAROGRAPH (INSTALLED IN THE SEISMOGRAPH-ROOM AT ADELAIDE).

THE SEISMOGRAPH HOUSE AT ADELAIDE OBSERVATORY.

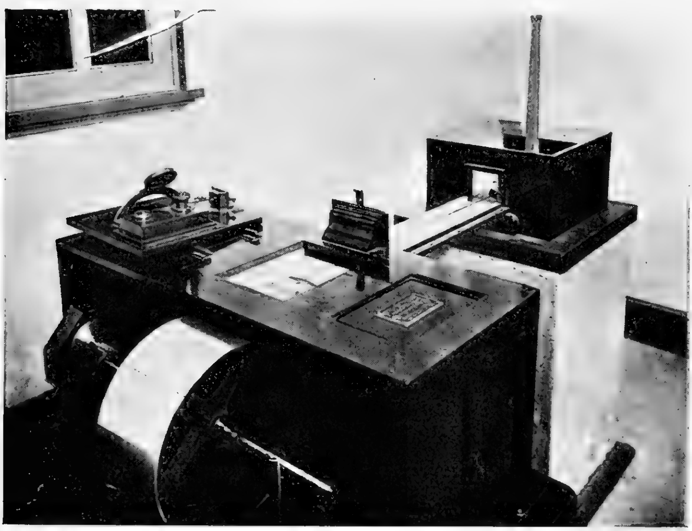
The building contains the Milne Seismograph, and Photographic Barograph and Thermograph. The bulbs of the thermometers of the Thermograph project through the southern wall, sheltered by the "Stevenson Screen" seen in the picture.

Another View of the Adelaide Seismograph House.

From the galvanised-iron hut seen on the left Professor Bragg sent the first long-distance wireless telegraph message in Australia.



Flashlight Photograph of the Milne Seismograph at the Adelaide Observatory.



The Seismograph Uncovered, Showing the Various Parts of the Instrument.

Professor Milne wrote of it:—"I found . . . much to admire. In some directions the instrument embodies improvements on its predecessors. I have examined two sheets of records it has given, and on one I find a large earthquake, *the first, so far as I know, automatically recorded in London.*"

Our seismograph has, therefore, something of historic interest attaching to it. A brief description may be here not out of place:—

The seismograph consists essentially of two parts, (1) that which is sensitive to the earthquake waves, (2) that which records these waves.

The part which, so to say, "feels" the earthquakes is a light aluminium boom or horizontal pendulum, suspended from a short steel upright bar, and swinging to and fro on a pivot at the bottom of this bar. The bar itself is part of an iron stand which rests on a brick and concrete pier going down some distance into the foundations of the building, and quite separate from the floor, as shown in Diagrams 1 and 2.

The boom is balanced by a weighted cross-bar, and supported by a thin silken tie to prevent sagging. Its free end bears a lozenge-shaped plate, shown in Diagram 3, in which is a slit which is just above and at right angles to a slit in the box covering a revolving drum—the recording part of the seismograph. Upon the intersection of these two slits light from a small lamp is reflected by a mirror, as seen in Diagram 1, and makes a straight line when the pendulum is at rest, and a wavy line when it moves (as it does when an earthquake wave reaches the pier) upon the photographic paper on the drum. Sudden and short deflections are, however, occasionally caused by the presence in the box of an "undesirable immigrant," such as a spider.

The recording arrangement in the Adelaide seismograph is a new and improved one. The light cylinder is mounted on a steel spindle, one of the projecting ends of which has a deep-threaded spiral, on which the drum advances 6 millimetres for one turn in four hours by gear connection with a clock, so that the bromide paper on the drum need only be changed once in four days. Another advantage is that only half the quantity of paper required for the original recorder is needed for this one; moreover it is easier to inspect and store the records, to recognise slight tremors, and to measure wave periods.

The time is marked hourly by an electro-magnet, connected with the clock, moving a shutter on its armature across the slit in the box for a period of a few seconds.

Some of the ends in view in the installation of the seismograph may be told in Professor Milne's own words:—"To determine the velocities in which motion is propagated round and possibly through the earth; to determine the foci of submarine disturbances, such as those which have interfered with ocean cables; and to throw new light on changes taking place in ocean beds."

It is to be hoped that the Australian contribution to this research may be a worthy one.

The photographs of the Adelaide seismograph which accompany this paper will serve to illustrate the description given.

Appended herewith is a list of earthquakes in South Australia since November, 1903, the last date for which the records have been published by the Australasian Association for the Advancement of Science.

These records are necessarily incomplete. They are principally the reports of postmasters, a body of men to whom, I may say, we owe a very great deal for their observations of natural phenomena, especially those relating to meteorology. There are, however, such large areas of South Australia which are sparsely populated, and still larger stretches of country in the interior quite uninhabited, that many earthquakes must have occurred without having been perceived, and probably many which have been perceived, especially those of the feebler kind, have remained unreported.

From the available information, which may be regarded as fairly representing the earthquake phenomena over, at all events, the settled portions of the State, we note that the South Australian earthquakes during the period 1903 to 1908 were few and of small intensity. Their distribution, as is indicated by the accompanying maps, coincides with that of quakes and tremors recorded during the last quarter of century.

On the maps, where the different colours denote different geological formations, localities where earthquakes and tremors have been reported are marked in black, and the shading of the black on these maps, according to its lighter or deeper tone, illustrates the relative frequency of seismic disturbances.

In the last twenty-seven years the greatest number of reported earthquakes is at Beltana, which is situated in the hilly country east of Lake Torrens. This locality reported twenty-six more or less severe tremors during this period.

Blinman, not far distant, reported twenty during the same period.

Kapunda and Eudunda, in the Murray Range district, 30 to 40 miles east of the head of St. Vincent's Gulf, reported twenty-two and twenty-one respectively.

An average of one earthquake per year, or less, in our districts of greatest seismic movement cannot be considered very formidable.

The only two moderately severe earthquakes noted in this State were those of 10th May, 1897, and 19th September, 1902. These are specially indicated on Map II. Both, but particularly the 1897 quake, were followed by many after shocks in districts near the epicentre.

In connection with the 1897 earthquake, tremors in the vicinity of Kingston, on our south-east coast, continued at intervals for some months, and all appeared to point to a focus in the ocean somewhere westward of that neighbourhood.

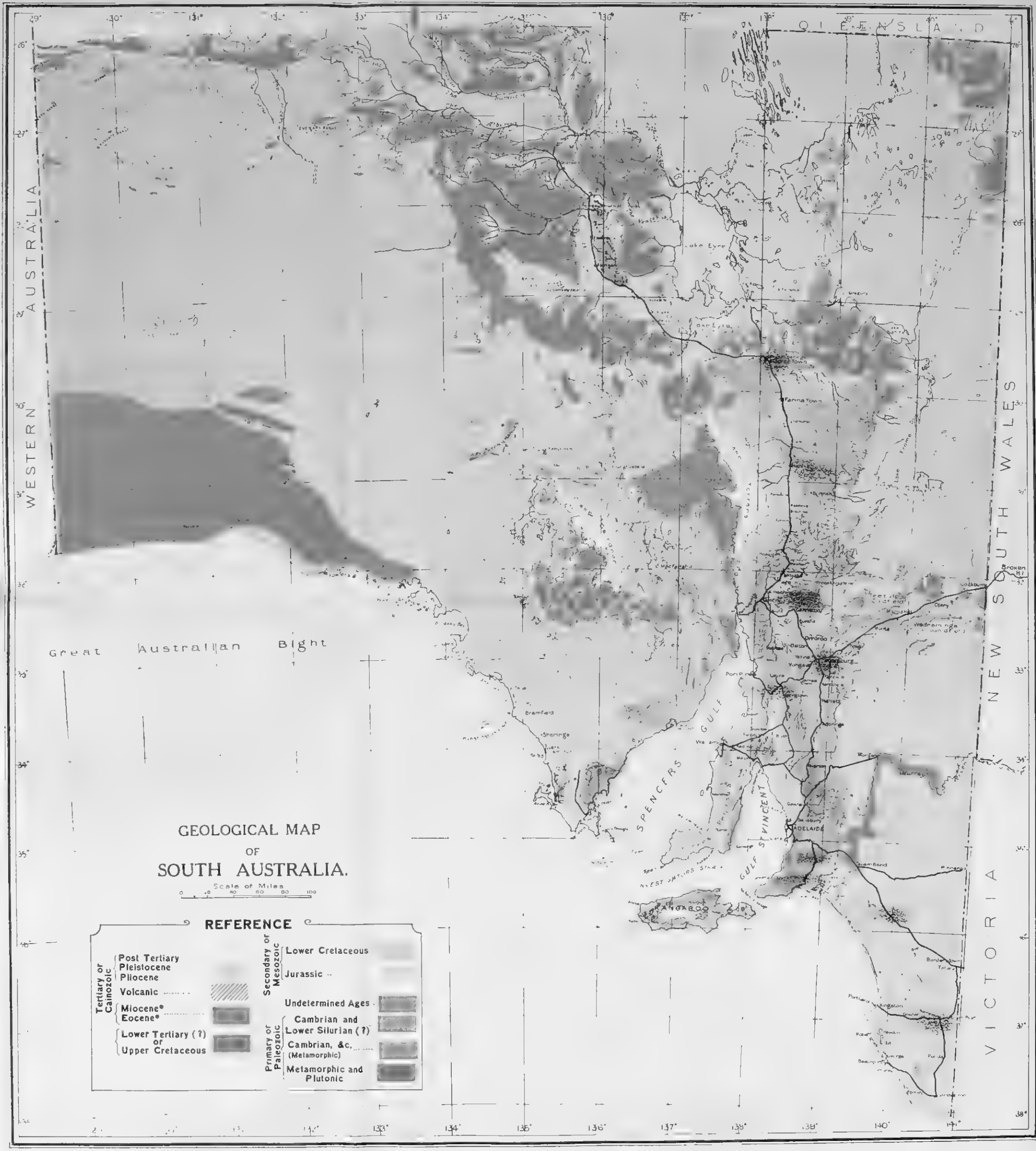
It has, therefore, been more convenient to indicate the whole of the area affected by this and the 1902 earthquake by black stipple marks.

Both these earthquakes showed a large epicentral area, and were felt far and wide in all directions. They were recorded from Streaky Bay on our west coast, right across to Victoria.

Most of our seismic disturbances, however, have been of a comparatively small intensity, on the average from IV. to V., on the Rossi Forel scale, and, with few exceptions, were not felt very far from the centre of movement.

MAP I Showing Earthquake Distribution 1903 to 1908.

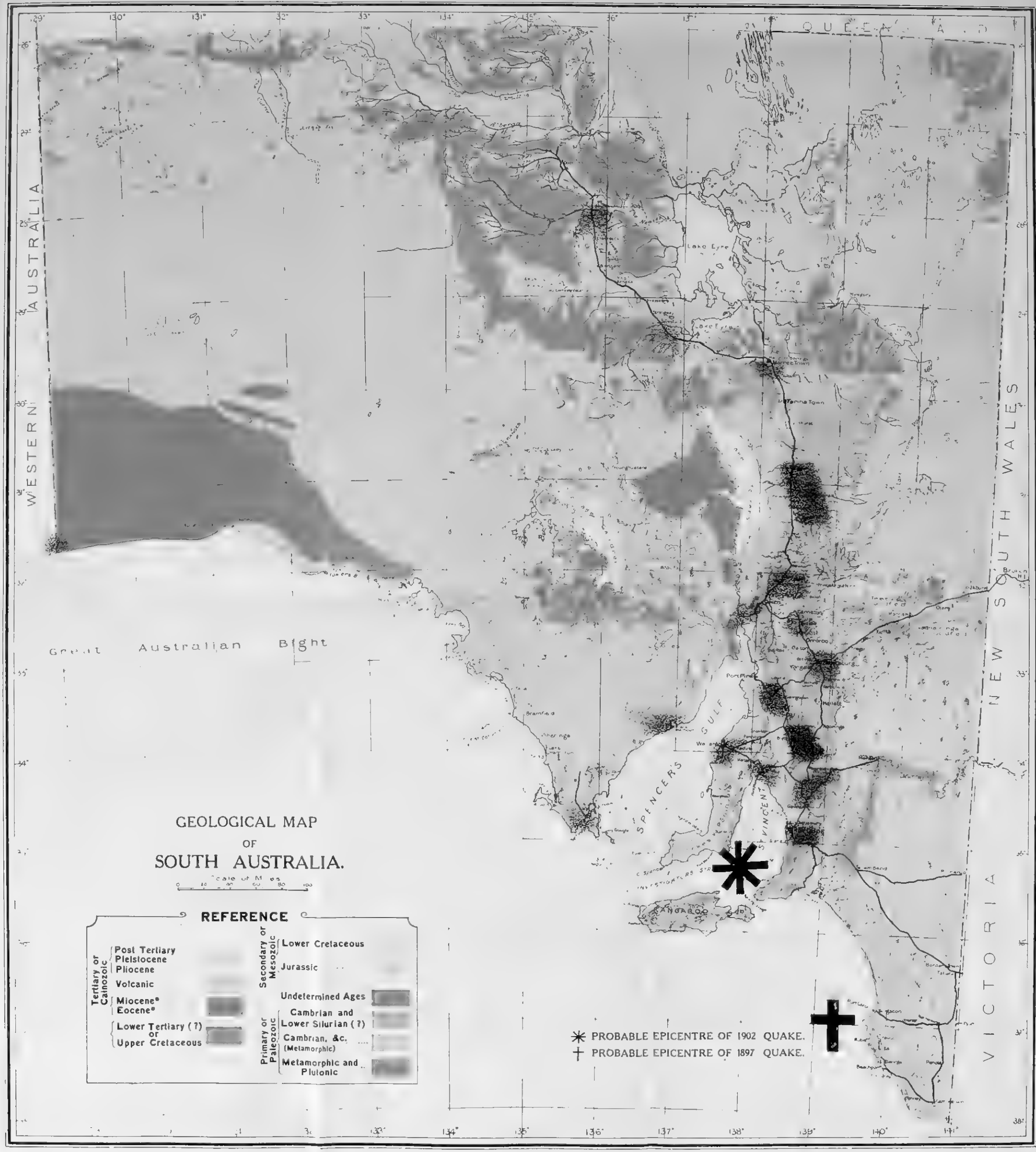
(EARTHQUAKES SHOWN IN BLACK).



MAP II Showing Earthquake Distribution 1882 to 1908.

(EARTHQUAKES SHOWN IN BLACK).

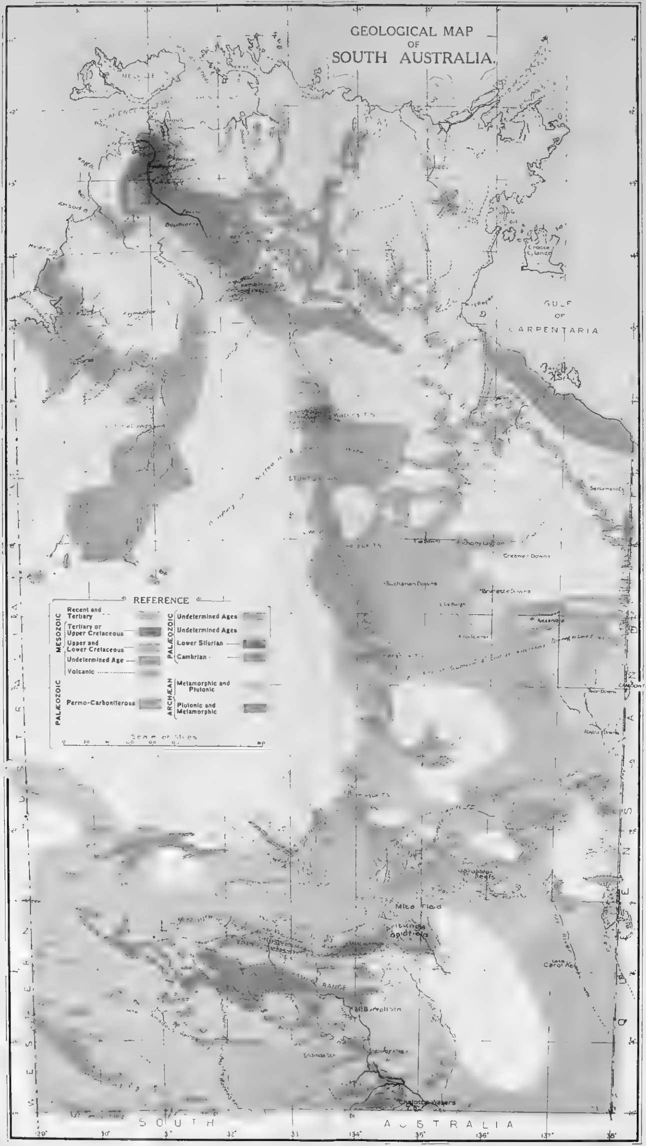
The dotted areas indicate regions affected by the Earthquakes of 1897 and 1902).



MAP II (a) Showing Earthquake Distribution in Northern Territory, 1882 to 1908.

(EARTHQUAKES SHOWN IN BLACK).

Note.—No Earthquakes were reported from the Northern Territory during the years 1903 to 1908.



South Australian earthquakes appear to illustrate very well the general laws enunciated by De Montessus de Ballore, who may be regarded as one of the best authorities on seismic geography—viz., that:—"Most earthquakes occur where the variations of topographic relief are greatest. (1) The most unstable regions are the most pronounced general slopes, the short and steep flank of a chain being the most unstable. (2) The unstable regions are associated with the great lines of corrugation of the terrestrial crust, either emerged or submerged."

Our South Australian recorded earthquakes seem to occur principally in the hilly and mountainous country east of Spencer's and St. Vincent's Gulf, extending northward to the Lake Torrens district.

In the geological map on which they have been marked this country is coloured slaty grey, and the rocks are principally clay slates, calcareous clay slates, shales, sandstones, quartzites, grits, conglomerates, limestones, dolomites, and kindred rocks, with granitic and other igneous dykes, lodes, and mineral veins. They are metalliferous rocks of the Cambrian, and perhaps Lower Silurian, period.

Lying uncomformably on them, and forming the bulk of the surrounding country, are the following formations, which are marked pale green on the map:—

Blown sand of the coast and interior, sand, clay, loam, gravel, marl, gypsum, mud, salt, travertine, and shell-limestone, calcareous, and peaty deposits of springs and swamps, sandstone, limestone, conglomerate, gravel, and boulder drifts, and kindred deposits.

Alluvial deposits, auriferous cement, and "deep leads" of the goldfields.

Lignite deposits. Limestone, clay, sand, calcareous sandstone, limestone conglomerate, and breccia of the coast.

These are formations of Post Tertiary, Pleistocene, and Pliocene ages, for the most part sedimentary deposits laid down on the ocean floor.

A large proportion of our earthquakes have been felt off the borders of these unconformable rocks. The character of the isoseismal lines of the 1902 earthquake in the whole of the districts east of St. Vincent's and Spencer's Gulf marks this region as one more delicately sensitive to seismic vibrations than other parts of our State. (*Vide* Map IV.) The question arises: What is the probable cause of our earthquakes? Our tremors seem to resemble in kind, though not in degree, quakes resulting from the dislocation of great masses of the earth's crust, like that of Bengal and Assam in June, 1897, when remarkable faulting took place, relative changes in the heights of hills as great as 24 ft., and changes of 12 ft. in their horizontal distances having been observed.

Investigations of the phenomena of this earthquake by the India Geological Survey Department showed:—

(1) "The absence of any strict epicentre, shocks of Number X intensity (Rossi Forel scale), being felt over about 6,000 square miles.

(2) "The great extent of the country affected, the shocks being distributed over an area of 1,750,000 square miles.

(3) "A notable number of after shocks, the great quake being followed by repeated shocks of less intensity than the primary one."

Having due regard to the proportion of the force producing that powerful disturbance (the greatest then recorded), to the force producing even the most widespread of South Australian tremors, one cannot fail to note, in the latter as in the former, these three main features; and the geological conformation of the country affected supports this view—younger beds lying unconformably against the mountain ranges, as previously mentioned.

In South Australia no dislocations visible to the eye have been found accompanying earthquakes; but the line of fault may lie in the direction of Lake Torrens, Spencer's Gulf, and St. Vincent's Gulf. The raised beaches of our coast are evidence of former small and sudden uplifts; and it is quite conceivable that such movement is going on to-day.

The great Calabrian quake of 1783, which shook all Sicily, and which has found a parallel in the terrible catastrophe that so recently again devastated those unhappy regions, was plainly a tectonic or dislocation disturbance.

Earthquakes clearly attributable to eruptions of Mount Etna, though violent near that volcano, have seldom been strongly felt across the straits in Calabria.

The geography and geology of the district, as well as the seismic records, show that this is one of the regions illustrating De Montessus de Ballore's general laws previously quoted.

Professor George Darwin's thesis (Proceedings of the Royal Society, June, 1881) gives some idea of the stresses caused by the transfers of load. The age-long denudation of the Mount Lofty and similar ranges, with the consequent deposit in our Gulf of the removed material, producing cumulative alterations of pressure and gravitation, may cause stresses and stress-differences sufficient for sudden down-thrust of the area of sedimentation and uplift of the denuded regions (about a local line of pivoting?).

Professor Gregory, writing to Sir Charles Todd, had little doubt that the shock of 1902, concerning which Sir Charles wrote a paper for your Association, was due to foundering under either St. Vincent's or Spencer's Gulf like the 1897 earthquake. The epicentre of the former was indeed, by all appearances, in St. Vincent's Gulf near the foot of Yorke's Peninsula, and that of the latter, the 1897 one, was off our south-east coast, in the vicinity of Kingston and Robe, (*vide* isoseismal Maps III. and IV.).

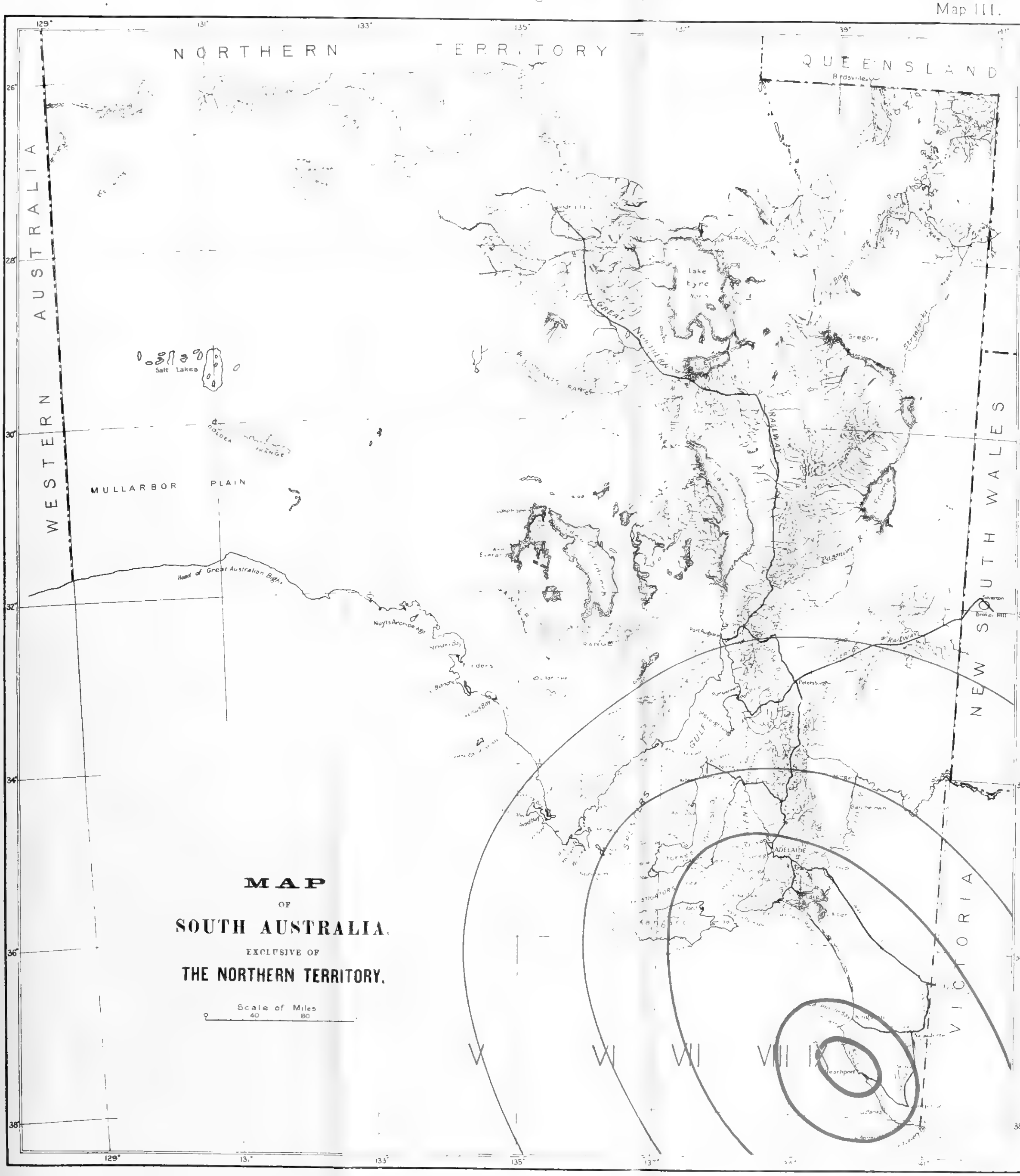
Similar causes have been, and still are, operating on both sides of Bass Strait, and Professor David considered that "further cracking of the earth's crust might have caused the bed of the gulf to still further fall at the point where it meets the Mount Lofty Ranges, or it is possible that that point of the range may have been squeezed up." (The "Register," 23rd September, 1902.)

Isoseismals. Earthquake of 10th May 1897.

(Reproduced from Map by Mr Geo. Hogben)

Note the direction of the lines in the ranges East of the Gulf

Map III.

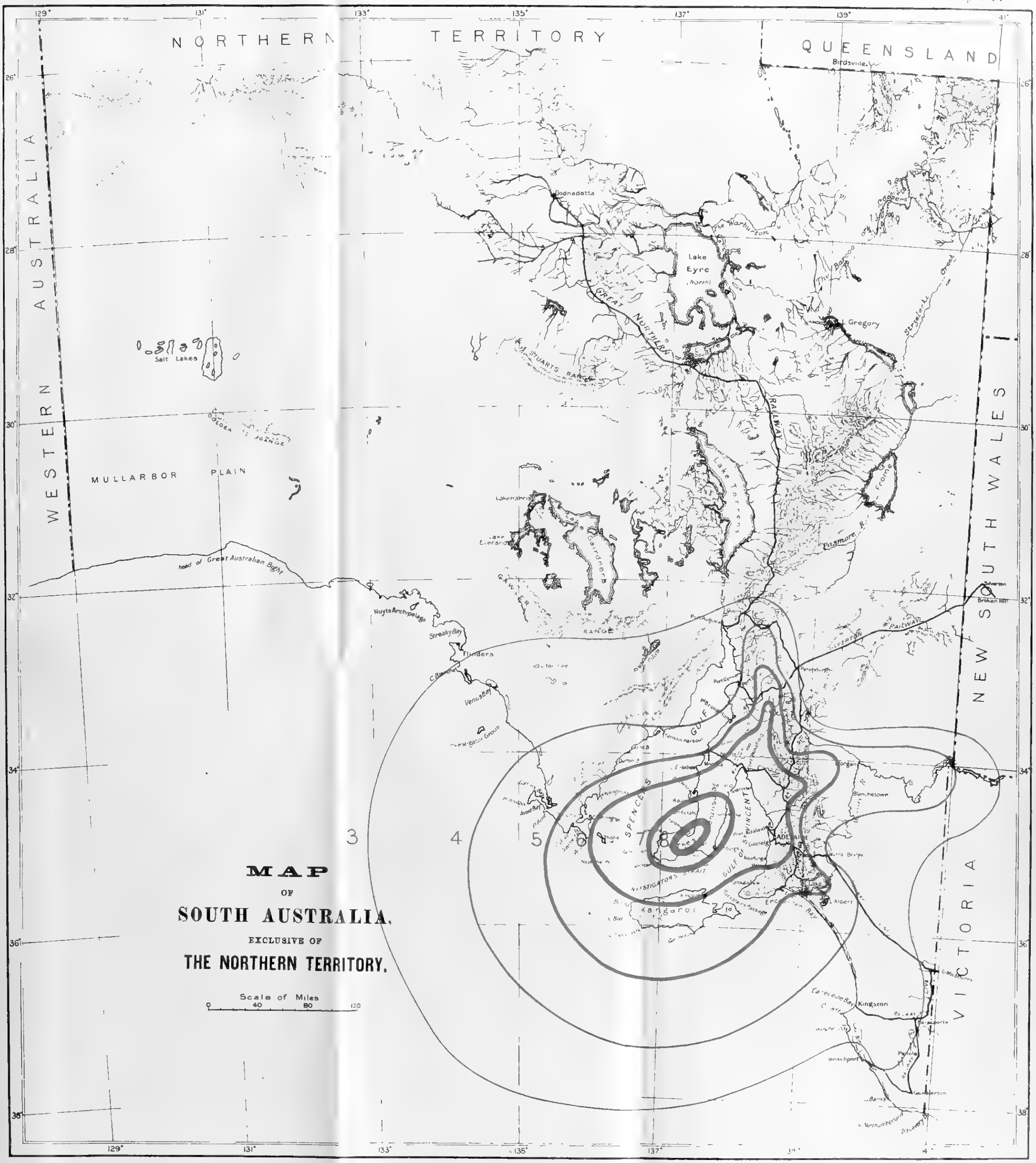


Isoseismals. Earthquake of 19th Sept. 1902.

(Reproduced from Map by Sir Charles Todd)

Note the direction of the lines in the ranges East of the Gulfs

Map IV.



The conclusion of the whole matter seems to point to a tectonic origin for South Australian earthquakes.

Date.	Name of Place.	Time of beginning of Shock, Adel., S.T., 9·30°E. of G.	Apparent Direction.	Apparent Duration.	Effect. Remarks.
1904. 6 April	Mylor	9·20 p.m.	N.W. to S.E.	...	Sharp shock, accompanied by long rumbling.
6 ,,	McLaren Vale ...	9·20 p.m. (about)	N.W. to E.	...	Slight shock.
6 ,,	Clarendon ...	9·14 p.m.	W. to E	10 secs. (about)	
6 May	Red Hill	6·22 p.m.	N.W.	10 secs. (about)	Slight tremor.
21 Sept.	Hawker	11·15 p.m.	N.W. to S.E.	10 secs. (about)	Sharp shock. Many persons were awakened by terrific noise resembling loud thunder. Distinct vibrations, continued 20 to 30 seconds. Shock most severe ever experienced.
21 ,,	Carrieton ...	11·10 p.m.	S. to N.	30 secs. (about)	Slight.
21 ,,	Wilson	11·15 p.m.	N.W. to S.E.	10 secs. (about)	A heavy shock.
21 ,,	Blinman	11·30 p.m.	moving S.	5 secs. (about)	Slight earth shock.
1905. 24 Feb.	Carrieton ...	2·31 a.m. (about)	N.E. to S.W.	10 to 20 secs.	Buildings considerably shaken. Rattling crockery.
24 ,,	Bendleby ...	2·30 a.m.	...	...	The most severe earth shock ever experienced here. Pictures shaken off the wall. After shock three distinct rumbling noises resembling distant thunder were heard.
22 Aug.	Auburn	4·7 a.m. (about)	N.E. to S.W.	35 secs.	Sharp. Buildings shook. Previous tremor.
22 ,,	Greenock ...	4·4 a.m.	...	15 secs.	Felt like a sharp jerk and then a rumbling.
22 ,,	Manoora	4·5 a.m.	S.E. to N.W.	15 secs.	Windows rattled.
22 ,,	Angaston ...	4·8 a.m.	S.E. to N.W.	10 secs.	Sharp. No previous tremors, but loud rumbling heard just before and after.
22 ,,	Port Wakefield ...	4·5 a.m.	...	15 secs.	Sharp; previous tremor at 3 a.m.
22 ,,	Freeling	4·7 a.m.	N.E. to S.W.	3 to 5 secs.	Distinct rumbling on approach and upon receding, which could be heard several seconds after the shock. Tremor of windows and furniture and creaking of fittings.
22 ,,	Marrabel	4·6 a.m.	S. to N.	1 minute (about)	Sharp shock.
22 ,,	Morgan	4 a.m. (about)	S.E. to N.W.	30 secs. (about	Slight shock.
22 ,,	Hoyleton ...	4 a.m. (about)	S.W. to N.E.	10 secs.	Sharp shock.
22 ,,	Tarlee	4·5 a.m.	N.W. to S.E.	25 secs.	Sharp.
22 ,,	Gawler	4·4 a.m.	...	3 to 4 secs.	Very slight.
22 ,,	Lyndoch	4·10 a.m.	N.E. to S.W.	5 or 6 secs.	Clocks stopped, crockery rattled, and some bottles shaken from a shelf in a store. Loud rumbling and creaking noise.
22 ,,	Roseworthy ...	4·7 a.m.	S.W. to N.E.	5 secs. (about	Doors, windows, and beds shaken.
22 ,,	Nuriootpa ...	4·10 a.m.	S.E. to N.W.	7 secs. (about)	Windows rattled, waking sleepers up.
22 ,,	Watervale ...	4·7 a.m.	N.W. to S.W.	10 secs.	Severe. Beds vibrated, crockery and lamps rattled, photo frames knocked down. First sensation like hurricane coming, then like distant thunder, then tremor following.

Date.	Name of Place.	Time of beginning of Shock, Adel., S.T., 9·30° E. of G.	Apparent Direction.	Apparent Duration.	Effect. Remarks.
1905. 22 Aug.	Hergott Springs ...	5·54 a.m.	N.W. to S.E.	35 secs.	Sharp shock.
22 ,,	Eudunda ...	4·6 a.m.	S.E. to N.W.	15 secs.	A clock facing due N. had pendulum forced against glass, an ornament in a bracket in N.W. corner fell on and broke a "treble" piano lamp. Back of piano is against a wall facing due E. A low rumbling preceded for a short time a violent tremor, which was followed by a longer low rumbling. During the tremor buildings seemed to rock and the noise was very loud. Doors and windows rattled and were considerably shaken.
22 ,,	Stockport ...	4·6 a.m. (about)	N.W. to S.E.	15 secs.	Sharp shock.
22 ,,	Blanchtown ...	4·10 a.m. (about)	S.E. to N.W.	5 secs.	Sharp shock.
22 ,,	Sutherland ...	4·5 a.m	N.W. to S.E.	30 secs. (about)	Severe. Windows and crockery shaken.
22 ,,	Kapunda ...	4·6 a.m.	S.W. to N.E.	30 secs.	Sharp. Crockery shaken but no damage done.
22 ,,	Redhill	4 a.m. (about)	N.E. to S.W.	5 secs.	Slight. Rumbling sound followed by slight tremor and after moment's cessation a slight shock.
22 ,,	Nairne	4·10 a.m.	N.E. to S.W.	quite 60 secs.	Some of the residents report that plaster fell off their ceilings and, in one instance, to the N.E. of the village ornaments were knocked off a mantleshelf.
22 ,,	Wasleys	4·5 a.m.	N. to S.E.	20 secs.	Slight shock. Crockery shaken.
22 ,,	Hamley Bridge ...	4·9 a.m.	N. to S.	15 secs.	Sharp shock.
22 ,,	Balaklava ...	4·10 a.m.	...	...	Slight.
22 ,,	Stockwell ...	4·10 a.m.	...	15 secs.	Sharp. Windows and crockery rattled.
22 ,,	Mintaro Centre ...	4·5 a.m.	N.W. to S.E.	30 secs.	Severe. Doors and windows rattled.
22 ,,	Saddleworth ...	4·10 a.m.	...	45 secs.	Sharp. Booming noise like thunder, with ong rumbling afterwards. Windows and doors rattled.
22 ,,	Brinkworth ...	4·5 a.m.	S.E. to N.W.	1 minute	Sharp.
22 ,,	Farrell's Flat ...	4·5 a.m.	S. to N.	nearly 1 minute	Severe. Walls shaken, wooden ceilings distinctly heard to move as if cracking, bedsteads severely shaken. Rumbling noise for several seconds, then a crash as of heavy thunder.
22 Oct.	Coonalpyn ...	6 shocks between 12·15 and 12·51	...	about 6 or 7 secs. each shock	No rumbling. Windows and roof of railway station vibrated.
1906. 8 Feb.	Beltana	4·13 p.m.	N.E. to S.W.	6 secs.	Slight. Rumbling noise. Furniture shaking.
18 Mar.	Riverton	1·35 a.m.	N.E. to S.W.	10 secs.	Sharp. Loud rumbling noise. Walls shaken.
18 ,,	Auburn	1·40 a.m.	N.E. to S.W.	20 secs.	Severe. Shook buildings. No damage.
10 May	Hammond ...	12·30 p.m.	N. to S.	A few secs.	One clap, similar in sound to a dray colliding with a post, and lasting about as long, causing houses to sway a little.
18 June	Bendleby ...	5 and 6 a.m. (between)	...	...	Two shocks were felt between 5 and 6 a.m.
22 Aug.	Beltana	8·44 p.m.	N.E. to S.W.	4 secs. (about)	Sharp, like an explosion.

Date.	Name of Place.	Time of beginning of Shock, Adel., S.T., 9·30°E. of G.	Apparent Direction.	Apparent Duration.	Effect. Remarks.
1906. 1 Nov.	Laura	9·45 p.m.	S.W. to N.E.	5 secs. (about)	Very slight noise like distant thunder.
17 Dec.	Beltana	2·15 a.m. and 3·52 a.m.	E. to W.	1 min. (about)	First shock very slight. Second shock severe, with very loud rumble. Beltana is situated in bed of an old creek. It seemed as if the whole creek was settling down.
21 ,,	Carrieton... ...	11·39 p.m.	N.W. to S.E.	5 secs.	Sharp shock. Electric bells rang.
1907. 30 May	Naracoorte ...	8·28 a.m.	E. to W.	20 secs.	Sharp. Crockery knocked down and doors shook. People alarmed, rushed outside. No damage reported. Loud rumbling noise.
29 July	Jamestown ...	12·15 a.m.	S.W. to N.E.	...	A rather severe shock. Many residents were awakened by the low rumbling noise that immediately preceded it, and doors and windows were distinctly shaken by the vibrations.
14 Dec.	Carrieton ...	7·20 p.m.	N.E. to S.W.	12 secs.	Sharp. Crockery rattled. No damage.
1908. 10 April	Eurelia	1·57 a.m.	N.E. to S.W.	10 to 15 secs.	Windows and doors and movable articles rattled.
10 ,,	Hookina	2·5 a.m.	N.E. to S.W.	1 min. (about)	Houses trembled and cracked. Crockery, &c., moved rapidly. A long rumbling sound before actual shock, and rumble afterwards. Three distinct shocks within the tremor.
10 ,,	Clare	1·55 a.m.	...	5 secs.	Small utensils on dressing-table shaken.
10 ,,	Yunta	1·57 a.m.	...	50 secs.	Severe. Windows rattled and houses shook; also, hotel fixtures noisy.
10 ,,	Carrieton ...	1·55 a.m.	N.W. to S.E.	30 secs.	Crockery rattled.
10 ,,	Yongala	1·50 a.m.	S.W. to N.E.	10 secs.	Beds were shaken, and crockery and windows rattled.
10 ,,	Waukaringa ...	2·5 a.m.	N.E. to S.W.	8 secs.	Doors and windows shook, crockery rattled, iron on roofs trembled. Sound previous to shock resembled steam for several seconds.
29 Oct.	Second Valley ...	6·10 a.m.	S.W. to N.E.	...	Slight shock.
6 ,,	Eudunda	5·10 p.m.	...	20 secs.	It was accompanied by a loud rumbling noise like a heavy wagon passing over hollow ground.
6 ,,	Sutherlands ...	5 p.m.	...	...	The vibration caused windows, crockery, and furniture to rattle. It was accompanied with a loud rumbling noise like thunder.
6 ,,	Mount Mary ...	5·10 p.m.	E. to W.	...	It shook buildings, and made iron roofs and windows rattle.

3.—THE LAND OF THE GODS—ITS RELIGIONS AND TEMPLES.

(Illustrated by a Series of Lantern Views.)

By E. E. EDWARDS, B.A.

Though it may be said of the Japanese that they are essentially an undevotional people, there is no side of the national life which is so difficult to appreciate as that relating to religious matters. Religious instinct finds manifestation in temple, pagoda, idol, sacrifice, ceremony, procession, prayer, preaching, teaching, and in many other ways. While the archaic Shinto is the indigenous religion of the country, Japan has received, if not with open arms, at any rate with some considerable degree of hospitality, both Asiatic Buddhism and, in later days, the teachings of Christianity. Thus, at the present day, there exist side by side aboriginal Shintoism and the doctrines of Buddha and Christ.

In this paper I do not profess to enter into a criticism, but rather I propose to offer a brief description of Shintoism and Japanese Buddhism, with a few remarks concerning the introduction of Confucianism.

In this remarkable country, for centuries past, right up to the present day, there have been established two Pagan religions which have existed side by side without opposition—at least without serious opposition—by their adherents, for the Japanese who professes Buddhism still adheres to the old institutions, practices, and ceremonies of the native Shintoism. Though developed independently, these two religions have not been without important influence the one on the other. Since the introduction of Buddhism from Korea in the sixth century of the Christian era, Shinto temples and Buddhist temples have stood, and still stand, side by side.

The ancestors of the Japanese people (who were not the original occupants of the country) were not without a certain amount of civilisation, for, amongst other things, they had progressed from the stage of nature-worship to that of ancestor-worship, which, known as Shintoism, has obtained, in more or less modified form, to the present day.

The real religion of Japan, the religion still professed in one form or other by the entire nation, is the cult of ancestor-worship, which has always been universal. Probably the deification of ancestors amongst the Japanese was not of spontaneous growth, for it is found in some degree amongst the Chinese and other peoples of Eastern Asia. The Chinese word "Shin," Japanese "Kami," signifies spirit, soul, and is used to indicate the old Japanese gods; Tô (Dô) signifies "way," "doctrine."

Shintô, a word meaning literally "the way of the Gods," is the name given to the mythology and vague ancestor, and, to some extent, nature-worship, which already existed in Japan before the advent of Buddhism. Unlike Buddhism, Shinto possesses no sacred book, no set of dogmas, no moral code; no promise of Heaven, no threat of hell; indeed, in these respects Shinto hardly is entitled to be termed a religion. Native Japanese writers of the present day account for this absence of a moral code by the innate perfection of Japanese humanity, which is supposed to be without the necessity for any such assistance. They aver that it is only the depravity of outcasts like the

Chinese and Western peoples which renders necessary the appearance of sages and reformers. In this system of nature-worship the most prominent objects of worship, for example, heaven and earth, sun, moon (not stars), fire, &c., are intimately associated with the history of the creation of the primeval ancestors with which they are to some degree identified. We shall see examples of this later on.

The most remarkable feature of Shintoism, or the Kami doctrine of Japan, is the divine honours paid to Kami or the spirits of famous princes, heroes, and scholars, and legions of subordinate gods. As just remarked, the lack of the essential marks of a religion, a definite creed and a code of morals, hardly entitles Shintoism to be termed a "religion." Indeed, Kami worship can be termed a religion only by virtue of its expression in temples, prayers, and sacrifices. But it does possess an appreciable feature in its elaborate ritual. Kami is a worship in the form of sacrifice and a kind of liturgy in the shape of an address and a prayer directed to the spirit and called "Norito." The ethics of this particular "religion" (if I may use the term) are derived from the philosophy of Confucius and other Chinese sages. The introduction of pilgrimage is an innovation following the practices of followers of Buddha.

Shinto (First Period).

Three periods may be observed in the existence of Shinto. The first extends to about the middle of the sixth century. During this time religion was in its most primitive state; indeed, the Japanese had no notion of religion as a separate institution. Homage was paid to the gods and to the departed ancestors of the Imperial family; prayers were offered to the gods of the winds, to the god of fire, to the god of pestilence, to the goddess of food, &c. Amongst the ceremonies connected with the religion of the day were purifications for wrong-doing and for bodily defilement, as, for example, for the coming in contact with a dead body. Birth and death were considered specially polluting, so much so, indeed, that anciently there were special huts (ubuya) built for the mother about to give birth to a child; or "moya" for the man who was dying or sure to die of disease or wounds, *e.g.*—Miyajima. Water was the element of purification, *e.g.*—washing hands at temples, and rinsing the mouth with salt and water.

But, still, popular ideas concerning the unseen were of the vaguest; no code of morals yet was formulated. The idea of Heaven and hell did not yet exist, although certainly some gods were considered good, some bad. There was no feeling of the supernatural as we think of it. At this stage the line between men and gods was not clearly drawn. A rude priesthood was at this time in existence, and to each priest was entrusted the service of some particular god, but preaching to the people was not yet. Shintoism at this period was a set of ceremonies, political rather than religious.

Ryobu Shinto (Second Period).

The second period, marked by the arrest of the growth of Shintoism in the direction of a religion, was brought about by the introduction of Buddhism about the middle of the sixth century of our era (552 A.D.). With the coming of Buddhism there was introduced into Japan a system of religion in which were temples with all that was attractive to the eye, gorgeous ritual, scriptures, priesthood, codes of morals, rigid discipline, and a system of dogmas, and metaphysics in which all was made positive and clear, that made the variant myths and legends somewhat uniform. This new religion did more than make powerful appeals merely to the senses; it also supplied food and nourishment for the imagination, partly by the doctrine of transmigration and the descriptions of distant worlds, which, with their angels and Buddhas in splendour and glory, were held out to adherents of all stations in life as the goal which all might attain. Buddhism, ever tolerant, peaceful, and accommodating itself to old religious conditions, diplomatically received the native Shinto gods—avatars of the ancient Buddhas. So, many Shinto ceremonies connected with the Court were retained, although Buddhist ceremonies took the first place even in the thoughts of the converted descendants of the sun.

Buddhist metaphysics were too profound, Buddhist ritual was far too gorgeous, the Buddhist moral code was far too exalted for the puny fabric of Shinto to offer any effectual resistance. This form of Buddhism, favoured by the authorities, spread very rapidly and became the really popular religion. In fact, the religious feelings of the nation went over to Buddhism. By gaining adherents at Court and amongst the leading men, Buddhism reacted upon the national traditions, thus compelling their collection and arrangement into definite formulas. In due time mythology, poetry, and Shinto ritual, various fragmentary legends and local usages, previously handed down by word of mouth, were committed to writing, and the whole system called Shinto—the way of the gods—the term being introduced in order to distinguish the old native way of thinking from Butsudô—the way of the Buddhas—the doctrine imported from India and China.

Shinto subsequently broke up into numerous petty sects, which gathered some little vitality by the fragmentary lore which they annexed from Buddhism and from Taoism, *e.g.*—divination and sorcery. At Court only, and also at a few great shrines, *e.g.*—Isé and Izumo, was a knowledge of Shinto maintained in its native simplicity. Indeed, for a thousand years many, if not most, of the Shinto temples were served by Buddhist priests, to whom is due the introduction of Buddhist (*i.e.*, Indian) architectural ornamentation, as well as ceremonial, *e.g.*, elaborate carvings, the form of the two-storied sammon, or outer gate, and even the pagoda itself, which, though essentially Buddhistic, was found in the most popular Shinto shrines.

By the edict of Ieyasu, the first Shogun of the Tokugawa dynasty, the bonzes (Buddhist priests) were appointed to keep the registers and to officiate at funerals, even those of the Shintoists. In several instances, *e.g.*—in the temples of Kompira and Hachiman, the so-called Shinto deities worshipped were probably unknown in pre-Buddhist ages, and owed their existence to priestly ingenuity.

The formation of a mixed religion, termed Ryobu Shinto, the fusion of Buddhism with the old gods and heroic legends of the Japanese—a compromise between the old creed and the new—no doubt, in part, accounts for the tolerant ideas regarding theological matters of most middle and lower class Japanese, who worship indifferently at a Shinto temple or the shrine of Buddha. The doctrines of metempsychosis and universal perfectibility taught by Buddhism naturally made it tolerant of other creeds and willing to afford hospitality to their gods in its own pantheon. Thus, the early Buddhist teachers were led to regard the aboriginal Shinto gods and goddesses as incarnations or avatars—the Japanese use a word (gongen) signifying, literally, "temporary manifestations"—of some of the many myriads of Buddhas. This mixed religon—Ryobu Shinto—lasted throughout the middle ages.

Revival of Pure Shinto (Third Period).

The curious state of things under Ryobu Shinto began to totter rather less than some two hundred years ago. The third period in Shinto history begins about the beginning of the eighteenth century and continues down to the present day. It is called the period of the "revival of Pure Shinto." During the seventeenth and eighteenth centuries, *i.e.*—under the government of the Tokugawa dynasty of Shoguns, the enthusiastically patriotic literati of Japan directed their exertions to reviving the traditions of the past. They resurrected old and forgotten manuscripts; old histories and poems were published in print, and the language of old Japan was revived and imitated. The movement grew until at length it became not only religious and political, but, most of all, patriotic. The Shogunate was looked at askance, because it had supplanted the autocracy of the heaven-descended Mikados. Fierce zealots sneered at Buddhism and Confucianism because they were foreign elements. It was urged that but two things were needful—to follow one's natural impulses and to obey the Mikado. The exaltation of the importance of the Mikado always had been the aim of Kami worship. This movement towards purification culminated in the revolution of 1868. Buddhism received a severe blow—in fact, Buddhism was disestablished and disendowed, and Shinto became the only State religion. To the Council of Spiritual Affairs was given equal rank with the Council of State. "Purification" went on apace. Buddhist and Ryobu Shinto temples were denuded of their ornaments. Special commissioners were appointed to make investigations wherever an old Shinto temple had gradually made way for the worship of Buddha, and, if there were but a scintilla of right, the Kami was replaced in his hall. From the mountain temples of Tateyama, Haku-san, and other spots, the statues of Buddha were (in 1873 and 1874) removed from the small temples, and replaced by mirrors and gohei. Shinto prayers took the place of prayers to Buddha, and Buddhist priests no longer were suffered to "contaminate" Shinto shrines. All buildings were removed if they did not properly belong to Shinto establishment, such for instance as pagodas, belfries, and richly-decorated shrines. Thus, zeal for this system of "purification" resulted in the destruction of many precious structures. Kompira, once a Buddhist shrine, was taken possession of about 1872; and, in 1875, the pagoda, and most of the temples reared by Buddhist piety were rased to the ground and replaced by new Shinto structures. The popularity of Kompira was little affected by the change; for in Japan religious beliefs sit lightly on the people, who, provided there be an ancient shrine to resort to and at which to purchase charms, care little what form of faith may be there professed.

As a result of this purification, the visitor to Japan to-day, while he loses much that charmed the eye thirty or forty years ago, or less, nevertheless has better opportunity of making himself familiar with the "pure Shinto" style, which, while simple, at the same time is unique as being one of the few things which was not imported from the mainland of Asia.

Restoration of Mikado.

With the revolution of 1868 came the restoration of the Mikado's authority; old traditions became paramount; thus the divine right of the sovereign once more was openly acknowledged and proclaimed.

Buddhism had had hold of the common people so long that they viewed with regret the demolishing of gods which for centuries they had been wont to worship as part of their daily life. Centuries of unquestioning obedience to the commands of those in authority had, during the years of "purification," caused these same people to obey the dictates of their superiors as a matter of course. But, as was to be expected, the bonzes (Buddhist priests) took the matter much more to heart, some preferring to consign their temples to Nirvana rather than to the hands of Shinto priests. Thus, the finest temple in Tokyo, that of Zôzôji in Shiba, built by the Shogun Ieyasu, perished in the flames, together with its store of ancient art treasures, shortly after the order for its transformation into a Shinto temple. And this so late as New Year's Night, 1874.

Rally of Buddhism.

But the new "purified" order of things was not to last. Buddhism was not long in rallying. The Spiritual Council sank to the rank of a mere department, and afterwards lower still. The whole thing has dwindled down. The efforts on the part of the Government to supplant Buddhism by Kami worship have now been very considerably relaxed. Nevertheless, Shintoism to-day still is so far the official cult that certain temples, *e.g.*—Isé and Nikko, are maintained out of public moneys; while the attendance of certain officials is required from time to time at ceremonials of a semi-religious or semi-courtly nature, *e.g.*—the Emperor returning thanks at Isé for success in the war with Russia.

In effect, the endeavour to supplant Buddhism by Shintoism really was an attempt to set up as the national religion a religion both hollow and unsatisfying. This and the opening up of the country to foreign influences, together with the spread of modern thought, would prevent the subsistence of beliefs which only were possible while the Mikado lived in a retirement and seclusion which allowed him to be wrapped in so divine an atmosphere that awestruck reverence forbade the utterance of the name of the divinely descended ruler.

Shinto (Descriptive).

While the indigenous religion of Japan is Shinto, Buddhism in its Chinese form was imported from India through China and Korea in the sixth century of the Christian era. But, though Shinto and Buddhism long have stood, and still stand, side by side, it must not be imagined that the Japanese people are, therefore, divided into two distinct sections, each professing to observe one of these religions exclusively. As a matter of fact, Shinto and Buddhism in practice are so thoroughly interfused that the number of pure Shintoists and pure Buddhists must be extremely small. Every Japanese is, from the moment of his birth, placed by his parents under the protection of some Shinto deity. On the other hand, the funeral rites are conducted, with few exceptions, according to the ceremonial of the Buddhist sect to which his family belongs. In recent years only has burial been revived according to ancient Shinto ritual, and this after almost total disuse for some twelve centuries. Shinto requires of its adherents little more than a visit to the local temple at the times of annual festivals; it does not profess to teach any theory regarding the destiny of man, or of moral duty. Accordingly, the Buddhist priests have a fairly free field for the teaching of moral dogma, the exercise of splendid rites, and the display of gorgeous decorations. Shinto, a compound of nature-worship and ancestor-worship, has gods and goddesses of wind, ocean, fire, food, and pestilence; of mountains and rivers, of certain special mountains, certain trees, certain temples —eight hundred myriads of these deities in all. Shinto concerns itself not with moral teaching. Its theory is to follow one's natural impulses, and the decrees of the Mikado. The important thing is to conserve the national morality which inculcates love of country, loyalty to the Sovereign, filial piety, family harmony, respect for parents, goodwill among sons and daughters, and the worship of ancestors. These are civic and family observances. This moral system limits its aims to this world, and its practice contemplates no celestial reward. As already stated, the real religion of Japan, the religion still professed in one form or other by the entire nation, is the cult of ancestor-worship. It may be said without exaggeration that every Japanese man, woman, and child is an ancestor-worshipper, including the Christian convert and the Buddhist devotee. There is no preaching; neither are the rewards and punishments of a future life used as incentives to right conduct; and there are hardly any regular services for the people. Shinto is a belief in the continued existence of the dead, but whether such be one of joy or pain is not revealed.

The costumes of the priests (Kannushi) differ from those of laymen only when offering morning and evening prayers. At such times their dress consists of a long loose gown with wide sleeves, fastened at the waist with a girdle, and sometimes a black cap, bound round the head with a white fillet. No vows of celibacy bind the priests. At some temples young girls act as priestesses, but their duties consist, for the most part, of the pantomimic dances known as Kagura (*e.g.*, Kasuga shrine). Service consists of the presentation of small trays of rice, fish, fruits, vegetables, saké, and the flesh of birds and animals, also in the recital of certain formal addresses (norito), partly laudatory and partly in the nature of petitions. Although Shinto is divided into several sects, *e.g.*, Honkyoku, the Kurozumi Kyo, &c., they are so unobtrusive that the cult may well be considered homogeneous.

Every town, every village possesses more than one miya (Shinto temple). In 1898 there were 664 great temples, 191,242 shrines, and

15,983 Shinto priests. Each temple has its annual festival. Even the Buddhist believers take part in the ceremonies, and go to adore the Shinto gods. The festival provides a variety of entertainments for all classes of society. Thus, it is not only a religious ceremony but a social custom which adorns life with pleasure and gaiety, the while the Buddhist solemnities inspire only sadness and melancholy.

Confucianism.

Confucianism overflowed from China into Korea, where to this day it is said to be prominent even over Buddhism. It is but a short step across the water from Korea to Japan, where for some fifteen centuries Confucianism has done much to mould and shape the character of the sturdy islanders. The precise time when Chinese learning entered Japan by way of Korea has not been indisputably ascertained; probably it was between the third and sixth centuries. As a matter of fact, Buddhism to which the Japanese owe so many debts, was the means of introducing much foreign learning, and also was the vehicle whereby Confucianism reached the multitude of the Japanese people. The earliest missionaries to the country were most sympathetically in accord with the ethics of Confucianism and continued so down to about the seventeenth century. For a thousand years (say, from 600 to 1,600) the Buddhist religious teachers assisted in spreading the teachings of Confucius. True, in various ways, individuals introduced unimportant modifications; but, notwithstanding, the teachers were the means simply of transmitting without attempting to improve on the Chinese ethics. Originally introduced into Japan early in the Christian era, the Confucian philosophy lay dormant during the Middle Ages, that is to say, during the period of Buddhist supremacy. It awoke early in the seventeenth century when the great warrior Ieyasu, the patron of learning, caused the Confucian classics to be printed in Japanese for the first time.

For the following two hundred and fifty years Confucian ideas moulded the whole intellect of the country. Most acceptable to the Japanese was the Confucian doctrine of unquestioning submission to rulers and parents. This fitted in exactly with the feudal ideas of old Japan. The conviction of the paramount importance of such subjection still lingers on amongst the ruin of other Japanese institutions. The Japanese did not develop the Confucian system. There are not even any Japanese translations or commentaries worth reading. Little has been done beyond reprinting the text of the Confucian classics and also of the principal Chinese commentators. In this form, with a few marks to facilitate perusal by Japanese students, the Chinese classics formed the chief vehicle of every boy's education from the seventeenth century until the introduction of European models of education after the revolution of 1868. To-day they are practically neglected, though certain phrases still are extant in current literature and colloquial language.

Seido, the great temple of Confucius in Tokyo, is now utilised as an Educational Museum. The philosophy of the great sages, Confucius and Lao Tsze, exercises a strong effect on the formation of Japanese character.

Buddhism.

To Buddhism the Japanese owe a debt which hardly can be conceived. To Buddhism they are indebted not only for a religion but for their present civilisation and culture and their high state of perfection in many of the arts. Architecture, painting, sculpture, chess, cremation, embroidery, engraving, and even the introduction of the tea plant—in short, every art and industry that helped to make life beautiful—developed first in Japan under Buddhist teaching. Hearn asserts that "Art in Japan is so intimately associated with religion that any attempt to study it without extensive knowledge of the beliefs which it reflects were mere waste of time."

As the accompaniment of Chinese learning, spreading from the Ganges and the valleys of the Himalayas to China and Korea, Buddhism first entered Japan from Korea about the year 552 A.D. Buddhism spread to such an extent that for centuries it was the popular national religion. It was adopted even by the Mikado's descendants of the great Shinto Goddess of the Sun. This same goddess, so highly reverenced by the Japanese to-day, became a Buddha under the name of Dainichi Niorai. Yet, notwithstanding the remarkable progress of Buddhism, Shinto never was entirely suppressed. From the sixth to the eighth century monks and nuns from Korea and China visited Japan for the purpose of spreading the teachings of Buddha and securing converts. From the end of the eighth century it was by no means unusual for the Japanese monks to visit China in order to pursue their studies more nearly at first hand. Thus it is that the Buddhists of Japan adhere so closely, in general, to the Chinese school of Buddhism.

At the time of its introduction into the Archipelago the teachings of Buddha already were more than a thousand years old, and so it was only natural that variety of thought had split Buddhism, especially Chinese Buddhism, into numbers of sects and sub-sects. At present there are ten chief sects amongst the Buddhists of Japan and numerous sub-sects. Early Chinese sects still survive in Tendai and Shingon; while Nichiren and Shin are later Japanese developments.

The peaceful and thoughtful-looking Buddhas carved in wood or stone were introduced into Japan with an amount of pomp and ritual. But, as already stated, the new religion did more than appeal to the senses; it afforded food for the imagination in the doctrine of transmigration and description of distant worlds inhabited by angels and Buddhas dwelling in the splendours of paradise. Tolerant and accommodating itself to the native religious ideas, Buddhism soon found favour with the authorities and became the popular national religion which stands to this day. For centuries the people in Japan combined the worship of Kami with the worship of Buddha. "Until the epoch of the Restoration (1868), the credulity of the people and their confidence in the power of the gods was very great," wrote a former Kami priest. "There was," he remarks, "hardly an instant when one did not hear hand-clapping, drum-beating, and praying. Whether it was this sect or that, a Kami (shinto-god), or Hotoke (Buddha-god), an idol of wood, clay, or stone, the people worshipped it, prayed to it, and offered it rice, flowers, tapers, &c. The very pious prostrated themselves and touched the ground with their foreheads, hoping that thus their prayers would be the sooner heard, and repeated Namu Amida Buddha (Indian words meaning 'Hail to the Eternal Splendour of Buddha'), or Namu Miô-hô-renge-kiô ('Hail to the Salvation-bringing revelations of the law'—a Chinese translation used by the Nichiren sect of Buddhists), or Takamagahara ni kami todomari (the prayer of the Shintoists 'O Kami, thou who art enthroned in the highest space of Heaven').

"Religion brings no gloom into the sunshine of Japanese life; before the Buddhas and the gods folk smile as they pray; the temple courts are play-grounds for the children; and within the enclosure of the great public shrines—which are places of festivity rather than of solemnity—dancing-platforms are erected," and stalls are set out for the sale of small goods, charms, and other trifles. As Professor Hozumi remarks, "The worship of the Imperial ancestors and especially of the first of them, Amaterasu-Omikami, or 'the Great Goddess of Celestial Light,' may be styled the national worship." Nevertheless, in Japan there exists not only absolute religious freedom but the fullest tolerance of all religions. Perfect freedom of conscience is guaranteed by the Constitution, and to-day the Roman Catholic, Greek, and Protestant Churches exist side by side; while the Mormons are allowed to preach and the Salvation Army to parade the streets.

4.—WALLACE'S LINE.

By PROFESSOR S. B. J. SKERTCHLY.

5.—ON THE SEGAMIEH RIVER.

By PROFESSOR S. B. J. SKERTCHLY.

6.—ISLAND OF FORMOSA.

By H. H. VOSTIEN.

7.—GEOGRAPHICAL SIGNIFICANCE OF THE FROZEN MAMMOTHS OF SIBERIA.

By ARTHUR EXLEY.

8.—OCEAN CONTOURS AND EARTH MOVEMENTS IN THE SOUTH WEST PACIFIC.

Lecture by P. MARSHALL, M.A., D.Sc., F.G.S., Professor of Geology, Otago University, New Zealand.

It is well known that many distinguished members of this Association have from time to time published articles in the transactions and elsewhere in which the present distribution of animals and plants in the Western Pacific has been discussed. In many instances authors have argued that the distribution of life forms within the area can only be explained by assuming that in past geological ages continents and ocean wastes have had an altogether different extent and arrangement from those that they at present possess.

Appeal has frequently been made to ocean soundings and to the contours that they reveal, but in such cases the material on which the appeal has been based is chiefly the map published in the "Challenger" records, which has been copied with but slight alterations into many other publications. In general but little attention has been paid to the geological matters so far as structure and composition of the various land masses are concerned.

In this paper an attempt is made to embody the most recently recorded soundings that could be obtained in a general bathymetric map in order to show the most probable land connections that may have existed in the past, on the assumption of the general elevation of the whole region. Of late years many important memoirs on the geology of the islands in this area have been published. An attempt is here made to bring together the results of these memoirs, and to consider them with regard to the structure of Australia and New Zealand.

Ocean Contours.

The soundings recorded in the British Admiralty charts are rather numerous in the area between New Zealand, Samoa, New Caledonia, and Australia, and it is possible to arrive at what is probably an accurate idea of the nature of the ocean floor within these limits. Eastward the soundings are relatively few, but this is the less regrettable because those that are recorded suggest that the ocean floor is relatively flat all over the western part of that portion of the Pacific Ocean lying east of New Zealand, and that it lies between 2,500 and 3,000 fathoms from the surface of the water.

Southward, from New Zealand, shallow water appears to extend some distance, and the great depths of the area previously mentioned are nowhere attained, though, between the New Zealand Plateau and South Victoria Land, intermediate depths of 1,500-2,000 fathoms probably extend over a wide area, and the water appears to shallow gradually as the southern land is approached.

Westward between New Zealand and Australia the Tasman Sea is as far as known uniformly over 2,000 fathoms in depth, and its basin slopes steeply from the Australian Coast and from the south-west coast of New Zealand, though further north on this eastern side the steep slope recedes from the New Zealand Coast.

These general facts are recorded in many works of reference, and the main features are to be seen in maps printed in text books, such as "Chamberlain and Salisbury's Geology," "Berghau's Physical Atlas," and many others. In nearly every case these are based on the map printed in the "Challenger" reports, Vol. XXXVII.

They all have the objection that Mercator's projection is used, and this, of course, gives an overwhelmingly disproportionate area to districts situated in higher latitudes. In most cases too little notice is taken of the numerous soundings that have been recorded since the date of the "Challenger" expedition.

For these reasons a new map has been prepared for the purposes of this paper. A projection has been employed which reduces the disproportion referred to as much as practicable, and all the soundings recorded in the most recent Admiralty charts have been incorporated, as well as a few obtained from other sources.

An examination of this map reveals several important features to which reference must be made.

The Thomson trough occupies the main part of the area between the New Zealand plateau and Australia. It narrows to the northward, giving way to the ridge which extends north-westward from the New Zealand plateau. The Thomson trough terminates near the tropic of Capricorn, where depths of less than 1,000 fathoms are almost continuous from Australia to New Caledonia, and from the middle of this Caledonian rise the ridge, previously mentioned as forming the eastern limit of the Thomson trough, extends south-south-west, and bending to south-west reaches the New Zealand plateau. On the extreme west of the ridge is Lord Howe Island, and in its central part a well-marked shoal is found.

Close to New Caledonia on the south-west there is a small trench, and water more than 1,500 fathoms deep extends some distance south, separating the Howe ridge from the Norfolk ridge, which is parallel to it, and has the Britannia shoal in its centre. A narrow curved ridge unites Fiji and the New Hebrides. The Gazelle basin, uniformly 2,000-2,500 fathoms, separates the Norfolk ridge from the Fiji ridge, which runs 500 miles south from the eastern extremity of the Fiji Archipelago. A narrow and shallow trench separates the Fiji ridge from the remarkable Kermadec and Tonga ridge, which commences near Wallis Island, 150 miles south of the western end of Savaii, and thence continues to the south of the Kermadecs, and is separated from the East Cape of New Zealand by water less than 1,500 fathoms deep. This ridge is commonly represented as composed of two distinct portions, but I can find no records of soundings on the direct line between the two undoubted shallow areas, and the soundings on each side of the ridge are not deeper than those on each side of the Kermadecs and Tonga areas. I have, therefore, represented the ridge as continuous at a depth less than 1,000 fathoms. A highly irregular boundary separates the Gazelle basin from the New Zealand plateau. On the eastern side of the Tonga-Kermadec ridge occurs the most remarkable feature of the south-west Pacific—the profound trench which includes the Tonga deep and the Kermadec deep. In a portion of each of these deeps soundings of over 5,000 fathoms have been made; the deepest is in the Kermadec area, and measures 5,155 fathoms. These deeps are usually represented as separated by water of 2,000 fathoms, but there is little more reason for separating them than for separating the Tonga and Kermadec areas of the ridge, though, in this case, the connecting portion of the trench must be extremely narrow. Eastward of the Kermadec-Tonga trench the floor of the Pacific rises slowly to what appears to be a uniform depth of 2,500-3,000 fathoms over nearly the whole of its western portion. This depth is slightly exceeded south-east of the Chathams. Some of the soundings east of the Cook Islands are rather less, but there is no indication of any submarine ridge joining these islands, which appear for the most part to be huge volcanic mountains, sometimes with a veneer of coral, and reaching to a height of 15,000 ft. to 22,000 ft., in the case of Tahiti, above a nearly level ocean floor. The eastward extension of the New Zealand plateau is, in the present state of our knowledge, badly defined. The southward termination of the Tonga-

Kermadec trench is not yet known, but it certainly reaches almost to the latitude of the East Cape, and water of 2,000 fathoms depth is not far from the eastern entrance of Cook Strait. On the other hand, shallow water appears to extend continuously to the Chatham Islands, though a recent volume on the Geography of Australasia gives an area of more than 3,000 fathoms between the two lands. This appears to be due to an erroneous reading of 3,250 for 325 fathoms. Soundings of less than 500 fathoms are said to have been found by Sir J. Hector continuously from Macquarie to the Chathams, and this has led Farquhar to extend the New Zealand plateau far to the eastwards. All attempts to find readings of these soundings have proved unsuccessful, and, while it is probable that the plateau extends some distance to the east, the two soundings of over 900 fathoms near Otago Peninsula show there is much need for caution, while north east of the Campbell Island a sounding of 567 fathoms is recorded.

Elsewhere in the Southern Ocean the soundings are extremely few, and the boundaries between the different depths are certainly problematical. It was a little disappointing that the "Discovery" expedition did not add to its magnificent performance by taking a line of soundings at any rate to the margin of the pack ice.

Rock Folds.

Within later years we have received much information as to the lines of folding in the different areas of the South-west Pacific. In many instances the geologists who have investigated this matter have been able to come to some conclusions as to the geological periods at which the earth folds were formed. In particular, our thanks are due to Professor David, Dr. Woolnough, Mr. Mawson, Dr. Bell, and the officers of the reorganised geological survey of New Zealand. In Australia all the important earth stresses connected with earth folding appear to have acted before the Permo-Carboniferous period. The direction of the folds, as shown in Professor David's map, is mainly parallel to the present coast line.

According to M. Barnard, an ancient line of folding appears to have affected the older masses of New Caledonia before the deposition of the Triassic rocks, but the absence of fossils makes it impossible to arrive at any exact statement as to the exact period of folding. The direction was from south-west to north-east at right angles to the present direction of land extension. Dr. Woolnough describes, in Fiji, a series of ancient rocks folded along a N.N.E. S.S.W. line, but no period can be assigned for the earth movement.

In New Zealand, Gregory has frequently made reference to an ancient line of rock folds directed south-east and north-west. In Otago, one of the localities where this is described, there is a large area of schist rocks referred by Hutton to the Archæan; by Hector, provisionally, to the Silurian; and by Park, in the Bulletin No. 5, "New Series of Geological Survey," the non-committal statement "not older than the Carboniferous or Devonian" is made. My own observations have shown that, in many sections, especially at Lower Clutha, Tapanui, Athol, Hermitage, Browning's Pass, and the Waitaki Valley, there is a gradual transition from unchanged sediments to completely metamorphic rocks. In none of these sections can any line of demarcation be found between the two series, and the gradual change from one type to the other is not complete before from 3 to 5 miles of country have been traversed. It is, therefore, reasonable to refer the schists to the group of sedimentary rocks into which they graduate. In the first three instances given the sedimentaries contain fossils that are certainly of Triassic age, and are probably of the same age in the other localities. Apart from this it is at any rate certain that Triassic and Jurassic rocks, distinguished by distinct fossils, are deeply involved in the folds in the southern portion of the affected rock mass.

Another of the old fold lines of Gregory is in the north of the Auckland province. Here the folding action has almost completely obscured the stratification planes to such an extent, in fact, that both Darwin and Dana failed to detect a line of folding in the Bay of Islands. Suess remarks of this area, that Palæozoic rocks are "only the isolated fragments of the sunken range," and "the north-western coast, therefore, in no way represents the actual trend of the mountains."

However, Mr. E. Clarke has recently made a close examination of these rocks at Whangaroa, and Dr. Bell and he have extended their observations to the North Cape. During their work they have recognised a north-north-west line of folding, a conclusion opposed to that of the writer, gained, however, from less extensive work in 1906. Although this recent work establishes the north-north-west direction for the line of strike, there is no reason to suppose that it is an older line of fold than that of the main mountain line of the North Island. In fact, McKay found Triassic rocks at Spirits Bay, and Clarke thinks Triassic the extreme limit of geological time to which these rocks can be referred. No other observer, therefore, supports Gregory's opinion that an old N.W.-S.E. fold line exists in the extreme north.

It is well known that in New Zealand the main structural axis bends round in the south from south-west to south-east. There is, however, a large mass of ancient rocks further to the west—perhaps of Archæan age. In these Hutton distinguishes a N.W. dip that is a N.E. strike in 1875, and his conclusions have not been disputed. No important sections between these N.E. striking rocks and those with a N.W. strike has yet been described, though one occurs on the north-east side of Lake Te Anau. In this section there appears to the writer to be a great unconformity, but it has so far proved impossible to make a close inspection of it. In the north-west of Nelson minute and accurate work has been done by the Geological Survey on the Ordivician and other ancient rocks. A N.N.W. and S.S.E. strike was found there.

It is often taken for granted that the main fold line of New Zealand from the east of Poverty Bay to Cape Terawhiti and Culverden is of Carboniferous age. (Mawson, L. S., N.S.W., 1905, p. 474.) It cannot, however, be too clearly stated that, as recognised by Hutton in 1885, the main rock folds were formed in the late Jurassic. That this is the case is shown at Waikato Heads, Kawhia, Nelson, Hokanui Hills, and Coromandel Peninsula, in all of which places Jurassic rocks are involved in the folds, while in no known section is there any unconformity between Jurassic and Triassic rocks. The late Jurassic was the critical period in New Zealand. Since that period New Zealand has been essentially the same in outline and configuration, though elevations and depressions have repeatedly changed its extent. Though the main direction of the folds is as stated, Fraser has recently shown that in the Coromandel the strike is almost due N. and S., while on the western side, at Kawhia, Hochstetter long ago found a N.E. strike, and his observations have been confirmed by McKay.

Of earth movements later than this there have been many, and in New Caledonia they have been important. The Cretaceous coal deposits of that island are apparently not separated by any important unconformity from the Triassic, and have been involved in the same movements, a statement which points to rather later folding than in New Zealand, though here, too, the folding was continued into the Cretaceous.

Plutonic Rocks.

The presence of Plutonic rocks in any land surface must always be evidence of great erosion. The fact that such rocks occur at or above the sea level suggests that in many cases elevation has taken place in such an area. Since the Plutonics have been covered by other rocks their elevated position may be due to folding. It is important, therefore, to record the areas where Plutonic rocks are found in the South-west Pacific. There are, of course, many outcrops in Australia and New Zealand, and it is unnecessary to refer further to these.

Gabbro is found in Campbell Island.

Gabbro and granite in the Auckland group.

The Snares are formed of granite.

The Bounty Islands are composed of granite alone.

On Tahiti nepheline syenite occurs.

Granite has been recorded from Sunday Island in the Kermadecs by Thomas.

Anuralitised gabbro comes from Tonga.

Woolnough has recorded much plutonic rock from Viti Levu, and mentions that at Aneityum, Espiritu Santo, and Malicolo in the New Hebrides plutonics or their derivatives occur.

In New Caledonia there is a great mass of serpentine almost certainly derived from ultra basic rocks of plutonic nature.

Earth Movements Since the Cainozoic.

In the Cainozoic era a large part of the S.W. Pacific must have been at a far lower level than it is now.

The three regions in particular in which we have evidence of this are Fiji, New Hebrides, and New Zealand.

In Fiji, Woolnough describes marine soapstones as elevated at the present time to a height of 4,000 ft. above sea level. The age is not further stated than that they are certainly Tertiary. They cover the old rocks so completely that it is only in deep valleys and other places where erosion has been rapid that the plutonic rocks and slates are to be seen. During the deposition of these rocks the old erosion surface was considerably beneath the present sea level, and the absence of fragments of Mesozoic rocks in the Cainozoic conglomerates suggests that no such rocks were formed in the Fiji area; in other words Viti Levu was probably a land area throughout Mesozoic and perhaps Palæozoic times.

In the New Hebrides Mawson says a fold ridge was developed in Miocene times, but not before much Miocene limestone was deposited. Volcanic eruptions are mentioned by him as associated with the formation of the Miocene folds.

New Zealand, it is agreed by all those who have worked at this subject, was during the Miocene an area of pronounced subsidence, but there is much diversity of opinion as to the extent of the rocks that are to be regarded as of Miocene age. Sir James Hector classed few of the South Island Cainozoic sediments as Miocene. He even thought them to be in part at any rate of late Mesozoic age. Captain Hutton thought that the greater part of them were of Oligocene age. Professor Park since he left the Geological Survey under Sir James Hector has classed nearly the whole of these sediments as Miocene, and this view, which was first adopted by the writer in 1902, is the one that he still holds. The great thickness of the sediments thus classed, their general occurrence throughout both islands, and their frequent high elevation above sea level, proves that the Miocene depression was prolonged, general, and severe. It certainly affected the New Zealand plateau as far as Campbell Island in the South, and as far as the Chatham Islands in the East.

During the Miocene and probably towards its close volcanic action became prominent in many localities. Apparently in all cases elevation was then in progress. This was certainly the case at Dunedin, and though in some other New Zealand localities the evidence is somewhat less decisive, there is little reason to doubt that an upward movement was in progress at Banks's Peninsula, Oamaru, Taupo region, and Coromandel Peninsula, and many localities to the north of Auckland. The same appears to have been the case at Campbell Island and at the Chathams.

The fact that there is a nearly continuous fringe of Miocene rocks round the coast line of New Zealand dipping below the sea level, while inland they usually occur at much higher levels, sometimes reaching to an elevation of 4,000 ft. above sea level, may, perhaps, fairly be taken to prove that the interior portions of the land were more affected by the movements than the margin. This elevation was affected by local folding only.

Elevation and volcanic action were associated towards the close of the Miocene in the New Hebrides, and in Fiji. In both of these islands the volcanic material was andesite, as was the case in the North Island of New Zealand. In the South Island the rocks were more basic—usually dolerites or basalts—but in Dunedin there were important alkaline eruptions as well. Basic rocks were emitted at Campbell Island, Chatham Islands, and probably at the Auckland Islands at this time.

This movement of elevation appears to have been continuous up to the present time in the Fijis and in the New Hebrides, where the erupted matter has changed from andesite to basalt in the later phases. Here, too, Mawson mentions immense subsidences along fault lines, by which the present separation of the islands has been effected.

Evidence of elevation within comparatively late times from a geological standpoint is to be found in many other islands within the South-west Pacific region. In the Tonga Islands Lister states that raised coral terraces are at Vavau and Eua 1,000 ft. above sea level.

Among the Cook Islands Mangaia shows a "makatea" of raised coral. The same is seen at Mauke, while Niue consists entirely of raised coral, in which at least three terraces marking different stages of elevation are to be clearly seen. Darwin does not claim these islands as within his area of typical subsidence. His observations on the coral growths around them led him to state merely that they were not areas of rapid subsidence.

Tahiti on the other hand is classed by Darwin as a subsiding island, though several of the descriptions he quotes show that the coral reef is in places close to the shore, and at other times there is only shallow water between it and the shore. On the other hand Dana states that any submergence of Tahiti would form deep inlets striking far into the land. We have also a description by Guillemard and Keane which mentions the flat land extending round the island, and the circular terraces that are to be seen above it.

The present land forms of Tahiti thus evidently suggest recent elevation, though it must be remembered that Dana distinctly pronounced against this view, except, perhaps, at Bola-bola, but even there he regards any elevation that may have occurred as far from recent.

In New Zealand the elevation and volcanic action which closed the Miocene appear to have been long continued, and the land rose to a level distinctly higher than the present one. The evidence for this is to be found in the numerous drowned valleys which were eroded in Miocene sediments and volcanics alike in so many places. The rias of the Auckland neighbourhood, the harbours of Whangaroa and Whangarei in the North, Aotea and Kawhia further South, all traverse Miocene rocks. At Wanganui the artesian wells show that the true bed of the river is at least 600 ft. below the present sea level, though the rocks 100ft. above sea level contain Pliocene fossils.

In the South Island Otago Harbour is eroded in Miocene rocks, while on the western side Preservation Inlet passes through Miocene rocks at its entrance, and at the extreme north of this coast the West Wanganui Inlet is entirely surrounded by cliffs of Miocene rocks.

In Campbell Island there are several drowned valleys in rocks that are almost certainly of the same age, and the same is true of the Auckland Islands, but in these islands, as at Preservation Inlet, it is possible that the valley floors were eroded by ice below the sea level of the period of erosion.

These same facts may be quoted to prove that this great period of elevation was succeeded by a depression, for the full amount of which the later movement of elevation has not yet compensated.

No available descriptions appear to prove a similar downward movement in other South Pacific islands. In Fiji the elevation has been described as continuous by Woolnough, and in the New Hebrides the upward movement has been accompanied by earth blocks falling in along fracture plains developed during the earth movements which commenced at the close of the Miocene.

Whether the Australian coast was subsiding at this time does not appear to be known definitely, though it is realised that the eastern coast has been undergoing a downward movement for a long period, superseded by an upward movement now in places. In the earth forms of New Zealand the latest movement that is recorded is an elevation, but of unequal amount, in different parts of the land. This is most clearly seen in the extreme south-west, where on the shore of Foveaux Strait terraces reach to a height of 1,500 ft. above sea level. Hutton has recorded gravel terraces and raised beaches at various points and heights on the coast line extending north to the Thames. Percy Smith noticed others in Auckland Harbour, though only a few feet above sea level.

Rock shelves are also to be seen in many places. At Ewing Island, in the Auckland group, a very recent one is to be seen about 15 ft. above the present sea level. The flat granite tops of the Snares Islands are certainly a former level of marine erosion. The islets lying off the north-east coast of Stewart Island also indicate an old sea level from 50 ft. to 100 ft. above the present sea level. At Dunedin there is a shelf 300 ft. above the beach. On the shore of Rangitoto Channel, alongside of Lake Takapuna, near Auckland, a well-formed shelf is to be seen 6 ft. above high water, and Dr. Bell says that at the North Cape there is an indication of a recent upward movement of a few feet. Practically all New Zealand geologists are now agreed that the numerous river terraces on the west of the Canterbury Plains are due to movements of elevation. These features are not confined to Canterbury; they are as clear in Otago and Southland. In Nelson the effect of an upward movement is seen even more clearly, for a rock terrace is distinct on the Wairoa and Roding Rivers 20 ft. above the present river bed. The terraces on the Rangitikei and Waikato Rivers are also remarkable. This last movement has, therefore, been widespread in the interior and on the coast, but appears to have been greatest in the south.

It is well known that within historic times a spasmodic movement of important extent has been recorded in New Zealand. In 1855 the shore of Wellington Harbour rose 5 ft. during a severe earthquake. The effect was more pronounced on the coast line west of Wellington Heads, and it apparently increased in amount westward, for at Cape Palliser the rise was 9 ft. It is said by Lyall that there was a movement of an opposite character on the south shore of Cook Strait. The evidence of this is, however, less strong than for the movement near Wellington.

Volcanic Action.

Whatever may be the real nature of volcanoes in the scheme of Nature, it is universally agreed that their existence at any spot is an indication of crusted disturbances or instability. It is therefore of importance to consider their distribution with reference to the Tonga-Kermadec ridge and trench. In Tonga itself the active volcanoes, Tofua and Kao, with Latte and Falcon shoal are among the western islands of the group. The eastern are noticeably free from volcanic rocks. The Kermadec islands have shown some activity within historic times. Sunday Island was subjected to eruptions in 1872. On Curtis Island steam jets show that activity is only subdued temporarily. The soundings show no elevated ridge to the east as at the Tonga islands. Depths of 1,500 fathoms are shown close to the islands.

As previously mentioned the sea floor between this ridge and New Zealand is less than 1,500 fathoms deep, but there is little sign of a ridge as New Zealand is approached. The structure of Tonga is reproduced in the East Cape and hot lake district of New Zealand, for here the volcanoes are west of the structural ridge of the land. The Miocene limestones are at a higher level than the older slates which lie between them and the volcanic zones. A deep submergence (3,000 ft.) would therefore in this part of the land cause two lines of islands to be separated—the easterly line would consist of Miocene limestone; the westerly of volcanoes. The slates between them would be entirely submerged.

Traced further south these features entirely change. Even in the North Island the volcanic series stops abruptly at Ruapehu, and in the direction of its continuation is a series of late Cainozoic strata resting almost horizontally. Here, too, the altitude of the argillite peaks is far greater than that of the Cainozoic rocks that are still found to the east of them.

On the southern shore of Cook Strait the difference is more marked still. The range of argillites is still continued in the Kaikoura Mountains. The Cainozoic sediments to the east are now of still less importance. The volcanic rocks to the west, which even in the south part of the North Island is replaced by late Cainozoic sediments, do not extend across the strait; but their place is occupied by first the gravel deposits at the head of Tasman Bay, and then by the great folded zone of the Southern Alps.

North of the Tonga Islands this great ridge bends round to the westward towards Fiji. It appears, so far as may be judged by soundings, to be entirely cut off from the Samoa Islands by water 2,000 or 3,000 fathoms in depth.

In New Zealand the volcanoes which lie on the strike of the Tonga-Kermadec ridge have not emitted any lava within historic times. There is not even any evidence of molten lava reaching the crater of any of the volcanoes except during the eruption of Tarawera in June, 1886; but even on this occasion there was no outflow of lava, though bombs of andesite were ejected. Those mountains that have had explosive eruptions within modern times in addition to Tarawera are the following:—Ruapehu, Ngauruhoe, Tongariro (Te Mari crater), and White Island (Whakari). During the most violent recorded eruption of Te Mari, in 1895, Dr. Von Friedlander, who was then on a visit to the region, failed to see any reflection of hot rock on the steam clouds. Similarly in March, 1907, I failed to see any reflection on the clouds of steam and ashes rising over Ngauruhoe, which was then in explosive eruption. Stress has been laid by Trotter, Dana, and Jensen, as well as many others, on the well-known fact that four days after the Tarawera eruption Whakari showed unusual signs of activity, and that two months later there was an eruption at Niouafu, one of the Tonga group. Against this fact it is well to remember that the great volcanoes of the Taupo region showed no unusual activity, and that beyond a slight change in the activity of several hot springs at Rotorua and other places close to Tarawera there were no signs of disturbance in the volcanic zone of New Zealand itself. Again it frequently happens that Ruapehu is unaffected by the spasmodic action of Ngauruhoe, and a similar independence is shown by Te Mari; for during its period of greatest violence both Ruapehu and Ngauruhoe were quiescent. These facts suggest that too much importance should not be attached to the time relation of the eruptions of 1886, and even suggest that the occurrence of these within a few months of one another was fortuitous.

Outside of the Tonga-Kermadec ridge there is a volcano in a pronounced condition of activity at Savaii, and apparently the actual cone of present eruption only came into existence when the eruption commenced, and, notwithstanding the long and continuous eruption, only a small cone has been formed, though an immense amount of material has been ejected from the volcano. Previous to 1902, when there was an eruption from another cone on the same island, there had not been an eruption in Savaii from any of the cones for, perhaps, 200 years.

Further west the New Hebrides are now the scene of much volcanic action. The islands of Tanna, Ambryn, Lopevi, and Vanna Lava all have volcanoes, some of which are amongst the most active of the world's volcanoes. It appears that no very exact record has hitherto been kept of the eruptions that have occurred in this group of islands. In the Santa Cruz group Tinakolo is the best known for its activity. In South Victoria Land it is well known that Mount Erebus is frequently active.

The Volcanic Rocks.

Microscopic petrography has within recent years made exact study of volcanic rocks a necessary portion of geological research. By its use we have now become familiar with a great variety of rock types, and have a considerable knowledge of their distribution.

Within the South-west Pacific rhyolites are known from New Zealand only. Here with the fragmental pumice material they cover the greater part of the volcanic plateau of the North Island.

The occurrence of trachytes is very limited, so far as the islands is concerned, though very important, as shown by Jensen, on the eastern margin of Australia. They occur at Auckland and Campbell Islands, and at Dunedin, but are unknown elsewhere in New Zealand.

Andesites have a far more general distribution. Within New Zealand, Dunedin and Banks's Peninsula have andesites of somewhat peculiar characters. In the North Island typical andesites are found over a wide area. The greater part of the older Tertiary rocks of the Coromandel Peninsula are andesitic and similar types are widely distributed in the north of Auckland. The rocks of the present active volcanoes are exclusively andesitic. The Kermadecs, the rocks of which were described by Thomas and Speight, are formed mainly of andesitic rocks, though there is a variation towards a basaltic type.

Tofoa and Falcon Shoal, in the Tonga group, are andesites, but again there is an approach to a more basic type.

In Fiji Woolnough says the most recent rocks appear to be a series of andesites, but in the New Hebrides Mawson regards the andesitic eruptions as Miocene.

Alkaline rocks also have a wide distribution. Limits of space will not allow of a discussion of different alkaline groups. Those of basic and acidic character are here grouped together. The rocks of Erebus appear to be alkaline if the samples forwarded by the Nimrod expedition are a criterion of the composition of the whole mass. Rocks of a sub-alkaline character are found at Campbell Island, and there is a fine series of phonolites and related rocks at Dunedin. At Auckland the basanites are rather widely distributed, and their age is very late.

At Rarotonga a nephelinite occurs at the north and south end of the island, and at Aitutaki there is a typical nepheline basalt. In this connection the occurrence of alkaline plutonic rocks at Tahiti, as recorded by La Croix, is of great interest.

Basalts have, of course, a wide distribution. They are now being emitted at Savaii and the New Hebrides, and they occur in practically all the areas mentioned above, except in the volcanic plateau of New Zealand, though even here examples are found to the west and to the north of it. It appears that basalts have not yet been recorded from Tahiti, though dolerites are abundant. It is worthy of mention in this connection that in New Caledonia no Cainozoic volcanic rocks are mentioned by Heurteau.

Structure.

The tectonics of the South-west Pacific region have attracted the attention of many observers, and the following opinions appear to express the divergent views which are held:—

Suess, it is well known, contrasts the Pacific coast type with the Atlantic. It is important to quote the exact words of this contrast. With two quoted exceptions: "The outer side of a folded range nowhere determines the outlines of the Atlantic." "The inner side of folded ranges, jagged rias coasts which indicate the subsidence of mountain chains, fractured margins of horsts and fractured tableland form the diversified boundary of the Atlantic Ocean." With one exception, "The whole boundary of the Pacific Ocean, wherever it is known in any detail, is formed of mountain chains folded towards the ocean in such a manner that their outer folds either form the boundary of the mainland itself or lie in front of it as peninsulas and island chains." Of the Pacific, he says: "The structure of this ocean shows that it was already in existence in the Trias epoch." He appears to accept Dana's views "that the Loyalty Islands, New Hebrides, Solomons, New Ireland, and the Admiralty group are the outer arc of the Australian region," and to sympathise with Drasche's idea, "It would be sound geology to draw the eastern boundary of the Pacific Ocean outside the Island arcs from Kamchatka through Japan and onwards through the Macquarie Islands to Victoria Land in the Antarctic region." He has also entered into a comparison between the structure of Australasia from west to east, and S. America from east to west, which is rather too long to quote here, but it is noticeable that in this comparison no American parallel to the great basin of the Tasman Sea is mentioned.

Gregory has adopted these views almost *in toto.* In the Geography of Victoria a map shows the Australasian festoon uniting New Zealand with New Caledonia and New Guinea. Another structure line joins Tonga to the Ellice and Marshall Islands, while Easter Island and Samoa are the extremities of the South Pacific chain.

In a more recent map, "Geology Structural and Physical," the Australasian festoon includes the Solomons and New Hebrides. The Micronesian festoon extends from Tonga to the Marshall and Caroline Islands, and includes Samoa. The South Pacific chain extends from Easter Island to the Phœnix Islands.

Gregory adopts Suess's comparison of the structure of South America and Australia, but takes the section in the north of Brazil instead of the north of Argentina, as in Suess's comparison. The counterpart of the Thomson trough is the comparatively small depression between the eastern cordilleras and the main range.

The contrast between Pacific and Atlantic coasts is adopted, but Gregory calls the Australian coast sub-Pacific, the prefix meaning that the real structural Australian coast line is the Australasian festoon, which is broken through in so many places.

Prior has also adopted this contrast between Pacific and Atlantic coasts as expressing an earth truth, and has added that the Atlantic type of coast is associated with the eruption of alkaline rocks, the Pacific with andesite. He has stated that the geological results in Antarctica support this view, but, judging by a criticism by Gregory, this extension of Suess's opinions is not supported by him.

Mawson, in his paper on the "Geology of the New Hebrides," accounts for the features of these islands in the terms of Suess. Two lines of fracture—east and west—are described. The separation of the islands is due to "blatter" fractures and movements and cross faulting. The direction of the folds and faults is regarded as determined by the great "Hercynian" lines from New Guinea through New Caledonia to meet the Carboniferous fold of New Zealand.

Jensen, in describing the eruptions at Savaii, says it is probably on account of the situation of Savaii at the intersection of two great structural lines that volcanic extravasation has been so great here. He says further, New Zealand has a west coast covered with Tertiary eruptive rocks, with a sharp faulted front towards the deep ocean. More recently Jensen has accepted Prior's statement in regard to the association of Atlantic coast with eruptions of alkaline rocks, and states that alkaline eruptives only occur in block faulted regions, and are typical continental rocks. The islands on which alkalines occur must be regarded as relics of more extensive continents disrupted into fragments in the early Tertiary. The Eocene is regarded as the period when alkaline eruptions took place, and the alkaline rocks are supposed by Jensen to result from the absorption of salt beds and other stratified alkaline rocks by a magma. The views of these authors have been quoted because the facts that have already been mentioned are really the basis upon which theories should rest, and a consideration of them leads the authors to opinions quite different from those here summarised.

The classification of coast lines as Pacific and Atlantic in type is not yet accepted by many authorities. Thus there is no mention of it by Davis, Chamberlain, and Salisbury, Chamberlain's Physiography, Lapparent Geographie Physique. If the classification expressed a terrestrial truth, it should be not only a broad generalisation, but should apply equally to details. All the authorities quoted appear to regard New Zealand as a part of the old Australasian shore line. It should then be typically Pacific in structure. This is true of the west coast of the South Island, which is generally admitted to be the outer portion of a great fold.

If the east coast is considered, it must naturally be regarded as the inner side of the same fold, and therefore Atlantic in type. Further, the fold in Otago bends south-east, and is cut off by the coast line—again an Atlantic character. The shore line of Cook Strait is a rias coast, and the same feature is repeated from the Thames to the North Cape. Thus, if judged by its features, the greater part of the New Zealand coast line is Atlantic in character.

If the distribution of volcanic rocks is examined, the association of alkaline rocks with the Atlantic type of coast holds at Dunedin. At Cook Straits the towering andesitic cone of Egmont dominates the rias coast of the South Island. The coast from East Cape, where the mountain range is truncated, to North Cape is associated throughout with andesite rocks; that is, the Atlantic coast type is here found with the volcanic rocks said to be characteristic of the Pacific coast type. It is difficult to agree with Gregory that the coastal features of the South owe their regularity to the recent date of the north-east south-west movements. In the earlier part of this paper it was stated that movements had taken place before the Miocene period of such a character as to fold the Jurassic rocks into mountain ranges, and these folds had been worn down before the Miocene rocks were deposited. At the close of the Mesozoic the trend of the coast line had been clearly defined. If the coasts were defined by faults, evidence of this should be found between the Miocene and the Jurassic sediments, where the coast line was originally formed in the Miocene period. No such faults, however, have been found, though the depression of the coast line was so profound. In many places Miocene sediments rest with a clear unconformity on Jurassic sediments. On the other hand, the Miocene rocks form low cliffs on the sea front, and for the greater part shallow water extends some distance seaward—these features do not indicate dislocations of a recent nature.

The evenness of the coast line is believed by the author to be due to the recent movement of elevation, of which evidence was given earlier. This has been aided by the powerful drift along the coast which has blocked up many of the valleys eroded after the late or post-Miocene elevation, though in all places where high and hard land allowed of the formation of deep valleys during the elevation partially blocked marine inlets are now found. Jensen's statement in regard to the volcanic rocks on the west coast of New Zealand and the sharp faulted coast is opposed to actual facts. Whether the origin of alkaline rocks is as Jensen argues cannot be settled by the evidence offered in this region. However, it has been mentioned that the supposed association of Atlantic coast and such rocks is strikingly denied by actual occurrences in New Zealand. It appears somewhat heroic to regard such isolated islands as Rarotonga and Tahiti as fragments of a fractured and shattered continent.

It is impossible here to enter into a full discussion of the matter, but it may be remarked that the frequent association of alkaline and highly basic lavas is suggestive. Such association may be a result of magmatic differentiation. Such I believe to have been the case at Dunedin. The union of groups of Pacific islands into festoons and chains seems largely fanciful. That there was shallow water or land connection between New Zealand and New Caledonia in Triassic times is shown to be true by the identification of similar Triassic fossils in the two lands. The subsequent folding was probably effected at the same time, and in both countries the rocks have been penetrated by the ultra basic magmas. These facts coupled with the shallow water between the lands are, perhaps, sufficient to prove that they form portions, now isolated, of a common earth structure.

The similarity between Tonga and the north-east of the North Island of New Zealand again establishes a close relationship, and the idea is supported by the occurrence of a shallow water ridge between them—a ridge which extends through Fiji to the New Hebrides—and these islands show a similarity of structure, so far as later geological deposits are concerned, such as the association of andesites with raised limestones. There appears to be more reason to regard this ridge as a continuous structural feature than any other that has been mentioned in this part of the Pacific.

I can find no further support for the supposed existence of the South Pacific chain mentioned by Gregory than the fact that some groups of islands have an arrangement that is more or less linear. Soundings, however, show that these islands are, so far as known, isolated volcanic mountains towering high above an ocean floor which is remarkably level. The idea of Savaii lying at the junction of two lines of earth weakness does not appear to me to have any support from actual facts. Nor is such an explanation necessary to account for the extravasation of lava which, during the present eruption, has not been greater than in hundreds of other areas where volcanic action has been in progress.

Elevation and Depression.

In the enumeration of elevated areas many of the Pacific islands were mentioned, and it is possible that a large portion of the floor of the Pacific has been undergoing slow upward movement in late geological times.

On the other hand coral structures, such as atolls and barrier reefs, indicate the opposite. Darwin's theory of the origin of atolls has received such strong support from the Funafuti borings that in the absence of other evidence it is now reasonable to regard the occurrence of atolls as proof of subsidence within the area in which they are found. Now such atolls are found in the Fiji group and in the Tonga group; and barrier reefs are also present in the Fiji group, and Darwin mentions one at Tahiti. Within these groups there are evidence of two movements, the atolls indicating subsidence, the coral reefs elèvation. It may be that in volcanic areas coral reefs may be formed round the margins of volcanic shoals as Lister suggests is the case in the Tonga group. In other cases the elevation may have preceded the depression. However, at Fiji, Woolnough records continuous elevation for a long period at Viti Levu, but we do not at present know over what area this movement extends.

In the neighbourhood of the Cook islands, Palmerston, Suwarrow, Penrhyn, Danger Islands are all isolated atolls, and may be held to indicate elevation. The study of the land structure of these islands prove that in some places where Darwin supposed subsidence in progress there has in reality been elevation quite recently, but his main idea of differential movement is not traversed.

Folding.

It has been stated that many parts of the Pacific area under review have been folded. New Zealand, Fiji, New Caledonia, all have much folded rock masses. There is no reason to suppose that this action has ceased. The very idea of folding suggests the elevation and depression of two adjacent areas, an anticlinorium and synclinorium, and such action would easily and simply account for the observed movements in the South-west Pacific. It is well known that actual folds are often quite gentle rises; it is only in regions of maximum action that sharp mountain ranges or submarine ridges are formed, and then only after the folded rocks have been submitted to prolong subaerial erosion.

The most important feature of the marine area is the great trench east of Tonga and the Kermadecs. If this is regarded as a "graben" or rift valley it presupposes a very remarkable want of support within the earth's crust as a result of which a segment could fall 6 inches below the sea surface. On the other hand it must be remembered that the floor of the Pacific is 2,500 fathoms or more below sea level. The bottom of the trench is about as much below this level as the Tonga ridge is above it. It is, therefore, not unreasonable to regard the trench as a syncline and the ridge as an anticline of a huge earth fold of the progress of which the earthquakes are evidence.

Mr. Hoben has shown that an important centrum for earthquakes exists near the end of the great trench which suggests that it was still extending.

Conclusions.

The ocean contours show that—

1. The New Zealand Plateau extends to the outlying southern islands and has a north-westerly extension to the New Caledonia plateau, and that another narrow ridge extends to Norfolk Island.
2. The Tonga-Kermadec ridge is a continuation of the dominant mountain structure of New Zealand and is similar to it in arrangement of rock masses at its northern extremity.

3. Samoa is entirely separate from this ridge.
4. There is no indication in the soundings that the different island groups further east are connected by submarine ridges.
5. The Tonga-Kermadec trench is almost continuous at a depth of 4,000 fathoms from Samoa to East Cape of New Zealand.

The main period of mountain formation in New Zealand was in the late Jurassic and was possibly contemporaneous with rock folding in New Caledonia, but preceded the movements in the New Hebrides.

This great elevation was succeeded by a prolonged Miocene depression, but was followed by another elevation.

The coast line shows evidence of subsidence, but this has been succeeded by renewed elevation.

In the New Hebrides the elevation has been continuous since the Miocene, and the same is true of Fiji.

At Tonga, Nieue, and Mangaia, there have been upward movements in the latest geological times.

The occurrence of atolls in various places must be regarded as evidence of subsidence, or at least of no elevation.

The New Zealand coasts are not determined by fault planes, but their main directions are at least as old as the Miocene period.

Much of the New Zealand coast line is of the Atlantic type.

The occurrence of alkaline rocks in mid-Pacific goes far to negative the idea that alkaline eruptives are associated with the occurrence of the Atlantic coast type.

The formation of the Tonga-Kermadec trench may be an effect of normal folding.

There is nothing in the geology of this area to suggest that any of the oceanic basins have been formed by sudden subsidence.

Except for the Triassic fossils of New Caledonia and New Zealand, and, perhaps, in the Cainozoic mollusca of Australia and New Zealand, there is no palæontological evidence to suggest that any of the lands now separated were formerly united.

The rocks both volcanic and sedimentary fail to suggest any previous connection between lands now separated unless the occurrence of large masses of ultra-basic rocks in New Caledonia and New Zealand may be regarded in this light.

BIBLIOGRAPHY.

The following are among the more important of the works that should be consulted on this subject:—

Barnard, A.—L'Archipel de la Nouvelle Caledonie. (Hachette et Cie, 1895.)

Bastian, A.—Inselgruppen in Oceanien, Berlin, 1883.

Dana, J. D.—Corals and Coral Islands. (Sampson Low, 1875.)
— Characteristics of Volcanoes. (Sampson Low, 1890.)
— Geology of U.S. Exploring Expedition.

DARWIN, C.—Coral Reefs. (Minerva Library.)
— Geological Observations on Volcanic Islands. (Minerva Library.)

DAVID, T. W. E.—Atoll of Funafuti. (Royal Society, 1904.)
— Geological Climates. (Congrès Geologie International, 1906.)

DIESELDORF, A.—Gesteine und Fossilien der Chathaminseln, Marburg, 1901.

"CHALLENGER" RESULTS, 1873-1876.—Especially the petrology of Volcanic Islands and Bathymetric Map.

DUTTON, C. E.—Characteristics of Hawaiian Volcanoes. (U.S. Geological Survey Annual Report, 1883.)

FILHOL, H.—Mission de l'isle Campbell, 1875.

GUPPY, H. B.—Observations of a Naturalist in the Pacific, 1903.

GREGORY, J. W.—Geography of Victoria. (Whitcombe and Tombs, 1903.)
— Great Rift Valley, London, 1896.
— Geography, Structural, Physical, and Comparative. (Blackie, 1908.)

HAAST, J.—Geology of Canterbury and Westland, Christchurch, 1879.

HAHN, F. G.—Insel Studien, Leipzig, 1883.

HECTOR, J.—Outline of New Zealand Geology, 1886.
— Many papers in the reports of the New Zealand Geological Survey.

HEIM, A.—Naturforschenden Gesellschaft, 1905, Neuzeeland, Zurich.

HUTTON, F. W.—Geology of Otago and Southland, N.Z., Dunedin, 1875.
— Geology of New Zealand. (Q.J.G.S., 1885.)
— Geological History of New Zealand. (T.N.Z.I., 1899.)

JENSEN, H. I.—Several papers on the Petrography of the Alkaline Rocks of Eastern Australia. (Proc. Linn. Soc., N.S.W., 1906-1908.)
— Geology of Samoa and Eruptions of Savaii. (Proc. Linn. Soc., N.S.W., 1906.)
— Distribution Origin and Relationship of Alkaline Rocks. (P.L.S., N.S.W., 1908.)

KRUMMEL, O.—Ozeanographie. (Stuttgart, 1907.)

LISTER, J. J.—Geology of Tonga Islands. (Q.J.G.S., 1891.)

MARSHALL, P.—Geology of New Zealand. (Whitcombe and Tombs, 1905.)
— Distribution of the Igneous Rocks of New Zealand. (T.A.A.A.S., 1906.)
— Geology of the Centre and North of the North Island of New Zealand. (T.N.Z.I., 1906.)
— Geology of Dunedin. (Q.J.G.S., 1906.)
— Many Petrographical Papers in T.N.Z.I. from 1892-1908.

MAWSON, D.—The Geology of the New Hebrides. (P.L.S.N.S.W., 1905.) This contains a good bibliography of the literature of the New Hebrides.

NATIONAL Antarctic Expedition. (Natural Science, Vol. I., Geology, 1908.)

PARK, J.—Jurassic Age of the Maitai. (T.N.Z.I., 1904.)
— Marine Tertiaries of Otago and Canterbury. (T.N.Z.I., 1905.)
— Also several papers in T.N.Z.I., and bulletins of the Geological Survey.

SPEIGHT, R.—Geological History of Tongariro National Park. C., II. Wellington, 1908.
— Rocks of the Kermadecs. (T.N.Z.I., 1895.)

SUESS, E.—The Face of the Earth. Oxford, 1904-1908.

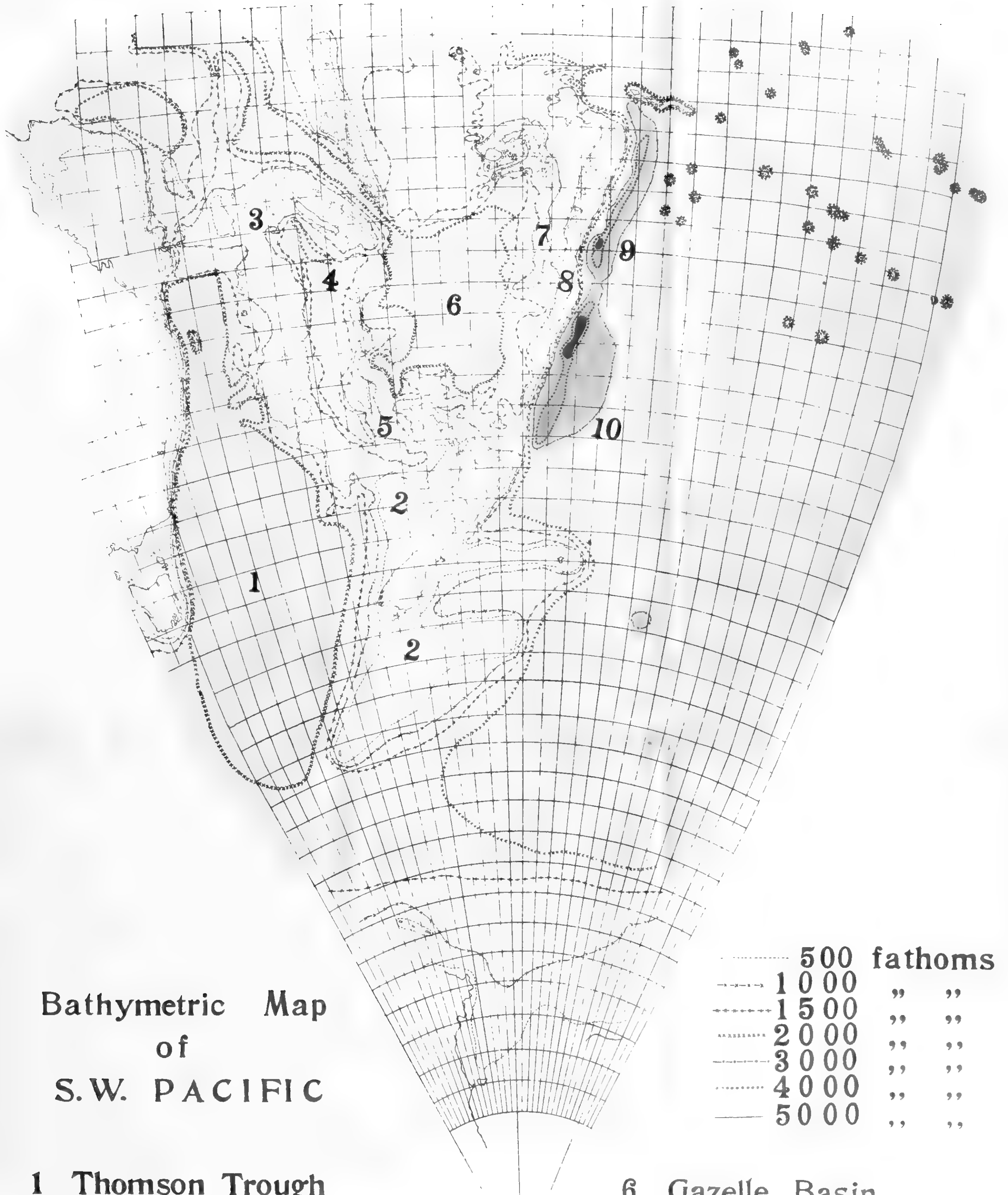
DE TCHICHATCHEFF, P.—Les Isles Oceaniques. Bailliere, Paris, 1878.

THOMAS, A. P. W.—Eruption of Tarawera, 1886.
— Geological Notes on Taupo and the King Country. (T.N.Z.I., 1886.)
— Rocks of Kermadec Islands. (T.N.Z.I., 1886.)
— Notes on the Geology of Taupo and Tongariro. (T.N.Z.I., 1887.)

VOJNICH, O.—Tonga Inseln. (Foldrojzi Kozlemenyck, 1907.)

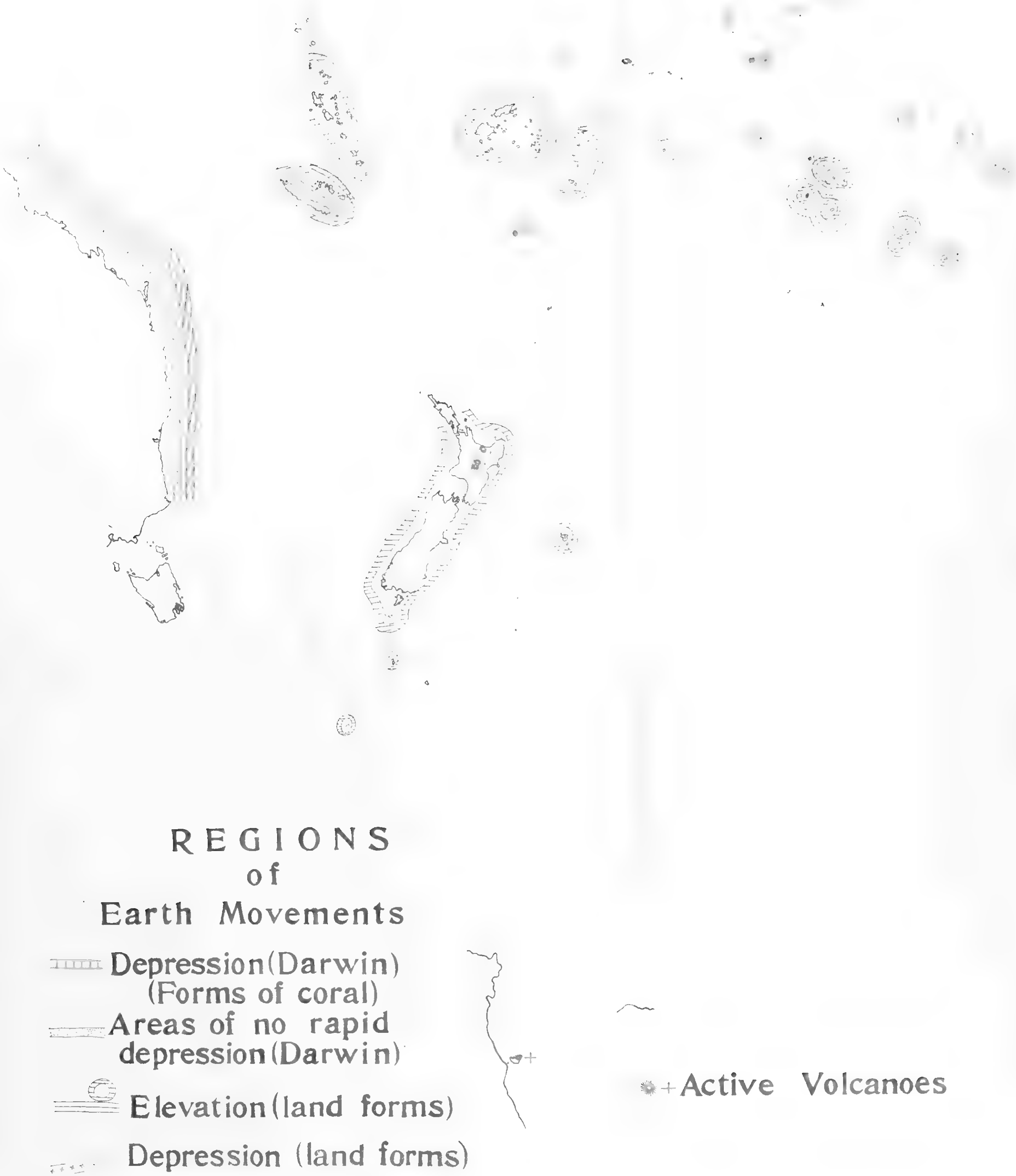
WILKES, C.—U.S. Exploring Expedition, 1882.

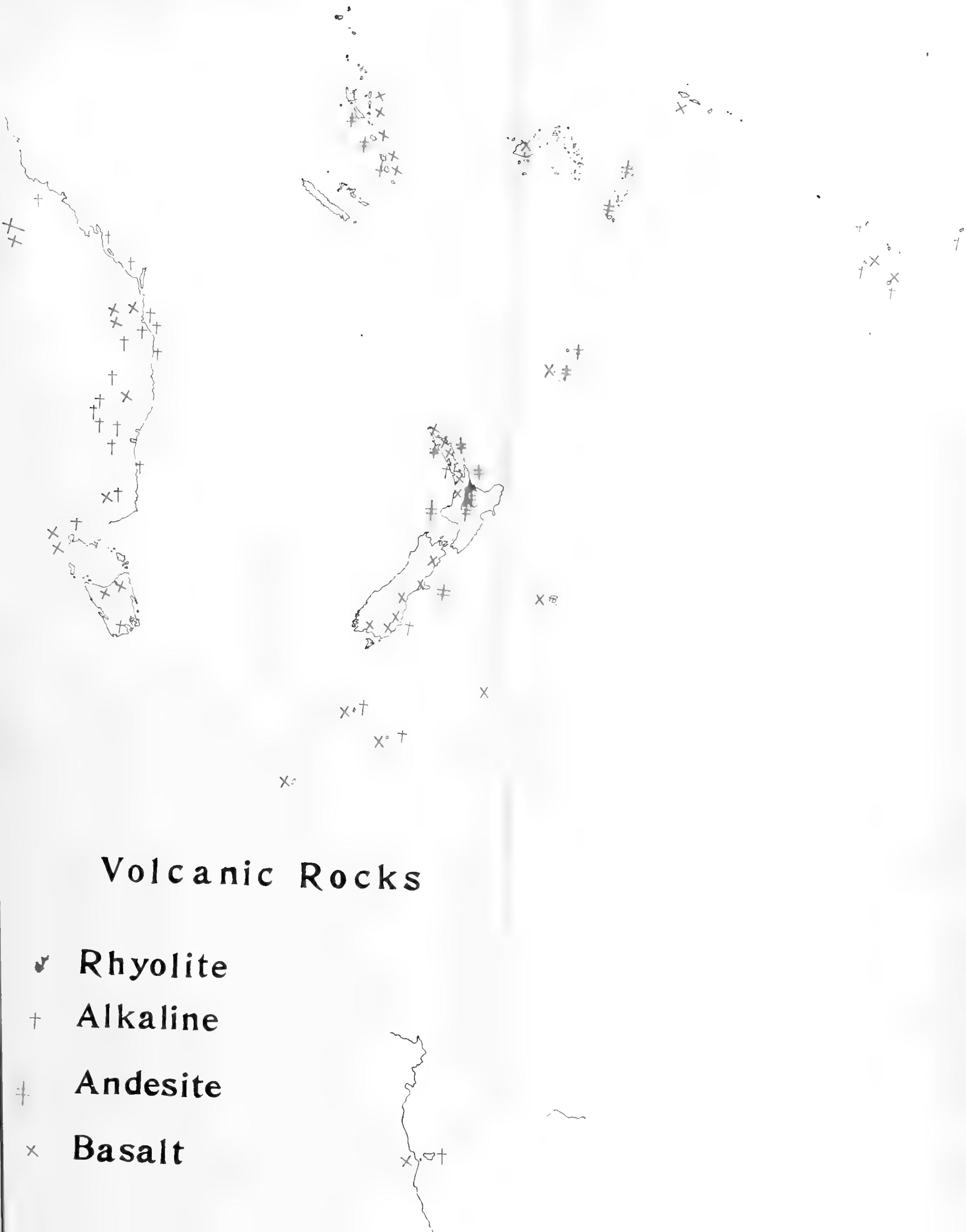
WOOLNOUGH, W. G.—Continental Origin of Fiji. (P.L.S.N.S.W., 1903.)
— Geology of Vitu Levu, Fiji. (P.L.S.O.N.S.W., 1907.)

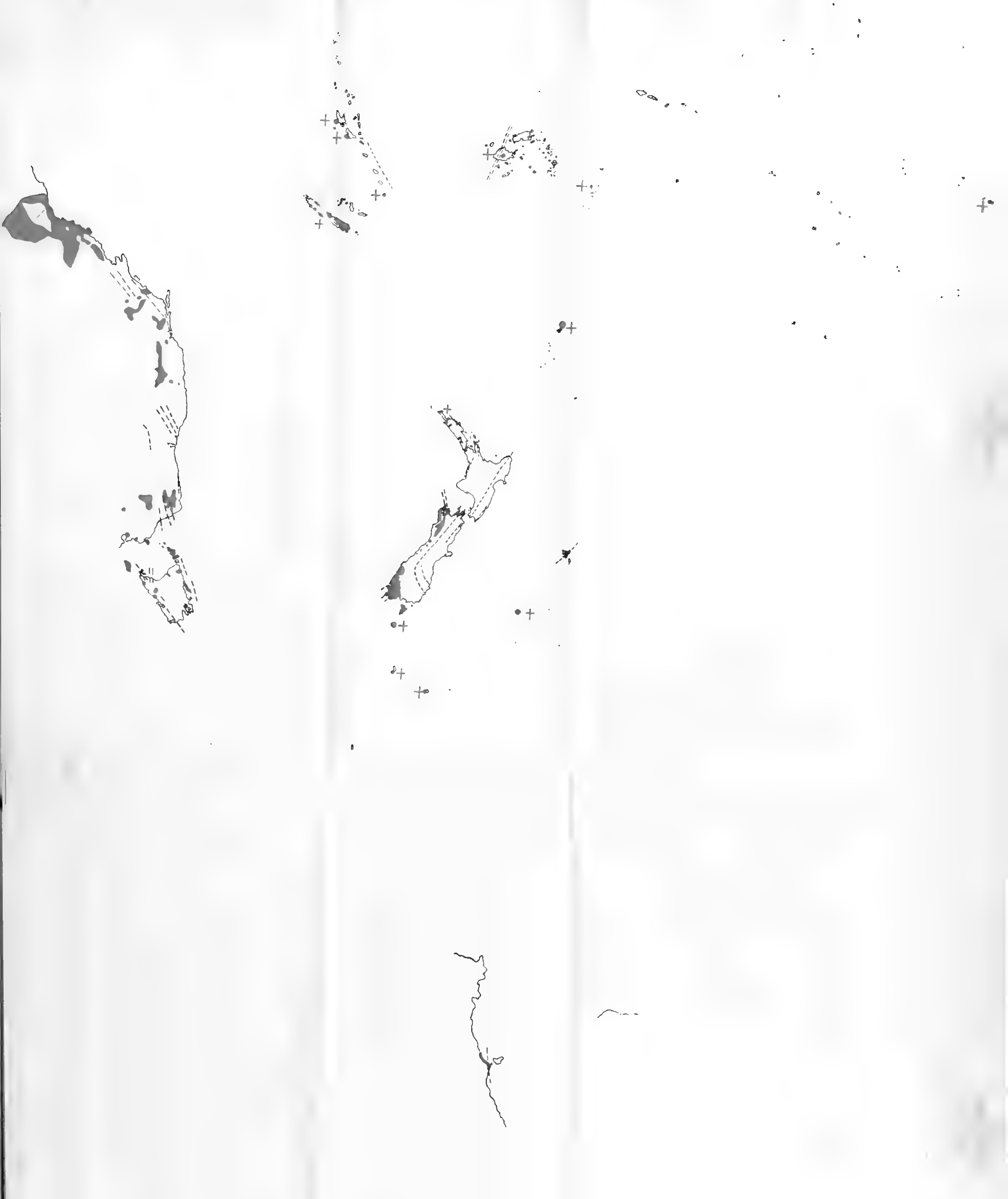


Bathymetric Map
of
S.W. PACIFIC

1 Thomson Trough
2 New Zealand Plateau
3 New Caledonia Plateau
4 New Caledonia Trench
5 Norfolk Ridge
6 Gazelle Basin
7 Fiji Plateau And Ridge
8 Tonga Kermadec Ridge
9 Tonga Deep
10 Kermadec Deep


REGIONS
of
Earth Movements
Depression (Darwin)
(Forms of coral)
Areas of no rapid
depression (Darwin)
Elevation (land forms)
Depression (land forms)
Active Volcanoes


Volcanic Rocks
Rhyolite
Alkaline
Andesite
Basalt


+Plutonic Rocks
Lines of rock folds

Section F.

ANTHROPOLOGY AND ETHNOLOGY.

PRESIDENTIAL ADDRESS

BY

MR. AUGUSTUS G. HAMILTON,
Director, Dominion Museum, Wellington, New Zealand.

[At the date of going to press, Mr. Hamilton's address was not to hand.]

PAPERS READ IN SECTION F.

1.—SOME NOTES ON SAVAGE LIFE IN NEW BRITAIN.

By REV. B. DANKS, General Secretary of the Methodist Missionary Society of Australasia.

Savage life is much more complex than many imagine. There are those who seem to think they have fully described the savage when they have applied such terms as ignorant, superstitious, cruel, &c., to him, forgetful of the fact that his life is as much the expression of his beliefs touching the world, the present life, and his hopes and fears for the future, as the life and usages of civilised nations are the expression of their convictions upon the same things. There is breadth, depth, and contradictions even in savage life that baffle the anthropolgist. These wild men ask the momentous questions we ask, viz.—Whence? Whither? Why? And the answers which satisfy them are found in the manners and customs of the people.

The savage is aptly called a child of Nature. The animal, vegetable, and mineral kingdoms, in so far as they come within the range of his observation, are known to him as it is given to few civilised men to know them, and there is to him deep mystery in them all, which mystery he explains to himself by an intense belief in supernatural powers. Savages are the world's most fervent spiritualists, believing that behind and in everything there is an appropriate spirit, to which it owes its corporate existence and which constitutes its powers for good or evil, its virtues or its vices. They fiercely express this conviction by eating the eyes and heart of their foes, hoping thereby to add to their own sight and courage the sight and courage of their late enemies. The burial of spears, clubs, canoes, wealth, wives, and servants with the deceased chief or husband is founded on the same belief, and the elaborate funeral ceremonies of the ancient Egyptians, observed through thousands of years, testify to the fact that such spiritual beliefs are as old and as widespread as the race. In this belief lies the power of the medicine man, the mesmerist, and the strong personality of savage leaders. Behind and in them all is believed to dwell the dread power of the spirit world, and the life of the savage is ordered and hedged about by his conception of the attitude of that world to himself, in which he literally believes he lives and moves and has his being. This is an aspect of savage life which is too frequently thrust aside by some as of little value, while, in point of fact, it really gives direction and colour to every custom and every phase of savage life. Their ignorance of anything beyond their immediate surroundings leaves them to speculate as to what is beyond, and some of their speculations are grotesque indeed.

The horizon has its mysteries, and all is a blank beyond it. The word for it in the Duke of York language is *Kabin a bual*—*i.e.*, "the beginning of places," and the puzzling question as to what became of ships when they reached this edge of the world was formerly often asked. Our own word horizon must have originally contained the same idea, being derived from a word denoting a circle, or a limit. On New Britain the word meaning horizon is *Turuturu Bakut*—*i.e.*, "the resting place or foundation of the clouds." Much of the little world within this circle was not known to them, there were many strange places within it they dared not visit, and so even this limited area was to them full of mystery and full of things and people to be dreaded and shunned. If that which is within the range of their own vision is so much the subject of superstitious speculation, we cannot wonder that the mystery of themselves, their life, the circumstances, and forces that influence them are all of the first importance to them.

Earthquakes are very frequent in New Britain; they terrify the people, and must be accounted for. Now on the island of Duke of York, the name for scorpion and earthquake is identical—viz., *gurea*, and the connection is this:—In the long ages ago a man was bitten by a scorpion, and in his rage he stamped upon it and killed it, and immediately the first earthquake resulted. Hence the people of those parts will not kill scorpions willingly.

All things were made by two mythological personages. One, whose name is *To Kabinana*, in both New Britain and on the island of Duke of York, made everything good and useful; he was also the founder of every art and trade. The rich soil, fruitful trees, and all useful animals were made by him, and he is the personification of wisdom and cleverness. To be named after this being, not in youth, but by reason of wisdom or cleverness, is to be paid the highest compliment. He is the pattern of a good worker in any direction, and to work neatly, strongly, and serviceably, is to be a *To Kabinana*. On the other hand, *To Pulgo*, in Duke of York, and on New Britain *To Kovúvuru*, is credited with having formed all the useless barren and stony land, all high hills, and everything evil, hurtful, ugly, clumsy, or ill-formed, and to call a man *To Kovúvuru* is to greatly shame him. How these personages themselves came to be, there is no tradition to say. They seem to be, in the minds of the people, the cause of all things.

The banyan tree is an object of special reverence and fear, and in this tree worship the New Britain savage is linked on to the savages of the world and the ancient civilisations, as revealed on the cylinders of Chaldea, some of which date back to 4,000 B.C., and in the folk-lore of many peoples, and still lingering among us, as some assert, in our maypole and Christmas tree. The banyan tree is one calculated to arouse curiosity and wonder among a primitive race. Contrary to ordinary methods of vegetable growth, instead of rooting first in the ground, it grows down to it. A seed carried by a bird or a breeze and lodged on some palm or tree, bursts into life, and sends down its roots to the earth in long rope-like tentacles. These each take root, and develop into a trunk, and many others follow, until the original tree on which it first sprouted is killed and hundreds of trunks, big and little, cover large areas of ground. Such deviation from the ordinary life of vegetable matter can only be accounted for, according to the savage mind, by supernatural agency, and the people regard the tree with great fear. This tree is also held in fear by the Indians. "A Bengal folk-tale tells of a certain banyan tree haunted by spirits who had a habit of wringing the necks of all who ventured to approach the tree at night. In another Indian story a tree that grew beside a Brahman's house was inhabited by a *Saakehinni*, a female spirit of white complexion, who one day seized the Brahman's wife, and thrust her into a hole in the tree."* It is, however, very difficult to learn what particular form of malice the Banyan tree spirit in New Britain favours. I am disposed to think the minds of the people hold it in a general dread of illness and death rather than as producing special forms of punishment for intrusion upon its sacred precincts, and it is one of the surest signs of growing enlightenment when a man dares its dreadful influence by approaching and handling the tree without fear and consequent illness.

A shooting star is to the savage of New Britain a thing of fear. On Duke of York Group it is called *a Wirua*. Now, *wirua* means to die by violence principally, and *a wirua* is the corpse for a cannibal feast. Hence, when a shooting star flashes across the sky, people cry out "*A wirua, a wirua!*" and the belief is that when the star flashes on its way a person has just been killed for cannibal purposes. In New Britain the name given to a meteor is *tulugiai ra virua*—*i.e.*, the soul of a body killed for cannibalistic purposes. Another name for meteor on one part of New Britain is *palalilivai*, the etymology of which is obscure. *Lilivai* means either the kneecap or the calyx of the cocoanut or scoop. *Pal* may mean skin or house, according as to its context. *Palalilivai* also means the *ignis fatuus*, the similarity of a meteor to which is clearly seen, and in all probability the word refers primarily to that. It is evidently a compound word, the true etymological meaning of which is now lost. The words *tulugiai ra virua*, however, show how vitally connected in the savage mind are human affairs with the super-human world.

The flying-fox is a favourite dish with the people, and is also an object of fear, especially in the islands of Duke of York. The word for a poor man is *qanau*, which is also the name for a flying fox, and again the connection of the human and the spiritual is denoted. This animal inhabits dens and caves of the earth, and becomes active only at night, a time which is full of terror for the savage. It is the

* The Sacred Tree. Mr. J. H. Philpot.

playtime of spirits when they vent their spite or play their pranks on men. Now a poor man, according to a New Britain savage, finds no welcome in the better land, but is driven forth as useless and unfit for the eternal companionship of the successful, so there the poor cease from troubling by not being admitted. For not being successful in securing earthly wealth, he is dashed against the trunks of the banyan tree, and then left to take up his abode in a flying-fox, if he can find one, and there are plenty of them. Should this creature be disturbed during the day and fly across country, the people are full of fear until it settles somewhere, and should it happen to do so on a tree overhanging a village, that village is greatly perturbed, especially if the inhabitants had taken part in killing and eating a person. Vengeance from a power they cannot successfully contend against is feared. So conscience makes cowards of us all, savage and civilised.

Communication with the spirit world is held to be possible, and there are no more faithful and ardent spiritualists in the world than the New Britain savages. I was once present at a native séance, which was held in an open space in the bush. The surrounding trees cast a deep darkness on the spot, so that it was impossible to see more than a yard or so ahead. It was black unrelieved darkness. I knew by the sound of much whispering that a great crowd of people was there. In the space there were two companies of men, one company at each end of the open space. They were all dressed in white, the spirits being supposed to like that colour. At the sound of a whistle these two companies marched past each other across the open, and so changed ends, making a weird procession, amid a profound silence. I said something to my neighbour and was immediately warned to keep silent. In answer to the question put in the lowest of whispers, What are they doing? I was informed that *Ingal*, the spirit they sought, would presently be so pleased with their wooing in this way, that he would reveal himself to them. There was deep feeling and great expectancy on the part of the crowd, so much so that the murky atmosphere was charged with it, and under such circumstances one does not wonder that the people think they actually see what they came to see. In addition to the marching already mentioned, there were in a house close by a number of the leading spiritualists of the town muttering and chirping as men did in the ages past. Presently a sound was heard in the forest, and a great subdued sob went up from the multitude, for was not *Ingal* coming? I waited long, but he came not that night, and it was soon mentioned that I was the unbeliever who kept him away, and I was urged to leave, which after a while I did. I was told next day that after I left he came, a sure evidence that I was the hindrance, which added to my security, for if I was stronger than *Ingal* I must indeed be strong. I was never again invited to a séance. This *Ingal* may enter into a man, and through him may be revealed the secrets of the *malira*, or charm either for good or evil use, and he is therefore much sought after. *Ingal* is supposed to live at the top of very high trees, and may be induced to come down and converse with men.

It is believed that the spirit of man may leave his body for a time, and enter into animals, birds, or fish. But should the creature into which the spirit of a man has entered be killed while he is in it, then the man's body dies. On one occasion in my town a man was wounded by a spear thrust in the shoulder during the night. Next morning he was questioned about it, and declared that he had entered into a fish, and happening to come near the reef on which were some men with a torch and fishing spears, the fish was wounded close to the fore fin, and so his body received the wound. How this could be one cannot explain, but whatever his people may have thought, they accepted the story, and no more was said. In this way men are supposed to take long journeys as birds into the bush, and come back and tell travellers' stories to their people as to what they have seen. Dreams are, of course, responsible for this belief, for dreams are to them real occurrences in the spirit world, hence the grotesqueness of many savage superstitions.

Charms are a great power with the people, and there are as many of them as there are clever or wealthy men. Every man may have (*i.e.*—buy) his own *malira*, or charm. These are believed to come originally from *Ingal* to some person who sells it to those who can buy. It is dear or cheap, according to its reputation. They are used for any purpose the purchaser desires. Now a love charm, now to secure acquiescence to indecent proposals, now to inflict disease, now to prevent recovery, or any other purpose in view. They mostly consist of leaves, bark, or sap of trees, and are sometimes administered in the food of the person to be influenced and at other times are counted effective through the simple incantation of the wizard. It will, of course, be seen by this that the same charm may serve many, and even opposite purposes, according to the desire of the owner. It may be used to guard himself and hurt his foe. There are, however, specific charms for special purposes, such as the *iquora*, which consists in pricking in a certain manner the footprints of a person, with the barbed bone of a ray fish. This brings upon the person thus treated by a *Tenaquaquar* (wizard) the sickness or evil desired. The *dokadoko* is a charm placed at the entrance of a fishtrap, and is supposed to induce fish to enter. Sometimes they, the *malira* or charms, are made out of anything that has had connection or contact with a person, such as remains of food of which she or he has partaken; earth from a footprint, excrement, spittle, hair, or clothing. Any of these things may be buried with incantation ceremonies, and thus through the process afflict the people concerned in various ways. The name of this custom is *puta* and the articles used *putaputana*. This last kind of *malira* is much guarded against. Expectoration is in the form of infinitesimal spray. (Stooling is always in absolute secrecy, and with the greatest care.) When shaving or cutting the hair, every scrap of hair is carefully burnt, and the crumbs of one's food also burned. Now, all these charms work by the power of the spirit world, and through the spiritual connection of things and men, and day and night people live and move and have their being in a spiritualistic atmosphere. They fear each other less as men than they do as men possessed of a powerful *malira*. To us this is ridiculous, but not so to them. There is no doubt with them; all is true, even the most incongruous and unreasonable statements in regard to these matters. They never think of the strife of spirit and power against spirit and power if these things are true, and, indeed, perhaps seeing they themselves strive against and jostle each other, it may but seem natural that the spirits also should so strive.

The thief, for instance, has his charm for his purposes in the *Turagan*, and for the detection of theft is the *palpalum*. Now *Turagan* means a certain evil spirit. It also means the bones used by a thief and which he placed on the chests of the inmates of a house when asleep, and they are supposed to keep them asleep while the thief takes possession of the household goods. A cheap and an easy method of carrying on burglary. It is also interesting to note that *Tabaran* also means an evil spirit and a despised poor person, so that it would seem that the savages of New Britain have the same idea about poverty as Tennyson's Northern Farmer, when he said to his son:—

"Proputty, proputty's ivrything 'ere, an', Sammy, I'm blest
If it isn't the same oop yonder, for them as 'as it's the best.
'Tis'n them as 'as munny as breaks into 'ouses and steals,
Them as 'as coats to their backs an' takes their regular meals.
Noa, but it's them as never knows wheer a meal's to be 'ad.
Take my word for it, Sammy, the poor in a loomp is bad."

The spirit of a thief, then, guards the thief by the charm called *turagan*.

The detection of theft is an elaborate affair, and costs money. Again, the detective is a dealer in spirits, and is called *To Palpalum*, from the name of the charm. It is sometimes a tedious business. All the suspected persons may be got together, and, after an incantation has been muttered by *To Palpalum*, they are each in turn made to suddenly strike out with the fist or suddenly straighten out the arm, and he whose elbow joint gives out a cracking sound is the thief. No protest can save him from the consequences or clear his character. Another process is to have all the town or village gathered on an open space. *To Palpalum* then passes in front of them all, his finger tips to his lips, and his elbow at right angles to his body, and pointing to the people. Passing along the line, he mumbles his incantation, and suddenly his arm involuntarily (so it is said) straightens out in front of some one, and that is the thief. Again, all believe the infallible sign, and the sooner he makes peace the better for himself. But should *To Palpalum* pass all and no indication ensue, there is yet another plan, which is to enter the house from which the goods were stolen. Standing in front of the place where the goods were usually kept, finger tips to mouth, elbow at right angles to body, muttering incantations, suddenly the arm straightens, and the direction in which the arm straightened is the direction in which the thief went. On *To Palpalum* goes still muttering to his finger tips. When he comes to a branch of the path he stops, and awaits direction, and only when given does he proceed. So he passes on under the direction of spirit guidance until he arrives at some house or person, and that person or the persons of the house are adjudged guilty. There is no evading the charge, the process is infallible!

The *Kubak* is a belief and a custom which illustrates a savage's view of the solidarity of the race, and the oneness of human life. It also indicates their belief in the power of personality. All this of course is not put into words by the savage, but there is some reason given, crude it may be, silly it may be,, but keenly felt and honestly believed in, which really means this. Now, the custom of *kubak* has to do with sickness. Should one feel ill, then all who stay a night in the same place must remain with him until he recovers, on pain of doing the sick one what may prove a personal injury. If the visitor should leave and pass a night elsewhere, the sick one will become worse, which condition is said to be the *kubak* of so and so. Hence, it is customary to isolate the sick, and only those who can stay with them till they are better or dead, are allowed to sleep in the same house or in the same enclosure. This superstition has a great hold upon the people. It hampers work and progress.

There are other traditions and customs of interest among the people, also beliefs of an interesting character, but those set forth in this paper are sufficient to establish that which I stated at the beginning—viz., that savages are the world's most fervent spiritualists. One would like to get at the savage's real mind, his philosophy of all these beliefs, and customs, for where we see root ideas striking so deeply into human life, and know that here we have the beginning of ideas having the capacity for a profound and far-reaching development, the savage becomes to the man who knows him a personage of deep interest. He is not the fool some think him to be, neither is he without capacity for great things, and he often does them in departments of human life and thought where we least expect to find it. He is worth deep study, but when the study is most searching we can no more fully understand and explain the savage than we can fully understand and explain the civilised man. He possesses, like other men, the mystery and majesty of personality which we clearly see when we have penetrated the outer husk of ignorance, and gained a glimpse of the man himself.

2.—MAORI RELIGION.—NOTES ON THE RELIGIOUS IDEAS, RITES, AND INVOCATIONS OF THE MAORI PEOPLE OF NEW ZEALAND.

By ELSDON BEST.

Among a primitive people, religion and magic are inseparable. We may put it in this way, that religious rites are often rites of magic, or that black magic entered largely into the religion of these folk, while ever as we fare on we note the firm belief in omens and the most absurd superstitions. There can be no line drawn between magic and religion, because the power that gives force and effectiveness to the rites of magic, or the milder ones which may be termed religious rites, proceeds in each case from the same source—namely, from the gods. This leads us to the fact that, in all primitive cults, morality is not a concomitant of religion, but is looked upon as having no connection with it whatever.

It is well to remark here that the Maori did not worship his gods. He possessed a budget of charms, spells, incantations, invocations, &c., that were numbered by hundreds, and were used in connection with almost every imaginable subject. None of these, however, would be termed prayers by any one studying them from our point of view. A small number of them may be classed as invocations, but the majority do not appear to rise above the level of incantations. In many cases it is difficult to get at the meaning of much of the phraseology used in these effusions. The whole of such items, from an invocation to the stars to give a plentiful harvest down to a charm to cause a child's top to spin, were known by the generic term of *Karakia*.

There was no worship of the gods. These gods (so-called) were mostly malevolent beings, and the gentlest and best disposed of them had the power to punish man for any neglect of the proper rites or observances due to them. And they used that power. At least the Maori will tell you so, and who am I that I should doubt him?

The system was not one of worship, but of placation. The gods were powers for evil. They could, and did, afflict man in divers ways, hence they must be placated, even the ancestral gods, the deified human ancestors of the people. These remarks apply to all Maori gods I wot of, with possibly one exception. That exception was the mighty Io, of whom more anon.

The native word that we translate as "god" is *atua*. This term really means a demon, a malevolent demon possessed of supernatural powers. These powers were mostly inimical to man, only a system of placatory offerings and invocations saved him from the pit of destruction. The power of the gods to preserve the life, health, and well-being of man, to cause plentiful crops, &c., was only exercised on the condition that the above offerings, invocations, rites, &c., were made or performed. Should these things be neglected, or any law of *tapu* broken, then trouble followed, and such neglectful persons were made to suffer.

It seems rather unfortunate that the early missionaries selected the term *atua* to define the Creator. It does not bring to the native mind the idea of a beneficent deity, but rather that of a malevolent power.

Maori religion was a good illustration of polytheism, for of a verity their gods were as the sands of the sea shore. In the first place there were the principal gods, such as Tane, Tu, Tangaroa, Rongo, &c., that were recognised by all tribes of New Zealand and Polynesia, each having his own empire and functions. Thus Tane was the origin and tutelary deity of forests and birds. No tree might be felled, nor bird taken by fowlers, until certain rites were performed in order to placate Tane. If these rites were not gone through, for example, at the opening of the bird snaring season, then the forest would lose its "health," that is to say, its vitality and productiveness, hence birds would be scarce.

Tu was the god of war, and to his service male children were dedicated with much ceremony. Tangaroa was god of the ocean, origin and tutelary deity of fish. Rongo was the god of peace, and presided over agriculture.

Besides these primal and widely known gods there were many minor ones that may be called tribal gods, such as Tunui-a-te-ika, Te Po-tuatini, &c. Many of these were known to several, or many, tribes. But another class consisted of merely local demons, who were known only in one district, or by one tribe.

The system of *tapu* was closely connected with Maori religion, indeed, was its most prominent feature. The extent to which this usage was carried was truly amazing. There were also different grades of *tapu*, some of which were most virulent, and disregard of such spelt death or disaster to man. Other forms again were much milder, and a transgressor of the rules of such did not endanger his life. The *tapu* pertaining to the dead, to burial places or mortuary caverns, to the god of war (as laid upon the members of a war party bent on blood vengeance), were of the strongest form. Also any spot where religious rites were performed was intensely sacred, and any ordinary person trespassing on such a spot was supposed to die, being slain by the gods. Another form of *tapu*, as that pertaining to a woman during the period of childbirth (and the period of segregation attendant thereon), and to those who handled bodies of the dead, may be likened to the "unclean" state of certain persons as mentioned in the Bible.

Many persons were extremely *tapu*, such as priests, important chiefs, and the firstborn male of a family of rank. Again, any place, or object, might be rendered *tapu*, if considered advisable. Birds, fish, fruits, crops, trees, &c., could be so treated, the result being that no one could touch them until they were made free and common again. Any road could be closed by being made *tapu*. A battle ground, or any place where human blood had been shed, was *tapu* for years. But a hundred pages would not detail all the aspects, causes, and effects of this strange system. One thing may be said of the system: The laws of *tapu* were respected, obeyed, upheld, as no other rules were in Maoriland. The cause of this reverence was a simple one. It was fear.

Ancestor worship, or rather the deification of ancestors, was essentially a Maori cult. It was a form of necrolatry, or hero worship. A man would placate the spirit of his father, grandfather, or ancestor, and make offerings to the same, that such spirit might protect his life principle, warn him of approaching danger, and give force or effectiveness to his rites and charms of black or white magic.

Another peculiar custom practised by the Maori was that by which the life principle of persons, lands, village homes, and forests was protected. Some object was selected, often a stone, and over it certain incantations were recited by a priest. This ceremony had the effect of imbuing such object with the sacred life principle of the person, persons, land, hamlet, or forest that it represented. This object was termed a *MAURI*. It was carefully concealed, its hiding place being known to very few persons. So long as the *tapu* of this object was preserved, no arts or spells of black magic could affect the persons, land, or whatever it represented. It preserved, or protected, the *HAU* of such persons or lands, that is to say, the sacred life principle, the physical, intellectual, and spiritual vigour and well-being. This is a subject that might be described at great length. We give a few illustrations here. For instance, if the concealed *mauri* of a village community were found by an enemy, he would at once pollute its sacredness, destroy its *tapu*, whereupon it would no longer possess any power to protect the folk of the hamlet, and they would be open to the attacks of the magic arts of such enemy. Again, when travelling through the country of a hostile tribe, it is well to keep away from paths, and safer still to walk along the bed of a stream, so as to leave no footprint. Because to every footprint you leave there clings a certain amount of *MANEA*, which is the *HAU* of the human footprint. An enemy could, and would, take this subtle essence simply by scooping up some of the earth on which the footmark was imprinted. This would be taken to a warlock versed in black magic, who, by means of certain magic rites, would soon cause your death, the soil being employed as an agent to connect the spells with yourself, or your vitality. A shred of clothing, a lock of hair, or spittle can also be employed as such an agent.

A person in a state of *tapu* was not able to mix freely with his kind. In some cases such a person led a most solitary and presumably irksome life, not even being able to touch food with his hands, and hence he would have to be fed by an attendant. When taking part in any religious rite, or engaged in any task that was *tapu*, a person was not allowed to return to his hut and family until such rite or task was completed, or until the *tapu* was lifted. On the return of a war party, with the *tapu* of the war god and of human blood on them, the members thereof had to undergo a "cleansing" performance before they could break off and disperse to their homes.

What may be termed the primal or principal gods, such as Tane, Tu, Rongo, and Tangaroa, are not usually termed *atua* by the Maori, but are looked upon as ancestors and personifications. Some of these would, presumably, be termed Nature gods by anthropologists. These primal gods were essentially originators, which the inferior or tribal gods, termed *atua*, were not. Thus, Tane was the origin of trees, plants, and birds, and represents that department of Nature.

A god, sayeth the Maori, cannot be seen by man, but each of the inferior, or tribal, gods has its form of incarnation *(aria)*. Such a form might be a bird, insect, lizard, dog, or some natural phenomena, as a rainbow, meteor, or comet. Again, the inferior gods, the *atua* or demons, have human mediums, termed *waka*, or *kauwaka*, or *kaupapa*. The human medium of a god would perform all the rites pertaining to its cult, rites of placation and invocation. It is a peculiar thing that this word *waka (HUACA*, as rendered by the Spanish chroniclers) was employed by the ancient Inca peoples of Peru to denote certain objects, or figures, of wood, stone, or metal that "Were regarded as veritable fetiches, that is to say, as the dwelling-places of spirits."* It was also applied to priests by the Peruvians, as it was by the Maori.

The primal gods, as Tane, Tu, &c., had no such forms of incarnation as the above, but for each of them a peculiarly carved stick was employed as a sort of medium of communication between the priest and the god.

We have mentioned one Io as a Maori god. Very little information can now be obtained anent this deity, but I was told by the last of the wise men of the Tuhoe tribe that Io was the first of all gods, and the principal one. The old man said—"The cult of Io was very ancient. He was a god of very ancient times. It was he who was the origin of all gods. He was the beginning (or first) of the gods." Only priests of high rank were taught the cult of Io and its rites. No home was sacred enough in which to perform such rites, or even to mention the name of Io, hence all such ceremonial performances took place out in the open and in some isolated spot. In fact, it looks as if Io was looked upon as a creator and supreme being.

* The Hilbert Lectures, 1884. Native Religions of Mexico and Peru. By A. Reville.

A member of the Ngaitahu tribe once told me that Io was born of Rangi and Papa, the Heavens and Earth. It is evident that the cult of Io was a very ancient one, and was overlaid and partially obliterated by the introduction of a number of inferior gods. No invocations to Io are known by the Maori of the present time, nor would they have been divulged by the priests who knew them, when Europeans first settled here, to such persons of an alien race. And why not? Because they were so intensely sacred, because everything pertaining to the cult of Io was so excessively *tapu*, that any divulging of such matter would mean the death of the divulger, and also, probably, the affliction of his people by some dire calamity. The gods did not deal gently with those who broke the laws of *tapu*. Also, the Maori saw at once that the strange new people who came across the Great Ocean of Kiwa from unknown lands were absolutely devoid of *tapu*, a wondrous tribe in many ways, possessed of much power and knowledge, but as void of *tapu* as those who camp in cooking sheds.

The few items pertaining to the cult of Io that have been placed on record are but fragments heard and remembered by the sons of some of the old priests of former days.

Sir G. W. Cox, in his "Introduction to Mythology and Folklore," speaks of the Io of classical mythology as a lunar myth:—"Io, who is said to be the daughter of Inachos, is pre-eminently the horned maiden, whose existence is one of many changes and wanderings, and of much suffering. In fact, her life is that of the moon in its several phases." This Io was changed into a heifer, the symbol of the young or horned moon.

The late Mr. John White obtained another crumb of information concerning Io—"The principal god was Io, who formed the earth and the heavens." He also obtained a fragment of what looks much like a prayer to Io, a true invocation, not a primitive form, such as an incantation.

T. G. Pinches, in his "Religious Ideas of the Babylonians," speaks of "The identification of so many gods with A, Ya, Jah, Au, or Yau," and gives the many names of Merodach as the god of planting, of strength, war, wealth, rain, the moon, &c., &c. He adds that—"These are not the only indications of a tendency to monotheism, or to the idea that all the gods were but manifestations of one supreme deity."

We observe in the cult of Io, as practised in ancient times by the Maori, the idea of a creator who made the heavens and earth, and was the origin of all other gods, as old Tutaka, my informant, put it. This seems to point to a state of monotheism that clashes with our knowledge of the very pronounced polytheism of the Maori in later times. It may be that, in times long passed away, the Maori Io also possessed many names as god of many departments, as we can see was the case with Tane. In later times these different names may come to have been looked upon as those of separate and distinct gods, a hint of the original belief being preserved in the statement that Io was "the origin of all gods." The cuneiform inscriptions translated by Mr. Pinches have preserved the "many in one" belief of the old time folk of far Babylonia, but the Maori had no form of script whereby to conserve his ancient beliefs and history. Mr. Pinches seems to think that the Babylonian priests were really monotheists, but that the bulk of the people were polytheistic. When reading Andrew Lang's "Making of Religion," I could not see my way to accept his idea that the original cult of primitive peoples was of a monotheistic type, and that these faiths later degenerated into polytheism, to again work towards monotheism among such races as made a considerable advance in general culture. There may, however, be some truth in this theory. *Quien sabe?*

In a cosmological genealogy collected by Major Mair, Te Ahau o te rangi (the Ahau of the Heavens) is given as another name of Io, who had Rangi and Papa. This word *ahau* (or *au*), in the vernacular, is the first personal pronoun, singular.

Maori religion was remarkable for its very numerous rites, its ritual or ceremonial fires, feasts, and offerings. Human sacrifices of a ceremonial nature took place at certain important functions, as at the erection of a large house, the launching of a large canoe, the tattooing of a chief's daughter, the ending of the period of mourning for the dead, &c., &c. In most cases of human sacrifice, the flesh of the victim was cooked and eaten at a ceremonial feast, but there were exceptions to this rule. The sacred or ceremonial fires, at which religious rites were performed, were kindled by the friction process; they could not be made by procuring firebrands from any common fire. The priest or his pupil assistant must kindle a special fire. Any place where such a *tapu* fire had been kindled remained sacred, and must not be trespassed on by the people, or punishment would be inflicted by the gods. This state of sacredness pertained to any place where religious ceremonies were performed.

Religious ceremonies were usually performed at the *TUAHU* or sacred place of the hamlet, or at the sacred water. The former was not a temple or building of any kind, but simply some secluded spot used as a place for ritual performances. The sacred water of a hamlet might be a stream, spring, or pond. At this water were performed many rites, including those wherein participants were sprinkled with water by the priests. Of these latter we may note peculiar ceremonies performed by priests over newly-born children, and over members of a war party before lifting the war trail and on their return from a foray.

At the ritual feasts the food was prepared in different ovens, each of which had its distinguishing name. The food for the priest was cooked in a special oven (steam oven) by itself. That for the first-born male member of the leading family was also prepared in a similar one, as was that for the priestess employed in the ceremony. Another oven would contain food for the proved fighting men, the elder warriors, and so on down to the largest oven of all, which contained food for the common people.

A Maori priest was termed a *tohunga*. This word simply implies an adept, not necessarily a priest, hence some qualifying expression is often employed to denote the speciality of the adept. A *tohunga ruanuku* was a warlock, a wizard, one versed in the deadly art of black magic. A *tohunga taua* was a member of the highest class of the priesthood, a head priest who attended to matters of importance concerning the welfare of the tribe. The *tohunga kehua* was of the lowest class, an inferior kind of shaman, who possessed but little knowledge of the occult sciences, and seems to have only appealed to the lower classes. The *tohunga puri* is not quite clear to me, but he seems to have been a wizard, if nothing more.

The principal *ariki*, or chief, was looked upon as the counterpart of the gods. He was the representative, the resting place of the gods in this world. Also. he was extremely *tapu*, so much so that he could not keep himself clean. His head could not be washed, or his hair dressed, because of this intense state of *tapu*. Hence his hair became matted and dirt-laden. The first-born male or female of such a family was ever in this condition. Only the principal *tohunga taua* might cut his, or her, hair, and then the operation made the hapless haircutter so *tapu* that, for the space of many days, he could do nothing for himself, and approach no one. Indeed, it took three persons to feed him at such a time. One prepared the food, afar off, took it to a certain place, and then retired, whereupon another advanced, took such food away, and carried it to a certain spot, and there left it. The third, and immediate, attendant carried the food to the priest and fed him, he not being able to touch food with his hands. Of a verity it must have been a deplorable thing to have been a bishop of the Maori Church.

The priests and shamans were the doctors of neolithic Maoriland. Their methods may be termed empirical, for they relied not on medicines; no root nor herb entered into their primitive pharmacy. They relied on thaumaturgics.

Animism is very noticeable in Maori religion and folklore, as one would expect it to be, while a curious system of personifications and allegorical myths is also noted. The many mythopoetic tales preserved from ancient times are of considerable interest to the collector of folk tales.

Of sun worship among the Maori I have nothing to say, inasmuch as I have not collected any notes on the subject. My old tutor knew nothing concerning it, at least he said that he did not. But he gave me some data of great interest anent astrolatry as practised by the Maori. At the ceremony of the first fruits, as performed in olden times, a long invocation was addressed to the stars by the priest officiating. In this invocation, evidently an ancient composition, each of the principal stars is addressed in turn and asked to cause all food products to be plentiful during the coming season. At the same time the priest laid an offering of the fresh young growth of plants, &c., at the sacred place of the hamlet. This was an offering to the stars that send food to man.

It would not be safe to say that the Maori possessed any system of phallic worship, but some exceedingly curious items may be noted in old-time customs and beliefs, some of which seem to point toward phallicism, or, at least, to a belief in universal sex in nature. One such item is the extraordinary powers assigned to the male organs of generation in man. For these held the power of saving man from disaster and death. When repeating a charm to ward off the shafts of magic, a man would place his hand "in the hollow of his thigh," as it is put in the Bible. This act gave the necessary power to his charm. Another item, stili more strange, was the rite known as *Ngau paepae*. A sick person would be taken to the village latrine, where, while the priest recited a charm, he would be told to bite the horizontal beam of the latrine. This would cure him, at least so sayeth the Maori. Likewise, a person about to start on a journey to distant parts would go through a similar performance, in order that the evil spells of enemies might be rendered harmless, or "toothless," as my informant put it.

But the female organ was black death and destruction, for it was this that brought death into the world.

We have not given a tithe of the items that should be described under the heading that this little paper bears, but *He aha koa!* The days are many that lie before.

I have often asked old natives the reason why their fathers gave up the practice of their ancient religion and accepted Christianity. Their answers were prompt and plain. It was because of the superior powers of the white man's God. A deity whose subjects could acquire written language, make guns and numberless other wondrous things, must be one worth cultivating; the ignorant Maori people might gain much from him.

A final word. When a Maori died, his spirit *(WAIRUA)* was supposed to leave the body and fare forth to the Spirits' Leaping Place, situated at the north-west extremity of the North Island of New Zealand, where it leaped into the ocean and descended to the underworld. This abode of the dead much resembled that of the ancient Hebrews. It was a realm wherein the spirits of the dead seemed to live much the same sort of life as they did in the upper world. The accounts given, however, are not by any means definite in statement, and do not agree. There was no form of belief in any system of rewards or punishments in the spirit land, no judging of the soul by an Osiris or Jehovah.

At the same time spirits of the dead were believed to remain near their old homes in this world, where they often caused much trouble by annoying the living. No effort is made whereby to reconcile these two statements.

3.—EARLY ARABIA AND OCEANIA.

By Rev. Dr. McDONALD.

As is now no longer disputed, there are in Oceania about 50,000,000 of islanders whose languages all belong to one stock. These languages are a perfectly well-defined family, called the Oceanic, and are admittedly descended from one original mother-tongue. Of the Oceanic there are four well-known branches—the Malagasy, the Malaysian, the Polynesian, and the Melanesian: these are independent branches—that is, they are not derived any one from any other of them, but only all from the same source. The speakers of these languages are widely scattered in the islands of the Indian and Pacific Oceans. From Madagascar, on the western side of the Indian Ocean, off the coast of Africa, to Easter Island, in the Pacific, is more than half the circumference of the globe. The Oceanic occupies, as it were, the middle region between Asia, Africa, Australia, and America, but it is not related to the African, Australian, or American aboriginal languages. On this ground it may be held as certain that the speakers of the Oceanic mother-tongue did not carry their speech from any of these three continents into the island world. Whether they carried it into the island world from Asia can only be determined, if at all, on linguistic grounds, that is, by proving that the primitive Oceanic was related, or belonged to, some known Asiatic family. The present paper is to state the view that they carried it into the island world from Early Arabia; and that the proof, the only available convincing proof of this is the linguistic proof that it was related, or belonged to, the Semitic family, being, not derived from, but a sister to the **Himyaritic, Arabic**, Ethiopic, Assyrian, Aramaic, Hebrew, and Phœnician, the existing Oceanic dialects, as the Malagasy, Malaysian, Polynesian, and Melanesian, being thus cousins to, not derived from, the existing Semitic dialects, as the Modern Himyaritic, Modern Syriac, and Modern Arabic; so that "the 50,000,000 islanders must be added to the number hitherto classified as Semitic speakers."

On looking at a map embracing the southern coast of Asia and this Indo-Pacific island region, it is not surprising that the south-eastern, or Indo-Chinese, peninsula first suggested itself, rather than Arabia, the south-western peninsula of Asia, as the starting point from which the Oceanic entered into and was diffused over the whole island world. And there are some whose minds have become so preoccupied with this idea that they reject the Arabian view because it is opposed to it. This, however, is not scientific. For, that the Indo-Chinese peninsula was the starting point of the island speech is an unproved hypothesis. And it has the whole vast central width of the Indian Ocean, lying between Malaysia and Madagascar, against it. Sir Joseph Banks, writing in 1771 (*see* his Journal, published in 1896, pp. 424-26), says:—

"From this similitude of language between the inhabitants of the Eastern Indies (Malaysia) and the islands in the South Sea, I should have ventured to conjecture much did not Madagascar interfere: and how any communication can ever have been carried between Madagascar and Java to make the brown, long-haired people of the latter speak a language similar to that of the black, woolly-headed natives of the other, is, I confess, far beyond my comprehension: unless the Egyptian learning running in two courses—one through Africa, the other through Asia—might introduce the same words, and, what is still more probable, numerical terms into the language of people who had never had communication with each other. But this point, requiring a depth of knowledge of antiquities, I must leave to antiquarians to discuss."

The Indo-Chinese hypothesis has failed to account for the facts, and to justify its existence, by not being able to show how, or why, or that, the Malagasy crossed the Indian Ocean from Malaysia; or that the Malagasy is derived from the Malay or Malaysian, though all are admittedly of the same origin. The opposite view, that Madagascar was the starting point, would, so far as the inter-island language diffusion is concerned, be just as tenable; and, so far as the negro element of blood in the Oceanic speakers is concerned, even more tenable: for thus at least some account would be given of the fact of the negroid element being in Melanesia as in Madagascar. (*See* various opinions in "Man, Past and Present," Cambridge, 1899, pp. 248-256). In the suggestion of Banks, considering the scanty data he had before him, there is something of the intuition of genius. It points to the same quarter for the starting point of the Oceanic, in consideration of the facts, as the Arabian view. The latter view has not only in its favour what he has pointed out, but the traditions of the human race from the earliest times. Arabia is at the apex of a triangle, one of whose legs reaches along the east coast of Africa to Madagascar, the other along the south coast of Asia to the Malay Archipelago, both being known lines of Arabian ship-borne commerce in the southern seas from times so ancient as before the Phœnician keels ploughed the Mediterranean. It was in Arabia, the mother-land of all the Semitic languages, and the seat of one of the earliest civilisations, that sea-going commerce, and that in these southern seas, was first developed by mankind. (Compare *Op. cit.*, pp. 490-7.)

But to come to the real point, to establish the Indo-Chinese hypothesis it is necessary to prove that the Oceanic languages belong to some known family of South-eastern Asia. But this has never been done. Bopp tried to prove they belonged to the Indo-European through the Sanscrit, Max Müller that they belonged to the Turanian through the Thai of Siam. Both, as Friedlich Müller has said, hopelessly failed. Yet down to the present day there are those who cling to some form of Bopp's view, and others to some form of Max Müller's, but it is scarcely necessary to say that where their distinguished leaders failed none of these have succeeded: and it may now be held as certain that this hypothesis, whatever may be the case with the other, must ever remain unproved.

To establish the Arabian view it is, of course, necessary, and all that is necessary, to prove that the Oceanic languages belong to the Semitic family. This can only be done by duly comparing the two groups (this is done in the present writer's work on "The Oceanic Languages: Their Grammatical Structure, Vocabulary, and Origin," Frowde, London, 1907), as to their phonology and letter changes, their triliteral stem-words with their internal vowel changes and external formative additions, and their pronouns and particles. To this work reference may be made for the full proof for the Arabian view. In what here follows all that is attempted is to give a number of little changed words of the one group compared with the same in the other, as the readiest way of setting forth a part of the evidence for the Arabian view, such as can be easily appreciated, not only by those having special knowledge of the Semitic and Oceanic languages, but also by those not having such special knowledge. On both sides each word is given in only one dialect. To give each in several dialects would be easy and interesting, but, while taking up too much space, would in no way add to the value of the evidence, it being the case that every word in the first column is a purely Semitic word, and every word in the second column a purely Oceanic word.

NOTE.—Efatese *b* = *b* and *p*, *f* = *f* and *v*, and *b* and *f* interchangeable; *s* = *ts*, *s'* = *th* in "this," nearly, *t'* = *th* in "with," *s'* = *sh*, *ḳ* and *ṭ* are modified *k* and *t*; *ḥ* is a stronger *h*, and *ḥ'* a stronger *ḥ*; *'* is the Semitic *ayin*, and *"* a stronger *'*.

Arabic	mizar'	Efate	miseri, part of a woman's dress
,,	'azzara	,,	seri, to put on the miseri
Hebrew	ēy (pronounced ē)	,,	ē, where?
Arabic	'alefu	Malagasy	arivu, a thousand

Hebrew	alaṣ	Efate	alat, to compress
Ethiopic	anama	Malay	anam, to weave
Arabic	nāt	Efate	nāt, man, home
Ethiopic	'aràfĕte	,,	ràfĭte, partition, wall
Arabic	is'	,,	is, foundation
,,	băkaa	,,	bōka, to strike
,,	bakata	,,	bokat, to strike
Hebrew	bin	,,	bun, discern
Arabic	batta	,,	bite, cut
Hebrew	ba'ar	,,	bara, burn
,,	tab'erah	,,	tabara,
,,	ba'ur	,,	baurĕ,
Ethiopic	bara	,,	biri, buri, stick, stab
Hebrew	bara (baru)	,,	baru, fat
Arabic	gaba	,,	koba, cut
,,	gafu	,,	kabu, kobu, inside, the belly
,,	gullu	,,	kulu, covering, clothing
,,	giled	Malay	kulit, skin
,,	gazza	Efate	kosi, cut
Syriac	gas	,,	kis, feel, touch, grope
,,	dak	,,	tak, as, like
,,	dakhana	,,	takana, like, as this
Arabic	(dabba), dabbu	,,	tabu, prohibited, "taboo"
Hebrew	duk	,,	tuki, to beat, pound
Arabic	darra	,,	tera, to be swift, &c.
,,	wamasa	,,	amos, rub
,,	wasil'	,,	asili, friend
Ethiopic	waraha	Savu	weru, the moon
,,	,,	Bima	wurah, the moon
Arabic	waken'	Malagasy	akani, nest
Ethiopic	zĕ	Efate	sĕ, this
Arabic	ziffu	,,	sibu, small feathers (birds')
Hebrew	zara	,,	siri, to scatter (seed)
Arabic	kafa	,,	kaba, follow, drive away
,,	faka (trpd)	,,	baka, (trpd), follow, drive away
,,	kaffa	,,	kafa, to cover, &c.
,,	zakafa	,,	sekof, to snatch
Hebrew	hereb	,,	karab, axe
Syriac	ḣab (to burn)	,,	kabu, fire, burn
Arabic	ṭara	,,	tiri, to fly
,,	ṭana	,,	tani, to cover with earth
,,	tans	,,	tano, earth
,,	ta's'	,,	tas, the sea
,,	tanna	Malagasy	tani, to wail, &c.
Hebrew	ẏada	Efate	ata, to know
Assyrian	aṣu	,,	atu, as, going outward, away
Arabic	ka	,,	ka, as
Hebrew	ko, kah	,,	ko, ka, this, here

Himyaritic	ka	Malay	ka, to, &c. (prep.)
Arabic	kabiyr	Efate	kabuer, old, grey haired
,,	kada	Java	kadi, like, as this
,,	ka	Efate	ka, that (conjunction)
,,	kara	,,	kari, to hasten
Hebrew	kaf	,,	kaf, to be bent
Arabic	kara	Maori	kari, to dig
,,	li Tigre, nĕ	Efate	ni, of, &c. (preposition)
Hebrew	le	Samoan	le, not
Arabic	mata	Efate	mate, to be dead
Syriac	mak	,,	mak, to be mild, &c.
Arabic	mallo	,,	malo, disgusted
,,	ma	,,	ma, with (preposition)
,,	mira	,,	mera, man, homo
,,	mas'a	,,	masa, go, walk
,,	sakat (saka)	Malay	sakit, disease
,,	masa	Efate	masi, to shave
,,	mawasi, mu'sa	,,	māsi, knife
Hebrew	sug	,,	suka, draw back
,,	naah	,,	no, abide
,,	navah	Samoan	nofo, abide
Arabic	karina	Efate	karei, dislike
,,	kara	,,	kuru, gather together
,,	zara	,,	suru, soro, to lie, deceive
Aramaic	'abad, avad	,,	afiti, slave
Arabic	'arĕfān (arafa)	,,	arĕfōn, knowing, diviner
,,	''aniya	,,	ani, abide, be
Hebrew	'amas	,,	amos, to carry
Arabic	durriyyat'	,,	turiai, young man
,,	'adera	,,	atara, young woman
,,	''alla	Samoan	ulu, enter
,,	''ara	Efate	ara, to join to
,,	fa	,,	ba, that (final conjunction)
Hebrew	paras	,,	biris, to break down
,,	pus	,,	busa, smash
,,	palas'	,,	bulus, turn round
Arabic	fakka	,,	buka, to open
,,	faka	,,	baku, to pluck out
,,	tafakka	,,	tafakka, burst out
,,	ma'aso	Oba	maso, living
,,	farefara	Efate	barefare, to move about
,,	far'u	Epi	baru, the head
,,	fa'a	Efate	boa, emit odour
,,	fah'a	,,	bok, to pant
,,	fara	,,	bora, to split
,,	tafarra'	,,	tabare, split open
,,	salla	,,	sila, crack (as thunder)
,,	selesala	,,	silasila, crack (as thunder)
Hebrew	sabah	,,	tubu, to swell
Arabic	sari	Maori	tira, mast (of ship)

Ethiopic	sahai, sai	Tarawan	tai, the sun
Arabic	sarra	Efate	saru, sound, roar
,,	sarir′	,,	saruru, sound, roar
Aramaic	sabet	,,	tabetĭ, to adorn
Hebrew	kal	Malagasy	kala, little
,,	kut	Efate	kita, to hate
Arabic	mak′us′ (ka′aba)	,,	makita, bent, curved
,,	mak′rur′ (karra)	Maori	makariri, cold
,,	kas′a	Efate	kasi, to rub, wipe
Hebrew	kasu kas′aw	,,	kasu, hard, strong
Ethiopic	reya	Fiji	rai, see
,,	rev	Efate	rai, rē, aspect
Syriac	rag	,,	raka, to be willing
Arabic	raba	,,	roba, to be insane
,,	riwak′ (rawwaka)	,,	reäkĭ, straining
,,	ra′s′o	Maori	roto, garden, lake, pool
,,	raka	Efate	raku, to bind up
,,	roko′ (raka′a)	,,	roko, to stoop
Hebrew	samat	,,	samat, to strike
Arabic	raka′	,,	raka, to lift up
,,	raferafa	,,	rabaraba, flap the wings
,,	saa	,,	sā, bad
,,	safoka	,,	sabo, ignorant
,,	s′aha	,,	sau, desire
,,	s′ala	Malay	saleh, proceed. call
Hebrew	s′aaf	Efate	safa, to pant, hasten
Arabic	taretara	,,	teratara, stagger
,,	taraka	,,	turuk, permit
,,	tawa	,,	tau, dwell
,,	tala	Samoan	tala, relate, recite
,,	taka	Efate	taku, fear
Hebrew	tukah (takah)	,,	tuk, toka, sit, abide
Arabic	ma′tūk′ (wat′ika) (Imp. tik.)	,,	matūkĭ, trusted, steadfast (taki)

The words in these two columns, word for word, triliteral stems and particles, have suffered, in the course of untold ages, but little phonetic change. But, in order that the weight of the evidence in proof of the Arabian view thus afforded may be duly appreciated, it is necessary to take into account, in so far as seen in the list, the purely Semitic inflectional modifications of these triliteral stem-words by internal vowel change and external addition; for of these all that space will permit to be done here is to refer to the work above named.

4.—SOME MANNERS AND CUSTOMS OF THE DOBUANS OF S.E. PAPUA.

By Rev. W. E. BROMILOW.

INTRODUCTION.

The information contained in this paper was obtained personally during a residence of seventeen years amongst the natives of the 'Edugaula tribe on the Island of Dobu, in the D'Entrecasteaux Group, off the coast of Eastern Papua.

I had many opportunities of visiting other tribes, and without examining minutely into their manners and customs ascertained that the customs in the various tribes differ considerably.

At Dobu, for instance, a polygamist's wives live in their own villages, where they have their own supplies of food. At Kiriwina (Trobriand's) the wives live in separate houses in the husband's compound.

At Dobu the villages are small, and, generally, not far apart, and the houses are built on piles. At Kiriwina the villages are much larger, farther apart, and the houses are built right down to the ground. Even in the D'Entrecasteaux Group various customs prevail in different tribes.

Dobu is about 3 miles long and 2 wide, and rises in the centre to a height of 600 ft. There is a large crater in the middle of the island, and there are hot springs both in the hills and on the beach.

When we arrived, in the year 1891, there were about 2,000 inhabitants living in seventy-three villages, mostly situated near the shore, right around the island.

There were eleven distinct tribes, with clearly-defined boundaries. The 'Edugaula tribe, living on the north-west side of the island, was the most numerous, and the most warlike. It was almost always at enmity with the other tribes, and had made a temporary peace with one of the tribes just before our arrival so as to join in war against a distant and common enemy. Within a radius of 10 miles there was a population of about 10,000.

A plan was formed soon after our arrival to massacre the whole of our party, but was put off at the advice of one of the chiefs. We were to be watched, and if we turned out to be of the right sort, I, as the leader of the band, was to be adopted into the tribe. There were two things which helped me to get into the confidence of the natives in a comparatively short time: Firstly, respecting their manners and customs as far as possible; and, secondly, learning the language. Confidence being established in a few years, when Signor Loria, of Italy, visited Dobu in his researches, we were able together to gather considerable information about the 'Edugaula tribe.

Some of this information is given in this paper.

ADOPTION INTO THE TRIBE.

Prisoners and all strangers were treated in one of two ways:—They were either killed and eaten, or adopted into the tribe with full rights. If it were decided that a prisoner should not be killed, he would be received without ceremony of a secret character by being presented with a block of land by the family adopting him. He would be called son, brother, nephew, &c., and be treated in everything as a member of the tribe.

Sometimes there would be a dispute as to the wisdom of the adoption, but when the decision had been made there would be no disabilities. On one occasion a girl-prisoner was brought to 'Edugaula, and the women took a fancy to her. The men wished to kill and eat her, but the women persisted that she was a fit subject for adoption, and took her into a house to protect her from the designs of the men, who, in the end, gave in to the wishes of the women. The girl was treated as a daughter of the tribe, married happily, and brought up a family, who inherit through her as if she had been born in 'Edugaula.

In our own case one day I was asked to go to the principal villages with my wife and daughter. A cocoanut tree was pointed out to me with a little land around it, and I was told that it was to be mine without payment, and I was to be "father." Another tree in another village was given to my wife in the same way, and she was to be "mother." A third tree in another village was handed over to my daughter, and she was to be "sister." The warrior chief, Gaganumore, then presented me with a pair of broad, white, shell armlets, and without any attempt at secrecy other than looking around to see that there were no strangers about, he made me acquainted with the signs of treachery and of peace. In some parts of South-eastern Papua the peace sign is made by touching first the nose and then the navel. On one occasion the commander of a visiting war vessel calmed the suspicions of the natives by answering from his ship a man who was most excitedly performing these signs as he stood amongst the crowd on the beach. When the Rev. Ambrose Fletcher and I paid our first visit to Bwaidoga, on Goodenough Island, as our whaleboat rounded the point at the entrance to Mud Bay, many coast villages opened up. When our boat was observed there followed great excitement. The women and children fled into the bush; the men seized their spears and ran behind the trees, whence they peered out on us. To allay suspicion we jumped to the bows of the boat and gave the nose and navel signs. Immediately there was a response, the men put their spears away, and the women and children came out of hiding with the greatest of confidence. As the scene of the visit of the gunboat was fully 50 miles south of Bwaidoga, amongst natives unknown to the Bwaidogans, it is evident these signs are used over a considerable area.

The signs at Dobu are somewhat different, each breast being touched in turn, to indicate that you are of one family. The signs of treachery are given with the eye and the foot.

THE POSITION OF WOMEN IN THE 'EDUGAULA TRIBE.

Descent is through the mother, to whose family the children belong. On the death of a woman the surviving consort goes into severe mourning under the charge of his mother-in-law, from whom he is only released after a succession of ceremonies. The widower then goes to his own village, leaving his children and all but his own actual possessions to his late wife's family.

The women are by no means slaves, but have a voice in all the family and village concerns. In many duties the women have a distinct sphere from the men, but in general matters they have an equal voice. They have ownership in land, and frequently prevent the men from selling native wealth.

The men clear the land for cultivation, and dig the ground for yam-planting. The women then plant the seed, and weed the garden. As the seed sprouts the men fix the poles for the vines to climb upon. The women harvest, store, and look after the supplies. Men are not supposed to take a yam from the storehouse, even if hungry, without the consent of the women. The men have full charge of the banana plantations. It is a sign of great affection to see a man and his wife working together in all things.

The men fish with nets, the kite, or hooks—the women's duty is to procure shell-fish.

The men make sago and do most of the work in the preparation of special puddings. The women prepare the ordinary meal by boiling, the men being allowed to roast yams or bananas. The women sweep the villages and paths. The men do all the house building, except thatching—which is the women's work, and merely means that the women thread the doubled sago leaf through the close-fitting reeds prepared by the men and tied on to the rafters. When the leaf is sewn on the reeds before they are tied on to the roof the men do the whole. It falls to the lot of the men to carry on war (though the women used often to fight amongst themselves), to make canoes, and lead in all trade expeditions.

In the last stages of the making of a war-canoe the women were not allowed even to go into the shed where the work was approaching completion.

In some special cases the men would put a special tabu on a cocoa-nut, an areca-nut, or other tree, making it sacred from woman's touch.

Women joined in cannibal feasts—the witches having feasts of their own at times with bodies stolen from the graves.

There are some very strong-minded women in the tribes on Dobu. One woman of my acquaintance went about like the men on trading expeditions, carried a chief's lime-gourd and spatula, and on one occasion in intertribal warfare rushed to the help of her men-folk who were being worsted and helped them to drive back the enemy.

The highest attribute ascribed to a woman is that of being "arawata," which means that she is a good gardener, and strong in caring for the food supplies. To be the possessor of a large supply of good yams in the storehouse, when the new crop is growing, is the best sign of character.

As mother-in-law woman is almost supreme. A man must always pay due respect to all his married relatives, but he must be especially considerate of his mother-in-law. On betrothal the young man must begin to make presents to his betrothed's mother, and continue the gifts to the end of the chapter. The best fish caught, the finest bunch of bananas grown, the most costly native wealth must go to the mother-in-law. Marriage is almost exclusively arranged by the women, and divorce is in nearly every case caused by the mothers-in-law.

Whenever a native utters an exclamation of pain, the cry is nearly always accompanied by the words "Sinagu! Sinagu!" ("My mother! My mother!"). So expressing delight he will say, "To do so-and-so is my mother!"

Amongst the women there are various classes, thus:—

I. The arawata, above mentioned, who is respected.
II. The abisida, or beggar, who is despised.
III. The werabana, or witch, who is feared.

Witches are considered to have great power. For instance, by occult influences a witch can deafen a person's ears, and so make him mad; or can cause his heart to burst, or drink his blood, or snap his veins, or break his bones. She can throttle a child at night by invisible fingers, can swamp or capsize canoes, climb to the top of mountains, cross from peak to peak on cords of fire which can be seen any dark night. She can descend into the earth and bring forth fruitful seasons, or epidemics of sickness, at her own sweet will.

The men seem generally content to let the women have their own way in domestic and general affairs, as long as they are themselves allowed to rule in war, and carry out trade expeditions. Occasionally a woman will be thrashed, but she has her remedy in divorce if the thrashing is too cruel or unjust. Occasionally, too, a witch will be drowned. For instance, the aunt of a chief was accused of practising witchcraft, and causing several deaths. The chief at last became ashamed of the repeated accusations, and took the old woman out to sea in a canoe, and drowned her by tying a big stone to her neck. He refused to listen to her protestations of innocence, and simply said he was ashamed of the reiterated charges.

LAND LAWS AND OWNERSHIP OF PROPERTY.

The laws about land are very simple, and never departed from. There are five classes of land:—

Asa, or village land; Waborebore, abandoned village site, but claimed by the original owners; Tanoa, garden plot; O'ai, a clump of trees; Ioiodaita, land without an owner. There is no land of this last class in the 'Edugaula tribe on Dobu.

Land is divided amongst families, and every individual has his own portion. Land is never sold, and cannot be alienated. It can be loaned for a term. A person dying may bequeath a portion to one not of his family, but the land returns to the family on the death of the legatee.

Land is never given in compensation to an aggrieved party. The boundaries are marked by small stones, which indicate each person's property. This boundary between the properties is called Tanolodawa, and is never altered. When any division of property takes place the whole piece of land bounded by the Tanolodawa is given undivided. Fights occur between the heirs if an attempt is made to break this rule.

When a man dies his land is inherited by his sisters' children, his brothers, and his sisters. His own children do not inherit, for they belong to their mother.

The deceased's mother may plant on the land; also his father until he returns to his own village as a widower. When a woman dies her land goes to her children, her sisters, her brothers, her mothers' brothers.

The first-born has no larger share than the others. The share of a child is taken care of by an elder until he is fit to use it himself.

A woman who marries makes her garden on her own land, being assisted by her husband and his relatives; she and her relatives help the man on his land. In both gardens the woman has full control of the yams, and the man of the bananas.

Seeing that these land laws are so clear on the point of inalienability, it is a tribute to the wise administration of the Government authorities of the past that so little trouble has occurred in the purchase of lands. In securing blocks of land for educational and mission purposes, I have always found the natives keep to the boundaries they agreed upon, and, except in the following case, the price also. On one occasion I had secured the promise of a small piece of ground from the owner—just big enough for the erection of a native house. When the Government official came to pay for the land, we found twenty men seated in line on a log waiting for their pay. Each of the men demanded equal payment, and at the same rate upon which I agreed with the one owner. They all declared they were equal owners. So I quietly declined to buy, offering the man I had dealt with slight compensation for his trouble. Immediately the other nineteen jumped up, and laughingly said they had only been trying to take us in.

We had to be very particular in the surveys of our land. For instance, the surveyor of one block could not very well follow a crooked boundary in every particular, so he took his line across a Tanolodawa. Under the exceptional circumstances, after much explanation, the owner of the next property consented to the alteration of the boundaries on receiving compensation.

One surveyor, in running his chain around a small block which had been previously purchased by the Government, mistook the exact boundary by a few feet. The original owner came to me complaining, and asking that I would act as interpreter. I gladly did so, and there was, of course, no difficulty in having the mistake rectified. At the close of the proceedings I left, and in a short time the native came to me in great excitement, asking that I would return to the surveyor a present he had given him. "If I accept the present," said he, "shall I not lose my true boundary ?"

Fruit trees belong to those who planted them, even if on someone else's land. In a village every tree has its owner, though a young heir has the right to climb any tree.

Pigs and dogs belong to the individual, unless they have been bought by a family or a village for a feast, or to be used as a family gift to married relatives.

Canoes, fishing nets, ornaments, and other native wealth, according to their value, may belong to the individual or the family. All things too large for individual ownership are owned by the family.

A man who acquires much native wealth in his own individual right is called Esaesa. Only a man can be called Esaesa, and only a woman Arawata. A family or a village may secure the title of Esaesa.

When a man dies his private property is taken by his sister's children principally, then by his brothers, and even his own sons may have a small share. If his sister's children are too young, his brothers will take their share, and pay the children back when they have grown up. Should one of the nephews attend to his uncle with loving care during the illness preceding death, he will become the tobuio, or preferred heir, and receive the biggest share of the property.

When a woman dies her bodily ornaments belong to her sisters' children, and her other property to her own children.

When I explained to a company of natives our laws of heredity, &c., they laughed at our ideas, and said that while no doubt we could teach them much, yet in these respects we could learn much from them.

TOTEM.

In the 'Edugaula tribe the totem seems to be of little use. The different branches of the tribe are distinguished by the names of the birds:—Parrot, dove, crow, eaglehawk. A man has at times saved his life by naming his totem when he has been in a strange place. Marriages in the same totem are frequent, and friendly relationships are established, but in war the totem is forgotten or deliberately put aside.

The totem bird is supposed to cry when a person dies. The bird of the mother's totem is eaten, but that of the father's tribe is not. But this can be accounted for by the fact that a child must eat nothing from his father's village.

WAR AND ITS CAUSES.

The 'Edugaula tribe had the worst name in South-east Papua for cannibalism, and were acknowledged to be the greatest warriors. There were very few tribes with whom they had peaceful relations. They were friendly with Bwaio, two miles away, on Fergusson Island, and with Duau, thirty miles to the south, for trade purposes. They were at peace with two other places because of tribal relationships, and with two other tribes because they had conquered them, and had sent some of their people to live amongst them.

They had intertribal fights—the slain being buried with ordinary rites. They fought in their canoes, and they made so many raids on the surrounding islands that the people were afraid to live on the sea shore. Several reasons were given by themselves and the other tribes to prove their pre-eminence in war.

I. The 'Edugaula tribe had no need for fortifications around their villages, or secret trap-holes with spears at the bottom in their paths, as the enemy never dared to come to them to fight or take revenge. They met with losses only when on expeditions, or when solitary individuals were caught away from home. On one occasion some tribes came in canoes to attack the Dobuans, but they were seen and attacked with such sinking of craft and taking of prisoners that no one ever tried again.

II. In intertribal warfare they fought on a cleared space in the open, catching the attacking spears most dexterously.

III. They were taught to paddle their war canoes in one way—bows on. The bow of a canoe was always dedicated to war, and the stern to peace. Other tribes could paddle stern first or bows on at will, but the Dobuans could only back water with their paddles in bringing a canoe in stern first. They were thus taught not to jump up and turn round to paddle away from the enemy, but to steer straight for the opposing canoes. Canoes of any size were never brought on to our beach bows first, as it would have meant war.

IV. The 'Edugaula tribe were the only natives in South-east Papua who ate human flesh and drank human blood raw! The other tribes were terrified at such doings.

V. Gaganumore, the leading warrior, following the custom of his elder brother, who had been the greatest fighter of the tribe, never made peace when he was a loser. He was never satisfied until he had his revenge.

The causes of war were very numerous. Spears especially were kept in the houses handy so as to be seized on the occasion of an offence being offered by anyone. The slightest quarrel would be the cause of spears, clubs, or tomahawks being brought out.

The following were causes of intertribal or other fights:—

(1) Revenge always had to be taken for slaying of a member of the tribe. *Exception:*—The death of a thief caught stealing and slain in the act is not avenged. A man of the 'Edugaula tribe went across the straits in the night to a village of Bwaio, on a thieving expedition. He was caught stealing a bunch of bananas out of a garden and killed. His friends simply said, "It is a shameful thing to steal from those with whom we are at peace. He has received his deserts."

(2) 'Ebe'Aila: War must be made as a matter of course against those places whence their ancestors secured prisoners and bodies.

(3) Though revenge might have been taken again and again for the slaying of a member of the tribe, war must continue whenever there was opportunity.

(4) Adultery.

(5) No one was said to die a natural death. Hence, on the death of anyone of importance, the sorcerer who was suspected to have caused the death would be attacked: his friends would defend him, and there would be war.

(6) Theft committed when absent from the village. On return someone would be suspected and accused, and a fight would result.

(7) Emwawasi: Not paying full value of debts owing, especially for stone-axes, bone lime-spatulas, shell armlets called moari, and ornamental pendants of red shell beads called bagi and arumoi—in fact, all articles worthy of the name of native wealth.

(8) Stealing a canoe in the absence of the owner.

(9) Foreigners were always killed, unless it was decided to make them members of the tribe.

(10) Moving land boundaries.

(11) Loiaia'ara: Paying a visit to a village with which they were at peace for the time, someone there might form a plot to kill one or more of the visiting party. Through the warning of friends the visitors escape. Patiently waiting their opportunity, when the plotter's anger is over, and he has forgotten, he will be caught and killed—hence war.

(12) The slaying of a rival in a love affair.

(13) Naming the dead. The dead may be named only when a mighty oath is taken, or by a sorcerer when all other remedies to save a sick man from death have failed. This seems to indicate some remains of ancestral worship.

(14) Practising with toy spears would very often result in a fight with true spears.

(15) Fish are often caught by being stupefied with a poison made from a root called Tua. If an outsider who had not used the poison dived after the fish he would be attacked. Hence, his friends would come to his help, and a fight would immediately take place.

(16) When women quarrel the men take little notice, until one of the women is wounded with a stick or a stone; then the men join, and a real fight ensues.

(17) Saying "Your father is dead." This saying seems to cause a feud even more quickly than calling out "You are in the habit of eating excrement."

(18) A woman using filthy language to a man might thus make him angry, and he might kill her. Her death would be avenged and war result.

(19) If a man used filthy language to a woman she would tell her relatives, who would at once get out their spears and rush to the man's village to avenge the insult.

(20) The act of a child in spoiling property might bring down anger on the parents, resulting in a feud and loss of life.

(21) A handsome young man who took all the women's hearts would most likely be slain, and his friends would try to avenge his death.

(22) Conjugal quarrels frequently result in suicide by one of the parties. The surviving consort will be blamed by the relatives of the deceased, and unless big payment be made a lasting feud will follow. A man has been known to pay his wife out by deliberately going unarmed to the enemy, who slay him. As a consequence, there is first of all a fight between the man's and the woman's relatives; and then unitedly war will be made on the enemy. Sometimes husband or wife will commit suicide by jumping from a tree, or from a precipice, or by hanging. Men prefer leaping from a high cocoanut tree so as to create a sensation in a frequented place.

(23) Treacherous peace was sometimes made so as to afford opportunity to take revenge.

(24) A brave warrior not receiving his proper share of food and spoil would raise a feud.

(25) The breaking of a tabu. Sometimes, for instance, a reef is made tabu, or sacred, on the death of a chief. This means that no one must fish on or near the reef until certain ceremonies are performed which release the tabu. Thus, fishing on a reef which is under tabu causes war.

(26) The talk of an old woman about one of the tribe having been slain long before would bring back old memories, and away the warriors would go to raid on the tribe, which had forgotten the old trouble.

(27) A man would marry a woman so as to get into the confidence of his father-in-law's tribe, with the deliberate purpose of murdering one of the tribe. A man has been known to act in this way so as to kill his wife's father. This treachery was considered justifiable, and the friends of the homicide would rally to defend him from the vengeance of the aggrieved tribe.

War may be waged against the relatives of the wife, but the slain must not be eaten. The person who kills a relation by marriage must never after partake of the general food or fruit from his wife's village. His wife alone must cook his food. If his wife's fire goes out she is not allowed to take a fire-stick from a house in her village. The penalty for breaking this tabu is that the husband dies of blood-poisoning!

The slaying of a blood relation places an even stricter tabu on the slayer. When the chief Gaganumore slew his brother (mother's sister's son) he was not allowed to return to his own village, but had to build a village of his own. He had to have a separate lime-gourd, and spatula; a water-bottle and cup of his own; a special set of cooking pots; he had to get his drinking cocoanuts and fruit elsewhere; his fire had to be kept burning as long as possible, and if it went out it could not be relit from another fire, but by friction. If the chief were to break this tabu his brother's blood would poison his blood so that his body would swell, and he would die a terrible death. The strange thing about this case is that no one seemed to wish to face the same penalties by killing Gaganumore in revenge.

When a distant expedition was planned, a leading warrior would act as Tonidoi (standard-bearer). For some time before our arrival Gaganumore was the standard-bearer for all expeditions. He would with his immediate followers prepare a feast for all who volunteered to accompany him. Before starting out he would harangue the warriors. They would perform incantations over their spears, slings, and clubs; charm their bodies to render them invulnerable; and encourage each other to be brave. The standard-bearer would launch his canoe, hold up a spear with a flag made from the leaf of the pandanus tied on the top of it. The other warriors would then paddle their canoes into line, stand up, and with shouts and yells exhort the standard-bearer in rough language to be fierce and brave. They would hurl spears and sling stones at their leader's crew, who would dodge them cleverly and return the compliment. Off they would start and follow the standard-bearer's lead. These expeditions would last often for days; villages would be raided in the early mornings, and fights take place whenever they could meet an enemy.

While the warriors were away the women would not sweep the villages, and the children were not allowed to make a noise. If prisoners were taken, as the returning canoes approached Dobu, conch shells would be blown, and drum beaten. This would be a signal to the women, who would sweep the villages, cook food, dress in their best grass skirts, and as the warriors approached dance down to the beach to meet the prisoners, and join in the preparations for cannibal orgies. While these preparations were being made the warrior-band would go to the standard-bearer's village, and help themselves to any bananas, cocoanuts, or areca-nut they could find.

All prisoners captured or bodies slain by the standard-bearer were handed over to his wife's relatives, or to the family which had lost one of its members in a former raid on the places just visited. If anyone else had captured or killed an enemy the prisoner or body would be handed over to the standard-bearer for his family, or to be given to anyone he wished.

The To-Unua (capturer or slayer) was not allowed to eat of the To-Esilai (captured or slain).

The Mebu (revenge-victim) would be tortured much worse than a prisoner captured from a tribe which had not ever killed a Dobuan of the 'Edugaula tribe.

The female relatives of the one whom the warriors had avenged would join in beating the revenge-victim with yams, spears, and clubs. The prisoner would be tied with his wrists on his knees, and carried as a pig with a stick under the armpits. He would be placed on a fire alive, but, unless they wished to be very cruel, half-stunned, the blood pouring out of the wounds made by those beating or hacking at the prisoner would be gathered in a cup and drunk, or eaten with cooked yam.

Some men grew so fond of cannibalism that when themselves unable to seek victims they would constantly pester their relatives to procure them human flesh.

All the people were not cannibals. Abstainers had a special name —Ligodi.

If the warriors should return unsuccessful, or one of their number should be slain, the standard-bearer would suffer by having his village attacked, and one or more of his houses burnt. The women, too, would refuse to sweep the villages, or cook good food, and would tie their grass skirts between their legs to resemble the man's T dresses, as a sign of displeasure.

Prisoners not killed were adopted as substitutes for deceased relatives, and were treated and loved as if real relatives—all the laws of the tribe being binding on them, even to that of exogamy.

A very interesting ceremony was performed on any boy who by his appearance gave promise of growing up to be a strong man. The little chap would be thrown into the sea when very young, and hauled out by his right hand. This would be repeated until he became thoroughly passionate. Later a special cocoanut shell filled with water would be charmed and broken over the boy's head with a stone, this baptism making him angry and without fear. He would be encouraged to use small spears which would be left in his way, so that any time his will was crossed he would rush at anyone who happened to be near, and even spear his own mother on the slightest provocation. Should his mother or anyone else be speared by the embryo warrior, it would be said, "What, was he angry without cause? Did they not charm water, and pour it over his head?"

BETROTHAL, MARRIAGE, DIVORCE.

The customs connected with betrothal, marriage, and divorce are so many and so complicated that a long paper could be written about them.

A few facts may be given.

Betrothal.

1. Children are often betrothed by their parents, so that feasts may be held and food exchanged. It does not follow that they will necessarily marry.

2. A man proposes to a woman by first getting the woman's consent to his sleeping with her in her usual sleeping place; then repeating his visits for several consecutive nights. The woman now speaks to her mother, who tells her husband. If the man is accepted, the woman informs him that her friends know, and that he may help them in their gardens.

The woman's brother will take the man to the future mother-in-law's garden. The first day he works all day, and his relatives are informed of the fact. Then commence betrothal ceremonies and the Tabu, which apply also to the betrothal of children.

Tabu I.—The betrothed pair must not eat in the presence of their respective relatives-in-law.

Tabu II.—The betrothed boy or man is expected to sleep with his betrothed in her mother's house, but only as brother and sister. Should the man go further than the compact allows, and the woman become pregnant, her relatives will reproach him with having anticipated the proper course of betrothal, and angrily hand the woman over to him without further ceremonies—an act which will be a constant disgrace to the woman in the future. In quarrels with her sex she will often be brought to tears by their reminding her of her premature marriage. If the woman is of good rank the man has to pay much native wealth to appease the anger of the woman's relatives. From the commencement of the betrothal, feasts are exchanged between the relatives of each party.

The man has to help the woman's relatives in gardening, house-building, &c., his family often joining with him. The woman helps the man in his private garden, and after a time there is exchange of help between the relatives of each party.

The parents of the man or woman may call the betrothed parties son-in-law or daughter-in-law, but the couple cannot call the parents father or mother-in-law; nor can the betrothed call each other spouse.

If a man and woman wish to be betrothed and the woman's relatives object the man withdraws generally. In some cases when the man's relatives object and he persists, they tell him to marry by himself, as they will not help him to give the food and presents necessary to complete the betrothal.

Proper betrothal ceremonies cannot be carried on without both families are agreeable.

Marriage.

The completion of the betrothal ceremonies terminating in marriage generally takes place at harvest time.

1. The bridegroom's relatives take fish, puddings, firewood, cocoanuts, and a stone axe to the woman's village. The bride's mother accepts these presents.

2. The bride's relatives go to the man's village and sweep it throughout. They receive from the man's relatives special presents, the mother getting the best native wealth.

3. The bride's relatives take uncooked food to the bridegroom's village, and cook it there for his friends to partake of.

4. The bridegroom's relatives cook food for the bride's relatives to partake of, and take uncooked food to the bride's village.

5. The bride's relatives make return presents of food to the bridegroom's friends, and the bride's mother puts some cooked food into the bridegroom's mouth to release him from the food Tabu.

(Note by the natives. The man is obedient to all these customs, because he is anxious to have a wife.)

6. The bride and bridegroom go to the man's village, and sleep in a house with the bridegroom's mother and sister. The mother and sister must be in the same room with the couple, or the bride's mother would complain that her daughter was not used to being alone.

7. The next day are the closing ceremonies. The bride's relatives give the bridegroom's relatives food; the bridegroom's relatives make more presents; and the bridegroom's mother puts food into the bride's mouth, thus releasing her from her eating Tabu.

Marriage Restrictions.—It is forbidden to marry blood relations on the mother's side. Susu includes all these relations. A village is made up of various Susu separated by clear boundaries. Marriage may be contracted in the village outside of the mother's Susu.

It is also forbidden to marry in the father's Susu, but only because by so doing rules concerning mourning feasts would be broken.

Marriage does not admit into the Susu.

Proper respect must always be paid to married relatives. There must never be too much familiarity with the spouse's Susu.

A man may marry as many wives as he can get, but each wife has her own house and garden in her own tribe or village. The chief or first wife, called Asematua, generally thrashes the other wives the first time she sees them after the marriage, but afterwards treats them as sisters. Whenever one of them comes to the husband's home she has to obey the chief wife.

Divorce.

A man likes to make as big presents as possible to his bride's relatives during the betrothal and marriage ceremonies so that if his wife wishes to divorce him for a trivial cause he will have the sympathy of those who have received the goods. Nevertheless, the causes of divorce are very numerous.

A divorced woman is not paid for by her next husband. The divorced man does not receive anything back after divorce, unless the divorce occurs soon after marriage, in which case the valuable articles are returned or their equivalents.

A wealthy man is not divorced readily; neither is a woman who is possessor of much yam seed. In some senses food stored up is considered more valuable than wealth in goods.

Some of the causes of divorce are:—

1. If woman is extravagant with yams.
2. Man not gardening properly.
3. Woman stealing from man's relatives.
4. Man's relatives not giving the woman cooked food occasionally as a sign of good feeling.

5. Woman not cooking food for man's visitors.
6. Adultery on woman's part.
7. Woman talking very loudly in man's village when strangers are present.
8. Woman rattling the spatula loudly as she takes lime from the gourd when the man's elders are present.
9. Man not fishing or not helping to provide other food for the children.
10. Man too lazy to join trading expeditions.
11. Breaking etiquette in each other's village.
12. Entering house in spouse's village when owner of house is absent.
13. Man or his relatives making use of wife's relative's canoe without permission.
14. Climbing on platform of spouse's elder while the elder is seated on the ground.
15. Man thrashing his wife in the sight of her relatives.
16. Severely thrashing wife in the man's village. She cries and complains to her friends.
17. Filthy language.
18. Calling by the name orphan or bastard, and saying that either party has no food.
19. Saying "Ugly mouth," "Ulcerous mouth."
20. Calling each other old. It is an insult for a husband to tell his wife that she was born before him, and so for the woman to say so to her husband.
21. Saying, "Your ears are thick and stuffed up. What did your mother ever teach you?"
22. Woman not cooking food properly.

INFANTICIDE.

Mode.—1. Putting foot on the throat. 2. Choking with hands. 3. Burying alive with deceased mother. The first Dobuan saved from this custom was a male child, whom Mrs. Bromilow persuaded the natives not to bury. The relations refused to nurse him, so he was brought up in our home, and is now fifteen years of age. 4. Leaving child on beach in the sun. 5. Refusing to suckle the child.

Occasions of Infanticide.—1. Birth of twins. One twin is killed because of the great trouble in nursing. Generally the female child is preserved because of descent, but if the mother has no male child to climb cocoanut trees for her she may ask for the female to be killed. A case was mentioned in which both female children were kept alive. Triplets are apparently not known. When we asked some old men if they knew of triplets they laughed boisterously over the very idea of such a thing happening.

2. Bastards are sometimes killed. A woman was taunted about her bastard child, whereupon she put him in the sun to die, and finally poured salt water into his mouth. When I asked her why, she said she could not bear the taunting.

3. The mother dying while the child is too young to run about.

4. After compulsory marriage. Sometimes a mother will force her daughter to marry against her will. Thrashing, scalding with hot

water, cutting the head with a shell, constant nagging, are the means used by mothers to persuade unwilling daughters. When a child is born after such a compulsory marriage the mother of the child will kill her offspring in secret and try to divorce her husband, unless her husband has been very good to her, and has overcome her hatred.

5. Sometimes when the mother's milk dries up, and no one in the tribe can or will act as wetnurse.

6. When the husband turns out to be a rake.

7. When the husband upon pregnancy deserts his wife for the time and marries a second wife.

Abortion is practised by jumping from a height, massage, lifting very heavy weights, playing games boisterously so as to fall heavily, and in other ways.

MISCELLANEOUS.

Sorcery is very prevalent. A true sorcerer has twelve different ways of causing death by occult powers; no one dies a natural death; life can only be saved by enchantments; evil hap warded off by charming. When any person dies there is always some good reason given why the enchantments have failed.

The dead of high rank were not buried, but the body would be carefully fastened on the top of a tree with a well-thatched roof over it. When the bones dropped they would be buried at the foot of the tree. The person of low rank would be buried in the death-chair in a circular grave, and be put out of the way as soon as possible—even before the breath was out of the body. Those of middle rank were buried in the death-chair, but with much ceremony, and not until death had really taken place.

The cemeteries were always in the centre of the villages.

The spirits of the dead went to Mount Bwebweso on Duau Island. The shadow of the body had a separate existence, and remained in the village.

The time of the people seemed to be fully occupied. They had great harvest festivals; they kept their gardens of yam, bananas, sugar-cane, and taro, in good order; trade expeditions were frequent; they made their own fishing-nets and kites; built houses and cut out canoes; taught their children legends, songs, and games; they scorned a Tolelewa—lazy man (according to their ideas of laziness); despised the Abisida—beggar-woman.

Their legends are very varied and account for the origin of fire, cannibalism, polygamy, earthquakes, the division of the land into islands. The legend about their birds is a lesson in natural history.

Let this paper, which is already too long, be concluded by one of the best of their legends.

The Story of the Flute.—The flute at first had no voice, but was simply of the vegetable kind. It spoke not. But there was a man in a band of singers whose voice excelled the voices of his companions in richness, and sweetness. As his companions sang first, no one cared for their voices, but when he of the rich voice sang everyone was pleased. So his friends became jealous, and speared him. He ran, but fell amongst the flute reeds dying. His voice passed with his breath into the reeds, and so the voice of the flute surpasses in sweetness any human voice. If his friends had only loved him the sweetness of his voice would not have been lost to man.

A FEW NOTES TO SHOW THAT THE DOBUANS ARE CHILDREN OF NATURE EVEN AS OTHERS.

1. There are harlots. A harlot does not sleep with her mother, and does very little gardening. She allows anyone to sleep with her for payment in betelnut, or tobacco.

2. A single woman, if virtuous, sleeps with her mother. She can receive the visits of lovers, to see whether a betrothal will come out of it or not.

3. A girl who refuses the visits of lovers is taunted by her mother with being "Nuebora"—an innocent virgin.

4. A single woman wishing to have connection with a man may: (*a*) Ask betelnut of a visitor. (*b*) Snatch, when passing, an ornament from his armlet, or his comb from his hair, or basket out of his hand. (*c*) Strike him with a stick, or throw a stone at him. (*d*) Stare at him or put out the tongue. (*e*) Send a verbal message through a child. (*f*) Speak to him familiarly. (*g*) Twinkle the eyes. (*h*) Pinch him. (*i*) Call him her "widower," or tell him his wife is no good.

5. A married woman acting as above must do so secretly. A single woman need not be very secret about it.

6. A man wishing to visit a woman may adopt the same methods as the woman, or go at night to the woman's house, play the native jaw's harp, and say "Baiobaio! Open the door that I may climb up." Sometimes a woman will ask a man his intentions before allowing him in. A man will promise a poor woman anything so as to sleep with her.

The moon is supposed to be a male, and menstruation is caused by his having connection with females at the age of puberty.

A man is not allowed to have connection with his true or adopted sister.

A man took his niece into the grass in the daylight, and the people to shame him composed a song about it, which they sang at their dances.

A woman in open daylight in the centre of a village called upon a visitor to have connection with her, which he did without their going into a house—the man going off boasting of it. The whole countryside rang with the incident, some expressing their shame, others taking the matter as a joke.

Male prisoners were stripped naked, the T-shaped leaf dress being thrown into the sea, and indecent remarks made. Female prisoners were stripped of their grass skirts, and tormented by being reminded by their captors of the times they had connection with their husbands. No captor was allowed to have connection with a female prisoner for fear it would spoil the body for eating.

Men of strong vitals have been known to wash the vulva, stuff it with bananas, and eat the whole after cooking. The native chiefs who gave me this information wanted me to joke a certain member of the tribe about his proclivities in this direction.

If a man wished to clear the women out from watching him at any occupation he would make as if he were loosening his leaf, and they would run away screaming with laughter.

The legend of fire traces its origin to a woman who got it from her menses.

5.—LANGUAGE AND SOCIOLOGY OF THE KUMBAINGGERI TRIBE, NEW SOUTH WALES.

By R. H. MATHEWS, L.S., Associé étranger Soc. d'Anthrop. de Paris.

During the past few years I have contributed to the Royal Society of New South Wales some original articles on the languages of Australian tribes.*

In the following pages I shall endeavour to briefly describe the elements of the grammar of the Kumbainggeri language, spoken by the aborigines inhabiting the north-east coast of New South Wales, from Nambucca to Grafton, and reaching inland to the Main Dividing Range. These tribes were originally numerous and powerful, but have so very much decreased during recent years that they are now only found in small groups at a few camping places reserved for their use by the Government of New South Wales.

In this language, in every part of speech subject to inflection, there are two forms of the first person in the dual and plural, in one of which the person or persons spoken to are included with the speaker; and in the other, the party addressed is exclusive of the speaker.

ORTHOGRAPHY.

The system of orthoepy adopted is that recommended by the Royal Geographical Society of England, but a few additional forms of spelling have been incorporated to meet the requirements of the Australian pronunciation, as follow:—

As far as possible, vowels are unmarked, but in order to prevent ambiguity of pronunciation, in some instances the long sound of *a*, *e*, *o*, and *u*, are indicated thus: ā, ē, ō, ū. In a few cases the short sound of *u* is marked thus ŭ.

G is always hard. *R* has a rough trilled sound, as in the English word "hurrah!" *W* always commences a word or syllable. *Y* at the beginning of a word or syllable has its ordinary consonant value.

The sound of the Spanish ñ often occurs. At the beginning of a word or syllable I have represented this sound by *ny*, but when terminating a word, the Spanish ñ is used.

Dh is pronounced nearly as *th* in the English word "that," with a slight sound of *d* preceding it. *Nh* has also nearly the sound of *th* in "that," but with a slight initial sound of the *n*.

---

* "The Thurrawal, Gundungurra and Dharruk Languages." Journ Roy. Soc. N.S. Wales, vol. xxxv., pp. 127-160. "The Aboriginal Languages of Victoria." *Ibid.* Vol. xxxvi., pp. 71-106. "Languages of Some Native Tribes of Queensland, &c." *Ibid.* Vol. xxxvi., pp. 135-190.

T is interchangeable with *d*; *p* with *b*; and *g* with *k*.

Ty and *dy* at the commencement of a word or syllable have nearly the sound of the English *j*, or the Spanish *ch*. At the end of a word or syllable, *ty* or *dy* is sounded as one letter, closely approaching *tch* in the English word "watch," but omitting the final hissing sound.

Ng at the commencement of a word or syllable has a peculiar nasal sound; at the end of a syllable it has the sound of *ng* in the English word "sing."

Nouns.

Nouns have number, gender, and case.

Number.—There is no special declension for number, but the noun is followed by words meaning two or several:—Nungo, a kangaroo: nungo bulari, a couple of kangaroos; nungo umaka, several kangaroos.

Gender.—In the human family, sex is distinguished by the employment of different words:—Nigar, a man. Nyumme, a woman. Kibar, a boy. Ngundalgan, a girl. Yerrai, or gugangi, a baby of either sex.

The gender of animals is denoted by using words meaning "male" and "female," placed after the creature's name, as Nungo kanaigan, a male kangaroo. Nungo kandura, a female kangaroo.

Case.—The principal cases are the nominative, causative, instrumental, genitive, accusative, dative, and ablative.

Nominative. This case merely names the thing spoken of, and requires no change in the noun, as, wandyi, a dog; guragai, an opossum.

Causative. When a transitive verb is used, the noun takes a suffix, as Nyummeu bakumbal marang, a woman a perch caught. Wandyidyu guragai yindang, a dog an opossum bit. Nigardu nungo buang, a man a kangaroo struck.

Instrumental. Nigardu nganya bindaimang tuandu, a man at me threw a boomerang.

Possessive. Nigargundi tua, a man's boomerang. Nyummegundi wakkar, a woman's tomahawk.

Accusative. This case is the same as the nominative.

The dative and ablative cases are declined by postfixes in a similar manner.

Adjectives.

Adjectives follow the nouns they qualify, and take similar inflexions for number and case.

Nigar burwai, a man large. Nigardu burwaidu nungo buang, a large man struck a kangaroo; and so on for the other cases.

It will be observed that the suffixes of both nouns and adjectives are subject to modifications, depending upon the terminal letter of the word declined.

Comparison. Nyam yūnggo—nyam dharwi, this is bad—this is good. Nyam dharruiŭnba, this is very good.

Pronouns.

Pronouns have number, person, and case, with two forms for the first person of the dual and plural. The nominative personal pronouns are as follows:—

Singular	1st person—	I	Ngaidyu, with trans. verb; Ngaia, with intrans. verb
	2nd ,,	Thou	Nginda
	3rd ,,	He	Guladhu
Dual	1st person—	We, inclusive	Ngulligai
		We, exclusive	Ngulligadhu
	2nd ,,	You	Bulagai
	3rd ,,	They	Bularidyu
Plural	1st person—	We, inclusive	Ngeagai
		We, exclusive	Ngeagaigiri
	2nd ,,	You	Ngudyambindyu
	3rd ,,	They	Gularigiri

The possessive and objective personal pronouns are—

Singular	Mine	Nganyundi	Me	Nganya
	Thine	Nginyundi	Thee	Ngena
	His	Gulagundi	Him	Gulannha

There are forms for all the persons of the dual and plural, but they are omitted for the present.

There are forms of the pronouns meaning "away from me," "towards me," &c., which must be passed over for want of space.

Interrogatives.—Warru, who? Minya, what?

Demonstratives.—Nyam, this. Mumum, that.

The language contains many forms of the interrogatives and demonstratives, most of which are inflected for number and person. Many of the demonstratives are likewise used as pronouns of the third person, a fact which accounts for the great differences in the third personal pronouns in each number.

When used with an intransitive verb, the nominative pronouns given in the table are employed, as, Ngaia dyun-gi, I am speaking. But when connected with a transitive verb, a causative form of the pronoun is employed, as Ngaidyu bindaimaigu, I will throw.

Verbs.

Verbs have the singular, dual, and plural numbers, with the usual tenses and moods. There is a form of the verb for each tense, which remains constant through all the persons and numbers of that tense. Any required number and person can be expressed by using the suitable pronoun from the foregoing table.

The following is a partial conjugation of a verb in the singular number, indicative mood:—

Indicative Mood—Present Tense.

Singular	1st person—	I hear	Ngaia ngaranggi
	2nd ,,	Thou hearest	Nginda ngaranggi
	3rd ,,	He hears	Guladhu ngaranggi

and so on through all the persons of the dual and plural.

Past Tense.

Singular 1st person—I heard Ngaia ngarawang

Future Tense.

Singular 1st person—I will hear Ngaia ngaranggu

The imperative, conditional, reflexive, and reciprocal forms of the verb are omitted for want of space.

PREPOSITIONS.

Between, pimita. On the other side, kawatadyula. On this side, ilāmgidda. Around, kokari. In rear, wallungga. In front, munggara. Down, warri. Up, kaba.

ADVERBS.

The following are a few of the more commonly used adverbs:—

Yes, nge. No, byekkai. To-day, gili. To-morrow, guraguradyu. Yesterday, nyūggundyirra. Bye and bye, gŭng-a. Long ago, tyallumbo. Soon, yaregili. Certainly, yare. Here, nyamyala. There, njŭngara. None, biwai. Always, illagaingai. When, mulla. How, dyugirgai.

The aboriginal equivalents of the English adverbs "here" and "there," and their modifications, are frequently used as demonstrative pronouns of the third person, and take the same declensions as the nouns they qualify.

Conjunctions, interjections, and exclamations are not important or numerous in this language, and will be passed over for the present.

NUMERALS.

One, guragun. Two, bulari. Several, umaka.

A MYSTIC OR SECRET LANGUAGE.

Before concluding this brief paper on the speech of the Australian aborigines, I wish to refer to a secret language, used by the men at the ceremonies of initiation, but is never spoken in the presence of women, or in the presence of such youths as have not passed through the necessary ceremonies. While the novices are away in the bush with the elders of the tribe they are taught a mystic name for surrounding objects, animals, parts of the human body, and short phrases of general utility. This language varies in different communities.

I have on several occasions drawn attention to the existence of this mystic tongue,* and five years ago I contributed to the Royal Society of New South Wales† some short vocabularies of the secret languages of the Kurnu and Kamilaroi tribes.

In connection with this subject it may be mentioned that in 1901 I contributed an article to the Royal Geographical Society of Queensland on some "Aboriginal Songs at Initiation Ceremonies."‡

SOCIOLOGY.

The Kumbainggeri-speaking people have a social organisation consisting of four intermarrying divisions or sections. The masculine and feminine forms of the names of the sections, showing how they usually intermarry, and the names of the respective sections to which the children belong, will be readily understood from the following table:—

Cycle.	Wife.	Husband.	Son.	Daughter.
A	Wirrakan	Kurpöong	Wirröong	Wanggan
	Wanggan	Marröong	Womböong	Wirrakan
B	Kooran	Womböong	Marröong	Karragan
	Karragan	Wirröong	Kurpöong	Kooran

To each of the above cycles there is an aggregate of totems attached, consisting of animals, plants, and inanimate objects. The totems of Cycle A belong to the sections Wirrakan and Wanggan in common; and the totems of Cycle B are common to the sections Kooran and Karragan. The descent of the cycles, sections, and totems is invariably determined through the mothers only.

The marriages shown in the above table are the normal unions. For example, a Wirrakan woman has a Kurpöong spouse, and her children are Wirröong and Wanggan. She may, however, in certain cases, marry a Marröong man, but her children would still be Wirröong and Wanggan. Moreover, the Wirrakan woman of our example could, instead of either of the above men, wed a Womböong husband, provided she were not debarred by too close a blood relationship; or, she could take a Wirröong spouse, unless similarly debarred; but her progeny would nevertheless be the same as in the above table, quite regardless of the denomination of her husband.

INITIATION CEREMONIES.

The Kūmbainggeri tribe possesses some important and imposing ceremonies of initiation, of which I have given a comprehensive account in a paper to the American Philosophical Society at Philadelphia, U.S.A.§ There is also an elementary form of initiation in this tribe, which I have likewise described in an article contributed to the Royal Geographical Society of Queensland.||

* Journ. Anthrop. Inst., London, vol. xxv., p. 310; also American Anthropologist vol. ii, N.S., p. 144.

† Journ. Roy. Soc. N.S W., vol. xxxvi., pp. 157-160.

‡ Queensland Geographical Journal, vol. xvii., pp. 61-63.

§ Proc. Amer. Philos. Soc., vol. xxxvii, pp. 54-73

|| Queensland Geographical Journal, vol. xv., pp. 67-74.

VOCABULARY OF KUMBAINGGERI WORDS.

The following vocabulary contains about 300 of the most important words in general use among the Kumbainggeri tribes. Every word has been noted down carefully by myself from the mouths of the old men and women in the aboriginal camps:—

English.	Kumbainggeri.	English.	Kumbainggeri.
Man	nigar	Woman	nyumme
Boy	kibar	Girl	ngundalgan
Youth	gurumŭn	Elder sister	dhuluganda
Novitiate	gurrŭnda	Younger sister	kumbirragunda
Elder brother	kuyumban	Wife	bulanyangan
Younger brother	kumbiri	Sweetheart	gindyagurai
Husband	girragurai	Mother	ngaliga
Father	baliga	Mother-in-law	ngurwañba
Clever man	ngullongurai	Person with family	bwaruamaga
Mother's brother	gurakulŭm	Child	yerrai

The Human Body.

Head	kali	Knee	bugga-bugga
Forehead	wan	Finger-nail	mirrindarra
Beard	ngo'be	Heart	burrang
Eye	mil	Liver	kunnanggara
Nose	dyingam	Caul	gumbangil
Throat	woro	Blood	murawura
Ear	ngalgan	Fat	marum
Mouth	dhullan	Bone	gulura
Tongue	ngarān	Penis	dyōn
Lips	tum	Testicles	murrang
Teeth	tira	Copulation	dyoimundyari
Breast (female)	ngutum	Masterbation	mulga-mulgai
Navel	nimbirra	Semen	wunya
Arm	dhalburra	Vulva	kwigara
Elbow	kuri	Nymphæ	dyindiri
Chin	yating	Anus	nyim
Shoulder	burum	Excrement	guna
Thigh	dharra	Urine	ngabun
Foot	dyinna	Venereal	dyarbung
Hand	mara		

Inanimate Natural Objects.

Sun	ngaian	Plain	gunnangan
Moon	giduñ	Creek	yaman
Small stars	winda	Wind	gurien
Large stars	birrar	West-wind	warriwai
Pleiades	kannagan	East-wind	gabuwai
Aldebaran	mura-ura	Pipeclay	kurulum
Sky	kara	Red-ochre	mukkai
Thunder	burumgai	Fire	wakai
Lightning	maraugai	Smoke	dhum
Rain	kulun	Thirst	balungging
Rainbow	kigui	Day	gaiwa

Inanimate Natural Objects—continued.

English.	Kumbainggeri.	English.	Kumbainggeri.
Dew	tingga	Night	ngunmur
Fog	gua	Morning	gulau
Frost and snow	wigan	Evening	nyagundyir
Hail	watai	Splinter	bigura
Water	ngaru	Grass	bukāwuru
Ground	watyara	Leaves of trees	tyanggora
Mud	nguluñ	Bird's nest	wiri
Stone	munim	Eggs	mirrubai
Sand	kittirru	Honey-comb	tungara
Light	kirra-wirra	Honey	mawa
Darkness	ngunmara	Food	nūngu
Heat	biwanbai	Grubs in trees	gāl
Cold	muggura	Grubs in ground	dyuburra
Camp	ngura	Flowers	gorai
Whirlwind	wiwang	Pathway	warroiñ
River	bindŭlbang	Shadow	mūtyang
Dust storm	dyulara	Summer	mukkurai
Mountain	dyulum	Winter	gullagara
Hill	gunnum		

Mammals.

Native bear	tunggira	Padamelon	gultyua
Dog	wandyi	Porcupine	mudyai
Wild dog	murrumgal	Kangaroo	nūngo
Opossum	guragai	Platypus	ngatum
Kangaroo rat	kulluga	Flying squirrel	banggo
Native cat	balandyim	Ringtail opossum	kilu
Bandicoot	gaiban	Flying fox	walumba
Wallaby	murkan	Bat	girrimurring
Wallaroo	dhandunggal		

Birds.

Birds, collectively	tyibbin	Eaglehawk	kurrira
Emu	nguruiñ	Pheasant	tyāwan
Crow	wagan	Magpie	guronggirra
Laughing jackass	kagung	Mopoke	gobuñ
Curlew	bŭrbunggir	Night owl	dyinnibunu
Rosella parrot	kangan	Plover	girgirra
Scrub turkey	ngurin	Crane	burraui
Native companion	gēlan	White cockatoo	kaiarra
Black duck	waradhai	Black cockatoo	billargan
Pelican	tyunggara	Fish hawk	ngungga
Swan	gunibi	Bowerbird	mumbin
Bat	girrimurring	Woodpecker	nyin

Fish.

Perch	bakumbal	Frog	tyaran
Mullet	bulunggal	Silverfish	gŭngurri
Eel	bōrga	Yellow-belly	ngulliwan
Bream	kai-i	Shark	yanggai
Catfish	gunolgiñ		

Reptiles.

English.	Kumbainggeri.	English.	Kumbainggeri.
Iguana	gumgalli	Carpet snake	dyumbal
Sleepy lizard	wandŭrga	Black snake	dungguñ
Small lizard	ganganbawali	Jew lizard	gungur
Death adder	dyambin		

Invertibrates.

Locust	yirrinba	Mosquito	gurā
Blowfly	burungan	Bulldog ant	gumum
Louse	munyu	Large ant	wōddyun
Nit of louse	timmin	Centipede	kiya
House fly	munyirram	Jumper ant	bungga-bungga
Bee	wūtyin	Spider	murrungguraga

Trees.

Wattle	tyāning	Gum-tree	māngurga
Pine	binderaga	Honeysuckle	wirrinda
Cherry-tree	dyidyimum	Ironbark	burrigirga

Weapons, &c.

Tomahawk	wakkar	Hunting club	buppāra
Koolamin	kulu	Boomerang	tua
Yamstick	kulbañ	Net bag	ngulain
Spear (wood)	bigura	Canoe	walu
Fishing spear	kummai	Paddle	tagudi
Spear lever	wommara	Head-band	wāllugan
Spear shield	kaugan	Narrow band	dyindan
Reed spear	kurragara	Man's belt	milia milla
Waddy shield	yurrōwi	Man's kilt	mura-gura
Fighting club	budyangga	Woman's kilt	tyubbi-tyubbi

Adjectives.

Alive	gunoai	Deaf	ngalganmuga
Dead	wali	Strong	dairi
Large	burwai	Afraid	wambiñ
Small	tyunoi	Tired	tyugawi
Tall or long	yuron	Blunt	mogoi
Low or short	dyarrigum	Sharp	ngūrgan
Good	darwi	Fat	marum
Bad	yunggo	Lean	tyunoi
Thirsty	ballungging	Hot	wikune
Red	muru-muru	Cold	muggure
White	gurāban	Sleepy	kunggoi
Black	guru	Sorry	narrawai
Crazy	krangiwai	Sick	tandure
Full	ngundilli	Stinking	wakun
Quick	kureebi	Angry	mirrandui
Slow	wannammararnya	Jealous	marrarai
Blind	milmugumbi	Greedy	ngirrum

Verbs.

English.	Kumbainggeri.	English.	Kumbainggeri.
Eat	bewanba	Laugh	dhuluñmi
Drink	ngumbi	Scratch	bittang
Sleep	bukkōra	Send	dyauga
Stand	dyuggana	Suck as a child	ngumbi
Sit	nganggi	Swim	bungge
Talk	gaii	Bathe	wurroging
Tell	dyuna	Shine	yarang
Walk	vanna	Spit	wara
Run	bilāgana	Smell	guruba
Bring	kurubilli	Throw	bindaima
Take	mana	Pitch, heave	birranga
Make	yila-giri	Whistle	wirrañba
Break	kamnga	Kiss	munūngga
Throw	bindaima	Vomit	kambin
Beat	bumierri	Dance	wakambang
Arise	boandyi	Corroboree	yauar *or* ngāre
Fall down	boaumi	Dive	bunggi
See	nyaga	Sting	bāwuging
Hear	ngarangga	Hunt	bikuring
Give	ngurā	Go	yarrang
Sing	dhalga	Bite	yindyang
Weep	tōnga	Pretend	kurriugai
Steal	wuruguñmu	Come	yannai-illami
Request	ngēmba	Carry	thumbari
Blow with breath	dyoga	Drip as water	buti
Climb	wanding	Come back	kārawa
Conceal	giding	Do	durrūnda
Jump	karatying	Chop	kaigi

6.—SOME ROCK PICTURES AND CEREMONIAL STONES OF THE AUSTRALIAN ABORIGINES.

(WITH ILLUSTRATIONS.)

By R. H. MATHEWS, L.S.

A number of interesting aboriginal carvings are found on the Burnett River, parish of South Kolan, county of Cook, in the State of Queensland. The drawings are cut upon some flat rocks in the wide channel of the river, at the junction therewith of Pine Creek. This point may also be defined as situated a little over 14 miles in a direct line south-westerly from the town of Bundaberg.

The rocks containing the carvings are a kind of hard sandstone, which during the greater part of the year are quite dry, but in times of flood are covered with water. Most of the figures are small, varying from a few inches in length to upward of 2 ft., representing native weapons, animals, human feet, and several nondescript devices. The outline of each figure is defined by a groove cut into the hard surface of the rock to a depth varying from $\frac{1}{8}$ to $\frac{1}{4}$ of an in. The width of the groove ranges from less than $\frac{1}{2}$ in. in the smallest to about $1\frac{1}{4}$ in. in the largest specimens.

The mode of execution adopted by the native artist was to make a row of indentations or punctures along the outline of the drawing with sharp-pointed pieces of hard stone. The spaces between the punctures were subsequently chipped out, so as to form a continuous groove. The positions of the punctures are still discernible. Mr. W. H. Franklin, of Bingera, who first brought these carvings under my notice, has known of their existence for more than thirty years. He says they were then somewhat plainer than at present, although still quite distinguishable.

One of my kind friends chiselled out a fragment of the rock containing part of a very distinct carving of a human foot with five toes, and sent it to me. The native drawing showed the entire foot, $6\frac{1}{2}$ in. long, but the heel end of it was broken into fragments in endeavouring

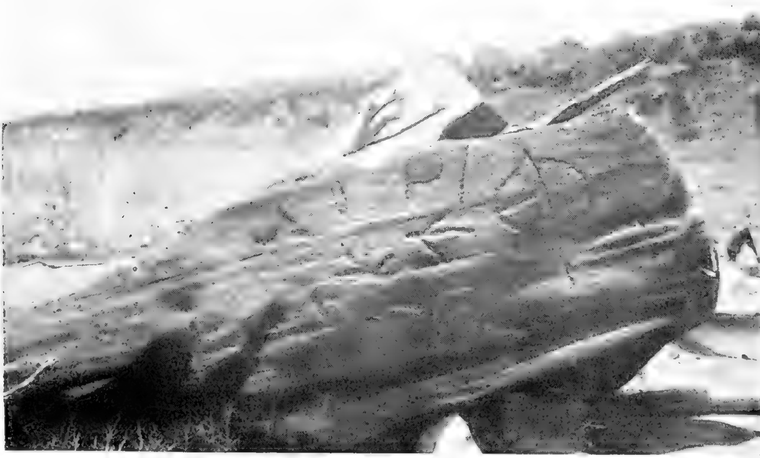
ABORIGINAL CARVING, BURNETT RIVER.

(Natural Size.)

to remove it. I have made an exact copy of the part of the foot which is in my possession. The broken line across the face of the drawing defines the boundary of the missing part of the foot. My drawing is exactly the same size as the carving on the rock.

Rock Carvings in the Burnett River.

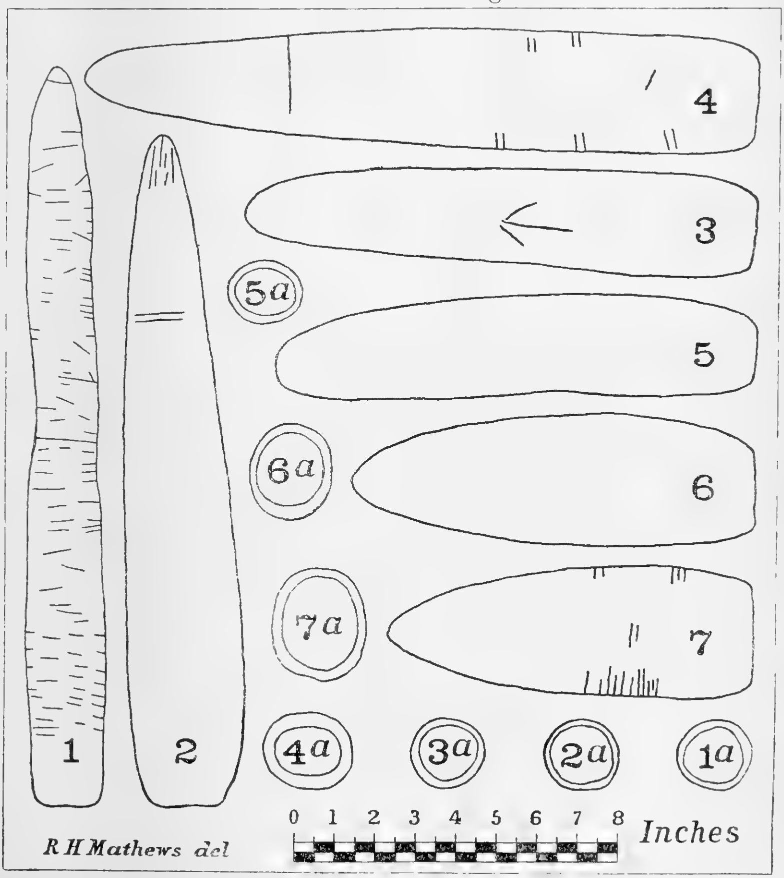
Rock Carvings in the Burnett River.



Rock Carvings in the Burnett River.

Certain remarkable stone objects, chipped and ground into shape by the aborigines, have been discovered over a large area of north-western New South Wales, which have not been observed in any other part of Australia. The principal tracts in which these prepared stones have been found are along the Darling River and adjacent country, from about the town of Bourke down to below Menindee; on the Warrego and Paroo Rivers from their junction with the Darling upwards to the Queensland frontier; and in the extensive region lying between Tibooburra, Mount Arrowsmith, Broken Hill, &c., and the Darling River. Isolated specimens have also been met with south-east of the Darling, almost as far as the Lachlan River. A specimen in the possession of the late C. S. Wilkinson was said to have been picked up about 1884, between the Narran and Barwon Rivers—the Darling being known as the Barwon in that part of its course. The latter is the farthest point east where such stones have been reported from.

In order to give the reader a clear conception of what these stones are like, I have made careful drawings to scale of seven out of



SEVEN CEREMONIAL STONES, N. S. WALES.

a considerable number of specimens in my possession, illustrating differences in size and shape, and in the character of the material; including also some which are rather profusely marked, and others which contain no inscriptions.

Fig. 1 is a long, nearly cylindrical piece of clay-slate, $18\frac{1}{4}$ in. long, its greatest diameter being 2 in. A large amount of chipping and grinding has been done by the native artificer to bring this implement into its present shape, especially at the pointed end, and also near the base. About the middle of the shaft the original surface of the stone is seen in a few patches some inches in extent. Commencing a little over an inch and a-half from the base, there are numerous marks, both horizontal and slightly oblique, all the way to the apex. About half an inch from the point one of these incisions reaches all round the stone. At the middle of the shaft another inscribed line encircles it; but the two ends of the cut, instead of meeting, overlap each other about 2 in., and are from a quarter to half an inch apart.

There are a large number of incisions scattered over most of the surface of the stone, about ninety of which are reproduced on the side seen in the drawing. In addition to these there are many other marks which, although distinguishable, are but scratches, and have never been anything more. They are of the same character as the well-defined cuts, but much shorter, and are not the result of accidental injury.

Fig. 1*a* gives a view of the base of the stone, in which there is a saucer-like depression, the perimeter of which is shown by the innermost of the two irregular circles, having an average diameter of nearly an inch and a quarter. This concavity has been made by picking into the surface with some sharp instrument, such as a pointed flake of hard stone, the remains of the punctures being still plainly discernible. After the picking was done the surface was rubbed or ground until it was fairly smooth. The depth of the hollow formed in this way is a little more than a twentieth of an inch. The specimen was found near an old native camp on Buckanbee run, Darling River, and weighs 3 lb. 12 oz.

Fig. 2 is a soft decomposed sandstone, $16\frac{5}{8}$ in. long, with a practically circular shaft, the greatest diameter of which is $2\frac{4}{5}$ in., from which it evenly diminishes to a well-defined point. Extending back from the apex are six vertical lines, and at $4\frac{1}{4}$ in. from the point are two slightly curved parallel incisions, cut well into the stone, with two similar marks on the opposite side, which are not, of course, visible in the drawing. These comprise all the marks on this specimen.

From the thickest part of the shaft to the base, the diameter slightly decreases, until the basal diameter (Fig. 2*a*) averages a little over $1\frac{3}{4}$ in. The diameter of the depression in the base averages nearly 2 in., and its depth is one-eighth of an inch. The stone was picked up on Kallara Run, Darling River, and its weight is 3 lb. 14 oz.

Fig. 3.—Another specimen of a soft sandstone, $12\frac{5}{8}$ in. long, $2\frac{1}{2}$ in. in its greatest diameter, and circular in section. Fig. 3*a* represents the base, into which is picked and ground a concavity seven-fortieths of an inch deep in the centre. It was found on Kallara Run, fronting the Darling River on the northern side; $4\frac{1}{2}$ in. from the base there is a cut which may have been intended for part of a barbed spear, $1\frac{7}{8}$ in. in length. Weight of the stone, 2 lb. 7 oz.

Fig. 4 is another implement of decomposed sandstone, $16\frac{5}{8}$ in. in length, which, by coincidence, is the same length as Fig. 2. At the thickest part the diameter measures $2\frac{9}{10}$ in., and a section through any part of the shaft would give an almost circular outline. On the face selected for illustration there are five pairs of incised lines and two single marks—one of the latter reaching round nearly half the circumference. On the other side of the stone, not visible in the drawing, are twenty-one marks, comprising triplets, pairs, and single cuts.

Fig. 4*a* represents the base, whose diameter varies from $1\frac{3}{4}$ in. to $2\frac{1}{4}$ in. The usual saucer-shaped concavity has a mean diameter of nearly $1\frac{1}{2}$ in., and its depth is one-twentieth of an inch. This well-shaped specimen was found on a sand ridge on Moira Plain Run, about 50 miles south-easterly from Wilcannia, and weighs 4 lb. 8 oz.

Fig. 5.—A fine-grained sandstone, $11\frac{7}{8}$ in. in length, with a maximum diameter of $2\frac{1}{2}$ in. The shaft is slightly curved or crescent-shaped, which gives variety to this specimen, but there are no incised lines now visible upon it. The concavity in the base, Fig. 5*a*, is three-fortieths of an inch deep. This stone was discovered on Culpaulin Run, about 16 miles below Wilcannia, Darling River. Weight, 3 lb. 10 oz.

Fig. 6, a soft sandstone, 10 in. long, with a diameter of $3\frac{1}{4}$ in. at the thickest part of the circular shaft. The depth of the concavity in the base, Fig. 6*a*, is five-fortieths of an inch, and the weight of the stone 3 lb. 7 oz. It was found at Tonga Lake, north-west of the Paroo River, in approximate latitude $30\frac{1}{2}$ degrees, and longitude $143\frac{3}{4}$ degrees. There are a few scattered inscriptions which are too much weathered to be decipherable.

Fig. 7 is made of sandstone, and comes from Pulgamurtee Run, near Cobham Lake, about 50 miles southerly from Tibooburra, in the north-west corner of New South Wales. The length is 9 in., and the greatest diameter $3\frac{1}{4}$ in. The side of the specimen illustrated contains eighteen horizontal incisions, some of which are in pairs, one has three lines, and the remaining eleven are placed contiguous to one another. There are a few similar marks on the other side of the stone. This specimen is interesting from its great thickness in comparison with its length, and from its symmetrical conical outline.

Fig. 7*a* shows the base of the stone, which is represented by two slightly oval outlines, the external one giving the size of the base and the innermost showing the perimeter of the concavity. The concavity stopes regularly from the margin towards the centre, where the greatest depth is three-twentieths of an inch. Weight of specimen, 2 lb. 15 oz.

The stones above described have ceased to be employed in the ceremonies of the remnants of the Darling, Paroo, and other tribes, and, therefore, it is not easy to obtain much information respecting their meaning and uses. An old aboriginal, named Harry Perry, whom I have often met at different places on the Darling, of which river he was a native, gave me the following information:—He said he had never seen the stones used, but his father and other old blacks had told him that they were employed in ceremonial observances connected with the assembling of the people at the time the *nardoo* seed was ripe. Adjacent triblets would be invited to participate in the harvest, and met at the appointed place, bringing with them various articles for barter with their hosts in exchange for the grass seed. Perry also said that such stones were used in incantations for causing the supply of game and other food to increase, for the making of rain, and other secret ceremonies. This statement was confirmed by another old man, who said the stones in question were kept by the head men, or "doctors," the women and uninitiated not being allowed to see them. On the death of the owner, they were hidden in the ground near an old camping place of his, or else near his grave.

A station manager on the Darling River told me that some thirty-five years ago he was one day drafting cattle on a sand ridge on his property. He was assisted by his white stockman and a blackfellow, all of them being on horseback. The trampling of the hoofs of the stock disturbed the loose sand and brought one of these curious stones to the surface. At lunch time, the manager picked up the stone, which was nicely marked along the shaft, and expressed his intention of taking it home to the house as a curio. The blackfellow interposed, saying that if such a stone as that were taken to the house, and any woman should see it, all the blacks would die. He accordingly took it away and covered it in the sand where it had been found. It is to be regretted that the manager, who was not then taking much interest in the customs of the blacks, did not make inquiries. The above incident is a corroboration of the sacred character of stones of this kind.

At a meeting of the Linnean Society of New South Wales, in 1884, one of these implements was exhibited on behalf of C. S. Wilkinson, 19 in. long and 4 in. in diameter.* In 1888, another specimen was shown on behalf of Rev. J. M. Curran, 11½ in. in length by a thickness of 2¼ in.† In 1898, W. R. Harper described some similar stones.‡ In 1902, Wm. Freeman exhibited a specimen 17 in. long and 3¼ in. in diameter, at the Hobart meeting of this association.§

7.—REMAINS OF THE STONE AGE IN VICTORIA,

By CHAS. DALEY, Hon. Secretary Field Naturalists' Club, Ballarat.

Around the southern coast of Victoria, on the open ocean or the shores of sheltered bays and inlets, may be found almost continuously abundant traces of the occupation of Australia by the native races.

More particularly is this noticeable wherever the freshwater streams join, or where rocky shelving reefs run out into the sea; for, at such places, when uncovered at low tides, food was abundant and more easily obtainable than on the sandy beaches, whilst the wooded bluffs and high sand-dunes also provided acceptable shelter from wind and weather.

Frequently near a sheltered headland, in the vicinity of fresh water, the natives for generation after generation made their shifting camps, using the same cooking-places or ovens for preparing their food, practising their ancient tribal rites, constructing their implements of stone, wood, and bone, for use in war

* Proc. Linn, Soc. N. S. Wales, vol. ix., pp. 507-508.
† *Op. cit.*, vol. xxiii., p. 436.
‡ *Op. cit.*, vol. xxiii., pp. 420 sq.
§ Rep. A. A. A. Science, vol. ix , p. 539.

or peace, and occupied in the pursuits pertaining to the condition of their primitive social advancement. The signs of their presence remain in the "mirru-yongs," or extensive heaps or layers of broken shell, mingled with charcoal, ashes, or fire-hardened clay, among and around which are found the stones used in breaking the accumulated shell-fish, in forming the ovens for baking or otherwise cooking their food, and in fashioning their stone axes, chisels, wedges, knives, adzes, and cutting implements. Here may be found stone axe-heads in various stages of completion, from the roughly-chipped material to the finely-balanced and smoothly-finished axe; chips of flint, quartz, and quartzite, used in cutting and scraping; pounding and grinding stones for the treatment of seeds and roots; stones used for sinkers in fishing, for shaping basket work; and also worn anvil-stones, used as a base in striking off chips and preparing the rough stone for serviceable weapons.

These kitchen middens, similar to those observed in all the older continents, are sometimes of immense extent, the remains covering acres of surface, and stretching almost continuously for nearly a mile, or even miles, in length. Here are abundant evidences of the toll which the ocean paid to these dusky inhabitants of her shores. The more common and accessible shells are numerous, such as limpets (*Patella tramoserica*), cockles (*Natica plumbea*), mussels (*Mytilus latus*), oysters (*Ostrea edulis* and *mordax*), *Purpura succincta*, *Scutus anatinus*, and large shells of the Haliotis, well preserved, but brittle when exposed. The cockles are usually broken, and the limpets show where a sharp stone has been used to detach them from the rock surface. These shells were probably collected in baskets or other receptacles, carried to the cooking-places, where fire was used to make their marine occupants more palatable to the taste; and the shells remain in countless numbers, and often in several layers varying in depth, the mute evidences of a race practically extinct in Victoria. On some parts of the coast, near farming selections, the remains, full of organic matter, are often removed to be used in fertilising the soil, excavations being made to a depth of many feet.

The sea has encroached upon many of these old camping-places; others are hidden beneath shifting sand, and some are now more distant from the shore on account of progressive alterations in the physical features of the district.

In the northern and western parts of Australia the mode of accumulation of these "mirru-yong" heaps still persists. In the Victorian "Naturalist," Mr. G. A. Keartland, the well-known ornithologist, mentions that he saw, a few years ago, the aborigines on the Fitzroy River, Western Australia, collecting mussels, which they boiled and ate; and at this particular place there were ten to fifteen dray-loads of shells. Mr. D. le Souef also mentions having seen in the Gulf country, North Australia, middens of burnt shell (chiefly *Arca granosa*), some of which were 30 ft. high and a quarter to a mile in length. As the local population was scarce, the inference was that many generations must have elapsed during the construction of these accumulations.

In Victoria, as elsewhere, the materials used in the construction of axe-heads varies somewhat according to the geological features of the district, but throughout Victoria generally there is evidence that diorite, or some similar closely-grained rock, was preferred for making the axe-heads; these were highly prized, and special products of other districts were given in exchange for the axes or the coveted material for making them.

An extensive native stone quarry of diorite near Lancefield, Victoria, reveals conclusive traces of having been regularly worked, probably for ages, to obtain pieces suitable for making axe-heads. Most of those formerly used in Northern Victoria and the Riverina district were probably obtained from this source, the native ovens along the Murray and its tributaries often containing diorite axes. The absence of stone on the great northern plains, of necessity, compelled the tribes of this district to obtain the material from the south.

Along the coast from Port Phillip westward, and particularly to the south of Geelong, the majority of the axe-heads, of which very many have from time to time been found, are of gabbro, or diallage rock, of which an outcrop, bearing evidence of having been worked by the aborigines, occurs near Batesford, about 6 miles from Geelong. This stone, although not so dense in texture as diorite, takes a beautiful polish, a sharp edge, and is specially suitable for axe-heads. Although not outcropping within some miles of the coast, pieces of gabbro, used as hammers for striking off chips, or sometimes roughly chipped for construction into axe-heads, may be found in the old kitchen-middens at Bream Creek, Torquay, Anglesea, and other places on the coast; whilst finished axes of gabbro, ground and polished, were not infrequently discovered.

Although material like gabbro or diorite was highly prized and sought after, yet, in the absence of more suitable material, quartzite, hard compact coast limestone, chert, and the denser basalts, were occasionally made into axe-heads and cutting instruments, although they were not such effective weapons. Stones partly shaped in the river beds or creeks by water action were sometimes chipped to shape; but the diorite or gabbro was quarried from the outcrop, and carried great distances to be manufactured into weapons. For splitting trees, or stripping bark, wedges of basalt, hard limestone, or sandstone, were chipped to the required shape. The anvil-stones of basalt or limestone were carried from the creeks or rivers to the camping-places, and are invariably hollowed in the centre on one or both sides by continued percussion; whilst smaller stones of similar materials, used for crushing shell-fish, roots, or tubers, &c., bear similar marks.

Among the shell-mounds, and near the ovens, are found cores of flint from which chips have been struck off, whilst numerous chips, lance or knife-shaped, occur with quartz-chips, the latter probably used for lateral insertion in fishing spears, for it seems the spear-head of the Northern and Western Australian blacks was unknown to the South-eastern tribes. Mills or grinding-stones are not so numerous in comparison near the coast as in the interior, where the food was more often of seeds, nardoo, &c. In Northern Victoria and Riverina, where stones are indeed a luxury, hundreds of square miles being devoid of stone, some fine specimens of grinding-stones have been found, often one or more feet in length, usually of a close and hard-grained sandstone, and hollowed out by ages of use on one or both sides. These were undoubtedly carried hundreds of miles, and were possessions of considerable value. The pounding-stones, pestle-shaped, perfectly rounded or with one flat surface, are usually of hard, smooth stone, such as quartz, diorite, dense basalt, or limestone.

From the nature of the material generally used, the successful manufacture of a stone-axe must have been a work of some difficulty. There was the initial choice of suitable material, often no easy task. When selected, the rough fragment was chipped into the required shape by successive blows from a hard stone used as a hammer, the stone being operated upon being held in the hand, and resting upon an anvil-stone placed upon the ground. Thus chipped, slowly and laboriously, but skilfully, the axe-head assumed shape, and was then ground until both shape and edge were satisfactory upon a hard, usually fragmental, sandstone or whetstone, but occasionally in the mass (*in situ*), running water, where obtainable, being used in the operation.

Sharpening stones, having a perfectly smooth concave surface, as the result of long friction and use, and into which the axe-heads closely fit, are sometimes found. Other stones, to judge by their shape and surface, seem to have been used as rasps for sharpening.

Where procurable, quartzite, on account of its clean fracture and sharp edge, was used for making serviceable knives. Frequently small rounded stones, quartz pebbles, &c., occur in the mirru-yongs; these may have been used in play, in ceremonial rites, in the practice of massage, or the larger ones, as among the Maoris, may have been employed in shaping nets. Bone implements, being more perishable, are seldom found, and were probably but little used among Victorian blacks.

It seems to have been generally and too readily accepted that the occupation of Australia by the black race was comparatively recent. The evidence in support of this opinion is mainly negative, but receives a reflected confirmation from the fact that the stone age is still existent in parts of Australia. In considering this subject we must remember that the native race was not a constructive one, and had no architectural ability by which to leave evidences of antiquity. It was in that low stage of development in which only most imperfect traces of existence could be left behind for after generations. Again, very little has yet been done in Australia by the few interested to systematically study this subject in the same way as in the older countries, with their numerous skilled observers and better facilities for tracing man's development from the paleolithic age to the present day. Yet, in Australia, we have the evident advantage of studying the stone age still in existence, and contemporaneous with our own civilisation. How far its evidences extend into the past is a matter for present and future research. Almost every creek, river, lake, and watercourse has some remains of the old native camps, whose study will throw light upon the past of a vanishing race. Our long coast line of 8,000 miles in extent is rich in similar testimony.

The great extent of these evidences of occupation, particularly near the coast and along the banks of our large streams, tells of a comparatively long period; but as yet so little observation has been made over the immense area on which our scanty population is settled that the question of antiquity of the Australian race is no nearer solution. Our river-valleys, gravel deposits, raised sea-beaches, and river terraces have yet much to reveal on the subject to the diligent and persevering inquirer; and, where investigation has been carried on, the results have been calculated to encourage wider and more systematic work in this direction. In Victoria chipped flint and quartzite weapons and implements were found some years ago in Post-Pliocene deposits near Bacchus Marsh. Similar evidences were discovered in the valley of the Hopkins River, near Wickcliffe, and in the terraces of the Wannon, near Glenthompson, also in the Hawkesbury River valley. At the Adelaide Congress, Dr. Klaatsch, in his lecture on the study of the aborigines of Australia, referred to the human-like footprints found in the sandstone formations near Warrnambool as very likely those of a "juvenile human individual of the Tertiary period."

Near Geelong, in the drift of an ancient watercourse on the Barrabool hills, Mr. Muldea, a well-known Victorian naturalist and geologist of forty years' experience, found many flints, water-worn gabbro axes and other weathered evidences presumedly of great age, judging by the deposit in which they occurred. In the gravel of an old river-drift near the Barwon River, the writer found several evidences of a similar nature, including a water-worn gabbro axe, weathered basalt wedges, and a grinding-stone, the latter being from an excavation made several feet deep, near the Barwon River.

A few years ago, a flint axe of old workmanship was obtained many feet from the surface during the construction of a well near Lake Counewarre. Many other individual instances of the discovery of aboriginal implements, &c., in old deposits might be cited, tending to show, however inconclusively, that the Australian aborigines occupied the country at a period very much earlier than that generally accepted. If the theory be entertained that the Tasmanian blacks were the true aboriginal race, and were driven out by the incursions of a later invading race, it is reasonable to suppose that their gradual retreat to the fastnesses of Tasmania before the pressure of invaders took place before the separation of the island from the mainland.

It may be noticed, in passing, that in the dialects of the aboriginal tribes of the southern part of the continent many words meaning "fire" or "burning" were applied to volcanic vents long since extinct. These names may have been handed down from the period when volcanic action still lingered in the south of Australia, prior to which occupation by the black race had taken place.

More definite data for deductions must be obtained before approximately determining the period of aboriginal occupation; and, in order to provide cumulative evidence from every part of the continent, close and careful observation, time, and comparison of facts recorded are necessary, for in this subject "the labourers are indeed few."

From what we at present know, the position of man in the geological record, as far as Australia is concerned, is "recent"; but with wider research it may be probably shown that, like the characteristic flora and fauna of Australia, which are survivals of geological periods long passed away in other lands, the stone age in Australia may be, as it were, "an arrested development," and may be found to have existed contemporaneously with that of the older lands as far back as the Pleistocene period.

8.—NOTE ON DOLMEN BUILDERS IN NORTH CHINA.

By PROFESSOR S. B. J. SKERTCHLY, late Geological Survey of Britain and of Queensland.

9.—JUNGLE LIFE IN NORTH BORNEO.

By PROFESSOR S. B. J. SKERTCHLY.

10.—THE REASONING FACULTIES OF SAVAGES.

By PROFESSOR S. B. J. SKERTCHLY.

11.—THE PHILOLOGY OF THE METALS AND GEM STONES.

By PROFESSOR S. B. J. SKERTCHLY.

Section G1.

SOCIAL AND STATISTICAL SCIENCE.

ADDRESS BY THE PRESIDENT,

G. H. KNIBBS, F.S.S., F.R.A.S., Etc.

Commonwealth Statistician.

THE PROBLEMS OF STATISTICS.

SYNOPSIS.

1. *Ancient Statistics.*—To-day the range of the application of the statistical method is very wide, and the problems being attacked and reduced are both numerous and significant. Any attempt to indicate the main features of these problems may be more accurately appreciated, if primarily we glance for a little while at the history of the subject. And such a review as is suggested will not be without value as regards the problems that must be attacked in Australia in the near future.

The science of statistics is probably as old as history, and we know at least that from the earliest times the exigencies of administration involved various statistical inquiries. In Egypt, as far back as 3050 B.C., the systematising of the arrangements for the construction of the pyramids demanded quite a considerable body of statistics; in 2200 B.C., maps of the whole country, and statistical data relating thereto, were compiled; in 1400 B.C., a complete *cadastre* appears to have been made by Ramases II.; and in 600 B.C., all the heads of the Egyptian families were duly registered by the police.

In China, in the description by Yuking of the Provinces, statistical results date as far back as 2300 B.C., and in 1200 B.C., what may be called topographical officials compiled elaborate statistical records of their districts.

In ancient Greece, the various classes of citizenship, the privileges of the citizens, their obligations of military and naval service, their property, and their taxes and public burdens, demanded the institution of many statistical inquiries of a systematic character. For example, in Solon's tax-census, in 594 B.C., the people were divided into four classes according to the supposed returns of their property estimated in wheat, and a poll-tax was imposed on alien residents; while a census in Athens, as far back as 309 B.C., distinguished the different classes in the population, there being 21,000 citizens, half that number of aliens, and nineteen or twenty times the number of slaves.

In Rome fairly elaborate statistics commenced from the time of Servius Tullius, while the first census in the presence of the Censors was in 435 B.C.

2. *Mediæval Statistics.*—Mediæval statistics were often very fully developed. Among notable examples may be mentioned the following:—The "Caroli magni memoratorium" of A.D. 807, and "Brevis capitulorum" of A.D. 808; Al-Mamun's "Description of the Khalifate" in A.D. 830; our own "Domesday Book," viz., that of William the Conqueror, in A.D. 1088; the "Land Register" of the Danish King, Waldemar II., A.D. 1231; and Macchiavelli's "Ritratti della Francia e della Allemagna" in A.D. 1515. These later examples of comprehensive statistical compilation reveal the importance attached in the Middle Ages to systematic summing up of public information by those who were responsible for the greater administrations.

3. *Modern Statistics.*—Modern statistical compilations answering to the same ideal may be said to have commenced with Sebastian Münster's work—viz., in his six volumes, appearing in part in 1536, and completed in 1544. This work, illustrated by maps, dealt with the boundaries, divisions, principal towns, history, State organisation, rulers, nobles, estates, armies, &c., military capacity, church matters, laws, customs, manners, &c., of practically all the countries of the civilised world; and of the principal cities thereof. Their commerce and wealth were also treated of in considerable detail. In 1562, Francesco Sansovini produced his "Del governo ed administratione di diversi regni ed republiche." Thus, Giovanni Botero's "Le relationi universali divisi in quatro parti" in 1589; Pierre d'Avity's "Les états, empires et principautés du monde, &c.," and the sixty "Respublicæ Elzeviranæ" commenced in 1626, are monumental examples of early modern statistical compilation.

4. *University Influence.*—At quite an early period University traditions greatly helped the development of statistics as a branch of organised knowledge. As far back as 1660 Conring introduced statistical studies into the University curriculum, his lectures becoming the model for those of Oldenburger in Geneva, of Bose, Sagittarius, and Schubart in Jena, of Beckmann at Frankfurt on the Oder, and of Herz at Giessen. The science of administration, finance, and statistics was widely taught. Thomas Salmon's "The Present Statistics of all

Nations" in 1724, Otto's "Primæ lineæ notitiæ Europæ rerum publicarum" in 1726, are works showing incidentally how marked must have been the appreciation of statistical information.

5. *Mathematical Development.*—Turning to recent times, it may be noted that the mathematical side of statistics has been advanced in a remarkable way, the proper domain and value of exact treatment being more clearly perceived. Through this, it is possible at the present time to set out in a more precise form the general results of all statistical investigations, whether these apply to the realm of physics or to those of biology, to so-called dead matter or to living matter and material forms. Such papers as appear in journals like "Biometrika," or in the "Archiv für Rassen-und Gesellschafts-Biologie," and many of the papers of various statistical societies testify to the fact that, on its analytic side, statistical science has in the last few years made extraordinary advances.

II.—EVOLUTION OF STATISTICAL SCIENCE.

1. *Origin of Official Statistics.*—Naturally enough, the presentation of statistical matter did not immediately take on perfect form. In fact, it was not till Gottfried Achenwall (1719-1772) began his lectures at Marburg in 1746, and produced his thesis, "Vorbereitung zur Staatswissenschaft der europäischen Reiche," that the science of statistics was cast into scientific form. The economists appear, long before this, to have used the word "statistics" as an account of those matters which profoundly concern the well-being of a State as such. Achenwall made a sevenfold division of these, viz.—

(i.) Literature and sources of information.
(ii.) The State, its territory and territorial changes.
(iii.) The land; climate; rivers; topography; divisions; abundance or scarcity of production.
(iv.) The population, its number and character.
(v.) The rights of rulers; the estates; the nobility and other classes of the population.
(vi.) Constitution of the Court and Government; the laws; ecclesiastical, school, and judicial administration; industry; interior and foreign commerce; currency, finance, and debts; the army and navy.
(vii.) The interests of national life and politics, and the outlook for the future.

The direct value of information of this kind was obvious, and led ultimately to the widespread establishment of official statistics. The foundations had, of course, been laid long before Achenwall's day. In his chief work—viz., "Six livres de la République," Jean Bodin, one of the ablest of France's political thinkers, had urged the re-establishment of the Roman Census as an adjunct of police powers. Georg Obrecht, in 1617, proposed continuous statistics of population, based upon rights of inquiry through the various Government organs. Lists of all births, marriages, and deaths, of guardianship, of the age of the people in three-year groups, and of its moral development, &c., were indicated as fundamental. Obrecht's proposals and explanations reveal a critical appreciation of what was essential in practical statistics, while his estimates of probable cost show that his insight as to means was no less incisive. Besold, in 1623, in his "Synopsis Politicæ Doctrinæ," von Senckendorf, in 1655, in his "Deutscher Fürstenstaat," Bœcler in his "Institutiones Politicæ" of 1674, and von Leibniz, in 1700, all urged the desirableness of official statistical inquiries.

The precedent for making such inquiries already existed, for, according to von Ranke (*see* "Fürsten and Völker" I., p. 120), as early as 1575, Philip II. of Spain addressed seventy-five questions to his prelates and corregidors regarding the condition of their districts, and the replies were classified for the King's use. In France, the finance and other investigations of Froumenteau in 1581, and of Pasquier in 1581, of Sully between 1597 and 1610, were fine examples of official statistics. In Württemburg, a registration of local citizenship, commenced in 1622, was made every twelve years. In Austria, the "Status Regiminis Ferdinandi" dated from 1637. In 1645, in Brandenburg, and two years later in Hesse, a registration was made of tax-collection bureaux, of peasant proprietors, and of men of other occupations.

In 1665, Jean Baptiste Colbert's statistics of trade appeared, and in 1684 annual accounts of births, deaths, and marriages in all sections of Brandenburg. The year 1696 saw the development of the English parliamentary papers, among the finest examples, if not *the* finest of public documents.

In 1719 Frederick William I. of Prussia began his half-yearly accounts of populations, their occupations, of houses and real estate generally, of the finances, taxes, &c., but it was reserved for Frederick the Great to make statistics the outcome of thoroughly methodical observation over a wide range of public matters. The scope of his scheme was well elaborated. The tabulations took account of social state, of age, of nationality, of deaths each month, classified under no less than fifty-six classes, of the agricultural population and holdings under various classes, and of industrial pursuits under 460 classes. In 1747 detailed reports of 70 to 100 different articles of commerce were issued; annual enumerations of population were undertaken from 1751, and of cattle from 1770. A list of factories was commenced in 1772; six years later, reports of harvests; and in 1782 of the number of ships. Statistics were also collected relating to the taxes, justice, military, and educational affairs.

2. *Comparative Statistics.*—The preceding discloses what had been achieved in what may be called official administrative statistics. They afforded grounds for a comparison for the same territory of one epoch with another. There is, however, another and wider point of view to be taken in matters statistical—viz., that which compares such developments with those taking place in other countries, either contemporaneously, or at corresponding periods of development, and also with causes not only of change in the one country with the lapse of time, but also of the differences between one country and another. Conring had required not only a description of the ὅτι, but also of the causal connection, διότι, of Aristotle, distinguished in time and space. He analyses causes as the—

(i.) *Causa materialis*, the population and its energies with the land and its productivity.

(ii.) *Causa finalis*, prosperity and its attainment.

(iii.) *Causa formalis*, the character of the State and its form of Government.

(iv.) *Causa efficiens*, the ruling powers, officials, and their auxiliaries and resources.

This Aristotelian view naturally developed in breadth as it passed to matters relating to affairs beyond the bounds of a single State—that is, as it became statistic in its larger sense. And it was in this that Anton Friedrich Büsching differed from Achenwall, forasmuch as he sought to compare the chief phenomena of political life as they were reflected in the statistical data of individual States, while Achenwall merely described the individual States themselves. It was between 1754 and 1792—viz., the year before his death—that the ten parts of Büsching's "Neue Erdbeschreibung" appeared, a work which by 1807 had been completed by Sprengel and others. "Das Magazin für Historiographie und Geographie," a journal which contained a large number of statistical figures from various lands, was issued also by Büsching between 1767 and 1793. It was these comparative works, demanding as they did the close scrutiny of details from different countries, that led to a marked advance of critical methods in statistics.

3. *The Human Being as the Basic Unit.*—Modern statistics differ from ancient largely in its recognition of the human unit as the basic element. In a democratic country this idea—viz., that the human unit is the element which, indeed, gives significance to all related facts—arises naturally and inevitably, though such an idea was by no means characteristic of the early statistical conceptions. The growth was gradual. Continuous and systematic registrations of the births, marriages, and deaths were, however, early made—viz., first in Augsburg in 1501, and then soon afterwards in several other German cities. In London, baptismal records date back as far as 1550, and, because of the plague, systematic records of death, known as bills of mortality, from 1532. Totals were published intermittently till about 1603, and at weekly intervals from that year onwards. Women were employed to inspect the dead, and to register the death, with the probable age and cause of death. The bills were issued in manuscript till 1625, but thereafter in print. Parishes were distinguished in 1625, sexes and causes in 1629, and ages in 1728.* One of the most notable contributions to the discussion of human life as of primary concern to the statistician is the treatise of Captain John Graunt, entitled "Natural and Political Observations on Bills of Mortality, Trade, Growth, Air, Diseases, &c., of the City of London." This work was presented in 1662 to the Royal Society, then founded only two years. Graunt reached the conclusions that the sexes are approximately equal in numbers; that war and pestilence exercise no appreciable effect thereon; that for every 13 girls born 14 boys are born, which, it may be mentioned, is slightly higher than the present Commonwealth ratio; that the ratio of births to deaths is constant; and that the elimination by death of 100 persons is at the rate of 36 in the first 6 years of life, 24 in the decade following, and then in the successive decades, 15, 9, 6, 4, 3, 2, and 1. Finally, he showed that the number of living persons could be calculated from such data. This may be

* See Ogle, Journ. Roy. Stat. Soc., Vol. 55, p. 437.

said to be the beginning of the actuarial point of view, a matter which, however, we must leave for the moment.

4. *Beginning of the Modern Census.*—It was not long after Graunt's time that the importance of a proper census was generally perceived. It has already been mentioned that from 1748 Prussia had annual enumerations of population. The earliest enumerations of population of modern times, however, were probably those in some of the colonies of North America, South and North Carolina dating back to 1700 and 1710 respectively. By 1753 the population of North America, as a whole, had been counted. The count of the population of Denmark dates back to sixteen years later—viz., to 1769.

The first proposal for a general census made in Great Britain was as early as 1753, the date of the enumeration of North America, but the proposal was not acted upon till 1800, when it was decided that the census should be decennial, the first being taken in 1801 by Rickman. This year also marked the first census for Holland and Norway. Brazil's first census was in 1817. In some of the Swiss Cantons, censuses were taken in the latter part of the 18th century, but it was not till 1836 that all the Cantons were embraced. Austria followed three years later than this (1839).

5. *The Elimination of Supposed Non-statistical Elements.*—Initially statistics embraced many elements, such, for example, as history, geography, political economy, law and administrative enactments, &c. But specialisation in each soon required its elimination from the general body of statistics proper. The incisiveness and methodical character of Adam Smith's "Wealth of Nations," published in 1776, had practically created "political economy" as an independent subject of knowledge. Stewart in 1799, Malthus in 1804, Ricardo in 1812, and McCulloch in 1825, in England; Say in 1803, Sismondi in 1819, and Droz in 1828, in France; Garve in 1794-6, Sartorius in 1796, Jacob in 1805, Kraus in 1807, Hufeland in 1807, Lüder in 1820, Rau in 1821, Pölitz in 1823, and von Rotteck in 1829, in Germany, all helped powerfully to develop the new science. It was the subject of lectures in the Universities, and, as treated, embraced all that was directly related to economic policy, and, indeed, much that previously had been held to peculiarly belong to the domain of statistics.

About the same time, Law and Administration began to be divided off with equal sharpness, the philosophical examinations of the subject by Kant in 1796, by Fichte in 1796, and by Hegel in 1821, tending to accentuate the severance.

Geography also became specialised, Gatterer in 1775, and Zeune in 1808, in his "Gaea," giving quite a new complexion thereto. The morphology of the earth's surface, and the conditions which such features impose upon human communities, were made the *point d'appui* of the new treatment. Ritter's great geography of 1818-1819, the greatest work of its kind of modern times, at once established the claim of this subject to independence of treatment, and secured its separation from statistics.

Collaterally, a rapid development of life insurance business—viz., at the close of the 18th and early part of the 19th century—established the foundations of actuarial science, which, though in its essence purely scientific statistics, demanded considerable specialisation for practical reasons. The failures of inadequately equipped institutions, and the arguments of Laplace, Baily, Lacroix, and Littrow—viz., that to be sound the foundation of insurance business must rest upon strict mathematical deductions derived from systematised experience—led to the founding of actuarial method.

6. *First Effect of Elimination of Various Elements.*—The initial effect on statistics, of the elimination of these various subjects, was that the whole system declined, and was little more than a tabular statement of various important facts. As a university study, it lost its pride of place, and doubt even arose as to whether scientific statistics was a possibility. But it was not long before it became evident that answers to quite simple questions relating to population and its various features, or to industry, &c., required special returns, and demanded well-ordered investigations, involving occasionally highly specialised treatment. This fact gave rise to a more critical study of the matter of statistics, and ultimately to the creation of the various official bureaux, and was responsible for the development of a clearer recognition of the proper nature of statistical science.

7. *Illustration of the Evolution of Scientific Idea of Statistics.*—Given sufficient ignorance of the subject, statistics will probably appear to be little more than a series of tabulations based upon more or less well-organised schemes of inquiry. That such a view is quite inadequate will, however, appear from a very simple case. Consider for a moment a series of tabulations of an increasing population, say, corresponding to the terminations of a series of years. The absolute increase year by year is, of course, immediately apparent,* but not the *rate* of such increase. If this absolute annual increase proved on examination to be in each instance the same fraction of the population, let us suppose, of the population at the end of the preceding year, we should then recognise the fact that the *annual rate of increase*† was constant. This increase, however, might be regarded as continuous throughout each instant during that year; hence, through that assumption, we should reach the idea of an *instantaneous rate of increase.*‡ On the other hand, the rate itself may, and, as a matter of fact, always does change. It is not the same from instant to instant; hence an approximate and useful study would be the nature of such changes of rate. We see, then, that it is in the progressive unfolding of the meaning of the rough data, or in the subsuming the crude results under some general conception, that the science of statistics is constituted.

8. *Statistical Prediction.*—Here one may digress somewhat to remark that the value of statistics lies chiefly in its scientific elements —viz., those that belong to systematised knowledge—and by way of illustration it may be pointed out that the history of the subject contains a remarkable example of the application of the idea of §" rate of

* $P_2 - P_1$

† $(P_2 - P_1) / P_1 = r$, a constant—*i.e.*, the constant annual rate of increase.

‡ $P_2 / P_1 = e^{\rho t}$ in which ρ is the instantaneous rate of increase.

§ $P / P_0 = e_\rho \phi\ (t)$

increase." In 1815, Elkanah Watson, of New York, undertook to estimate the population of the United States from 1820 to 1900. Singularly enough, up to 1860 his prediction was substantially correct, and, in fact, was only 1 per cent. in error that year. As a matter of fact, had he assumed, which he did not, that the exact rate of increase from 1790 to 1800 would be continuous, his predicted results would have been still closer to the actual up to the year in question.

9. *The Assistance of Mathematics.*—This illustration suggests the value to statistical science of certain mathematical conceptions. And primarily it may be remarked that the conceptions of the infinitesimal calculus have special utility in all questions of rate and of change of rate, while by the use of the function known as the *logarithm* of a number it is possible to see at once what is the nature of rates of increase, and of any changes in such rates. This relation may be examined either numerically, or graphically The graphic method involves the plotting of the logarithms of the number representing the populations as ordinates, against the corresponding years as abscissæ, instead of plotting the numbers themselves, as is usual. A constant rate is indicated when the successive points lie in a straight line, while a varying rate will give a curve. In the latter case the nature of the change of rate, since in that case it is not represented as a straight line,† can be analysed by simply practically repeating the process,‡ or using a suitable analogous process.

10. *The Value of Graphs.*—The tabular presentation of numerical results is, I believe, relatively modern. I am not aware whether in any systematic form it can be traced earlier than 1741. August Crome proposed in 1782 to represent results graphically by means of geometrical figures.§ In 1785 he showed graphically the relative sizes of the European States, and, in the following year, Playfair in England and Randel and Remer in Germany also utilised the graphic method. Strange to say, these efforts were not cordially received by statisticians generally, though Gaspair and Bœtticher in Germany and Beaufort in Paris in 1789, von Hoeck in 1794, and many others, adopted the new idea. Even to-day graphical representation is too little used, and unfortunately not always popularly understood.

The graphic presentation of statistical results has, as compared with the numerical, many advantages. Almost at a single glance one sees the trend of the events or facts represented, even for centuries of continuous observations, while to get a really complete idea from numerical tables requires prolonged study. Graphical methods of showing statistical results have, however, two other important uses besides that of simply presenting the results in a form readily appreciated. First of all, independent series of statistical facts may be

---

† *E.g.*, if $P = P_{\circ} e^{\rho \phi (t) t}$, we have on taking logarithms, $\log P - \log P_{\circ} = \rho \phi (t) t = \rho_1 t$ say, where ρ_1 varies with t, that is $\rho_1 = \rho \phi (t)$.

‡ Thus returning to the preceding example we should have on transposing and taking the logarithms of both sides :—

$$\log (\log P - \log P_{\circ}) - \log \rho - \log t = \log \phi (t)$$

Thus, if $\phi (t)$ were at^3 we should have

$$\log \phi (t) = \log a + 3 \log t$$

Again the equation of a straight line if $\log t$ be plotted as argument.

§ See his "Geographische statistische Darstellung der Staatskräfte von den sämmtlichen zu den deutschen Staatenbunde gehörigen Ländern," 1820-1828.

correlated, and such correlation is not infrequently unperceived until the graphical representations are compared. It is for this reason that graphs are of great value in discovering the interdependency of facts which *à priori* seem to be independent.

Secondly, graphical representation has a considerable analytic value; it enables one to distinguish, for example, the trend of facts as referred to periods of varying length, and to discriminate between minor oscillations or variations and general trend. Hence, graphical analysis is of special value for prediction purposes, and is a great safeguard against allowing too much weight to the figures for any single epoch or period.

11. *Recent Interest in Statistics.*—From the earliest times publicists have naturally been deeply interested in statistical results. It is, of course, one of his essential equipments. Recent years, however, have witnessed a striking change as regards the *popular* appreciation of statistical matter. "In 1903," said Mr. Bowley, in his paper last September, on "The Improvement of Official Statistics," "statisticians rather suddenly found their neglected wares in demand," and he notes that leading articles, public speeches, &c., "teem with statistical tables and arguments," though they do not always show a clear appreciation of the nature and limitations of statistical measurement.

Every civilised country has now well-elaborated official statistics, covering a wide range of its affairs. Political statistics, in the modern sense, arise from a clearer perception of what is essential for productive administration, and for what has been called, in the wider sense of the term, police regulation. The wise development of any territory demands that its affairs should be brought under systematic review. It is somewhat difficult, it is true, to distinguish between results which may be properly credited to wise or bad government and what may more properly be credited to the lavishness or niggardliness of Nature. And the "*post hoc ergo propter hoc*" fallacy may easily assert itself in this region. Nevertheless, it is universally recognised that an adequate statistic is essential to a critical review of a country's progress, and this is the *raison d'être* of the various departments thereof, whether they exist in the restricted field of an isolated branch of an administration or are sections of the work of a properly-organised bureau.

There is another direction in which the modern interest in statistics is of promise. Not only are economic facts becoming more susceptible of rational analysis, but great ranges of vital phenomena are also disclosing their inner meaning. In the study of individual cases one sees, of course, only the individual variations; in the study of aggregates or properly-formed averages one sees the regularities of the general trend of human affairs.

12. *Characteristic Features of Modern Statistics.*—The most striking feature of modern statistics is, however, its analytic efficiency. This may best be indicated by reference to an illustrative instance. The aggregate increase of population, or the increase by births, or by immigration, or aggregate diminution by deaths and departures, or by either, or the frequency or fertility of marriage, expressed as rates, are, strictly speaking, *crude* results, and are not

immediately comparable with similar results for other countries. To be immediately comparable, the two populations must be identically constituted as regards all relevant particulars.

In respect of birthrate, for example, in order to compare two populations, they should be similarly circumstanced as regards constitution according to sex and age, and, indeed, also as to marriage rate at each age, and also as to general economic conditions, or else the results must be so corrected as to represent what would have been given if they were thus similarly circumstanced.

Special inquiries may involve special treatment by way of corrections to be applied. For example, fertility varies with age; consequently, to ascertain whether the expression of the maternal instinct is equally efficient in two countries, the birthrates must be referred to that of a standard population definitely constituted as regards sex and age, preferably to the mean of the two, or better still to a population which could be regarded as normal according to some specific definition. Since fertility is greatly influenced by marriage, a really valid comparison requires, further, that the distribution of marriage according to age should also be identical, or should be corrected for, and still further—forasmuch as marriage is profoundly affected by economic conditions—the distribution of economic condition according to age must also be regarded as a factor affecting fertility and, therefore, also birthrate.

For many purposes, therefore, crude birth and death rates are very misleading. For example, the crude death rate for 1907 in the Commonwealth is only 10·90, but the *index of mortality* is 14·37, and this would be the actual death rate, if, while the proportion of deaths in each age-group remained the same, the Commonwealth population was identically constituted with that of Sweden, the constitution of whose population has been taken by statisticians as a basis for comparisons.

Another illustration—viz., one of an economic character—may be taken. A comparison of the total trade or the exports or imports of two years expressed in money value, is obviously vitiated by change of price, since an increase in value may actually correspond with a decrease in the quantity of commodities. For this reason it is necessary to use *index numbers*, or the ratios of the prices of commodities at the two periods compared, in order to so analyse the crude result as to know how much is to be attributed to increased volume of trade and how much to mere change of price.

The science of modern statistics, we thus see, tries to penetrate beneath the first appearances of the data, and endeavours to eliminate before comparison those elements which would vitiate the comparison, or failing this, to so correct the *crude* data as to make them fully comparable for any specific end in view.

III.—THE RANGE OF THE PROBLEMS OF MODERN STATISTICS.

1. *Classification of Statistics.*—There is and can be no unique classification of statistics, for the reason that the matter of its subdivisions, under various schemes of classification or from various points of view, overlap. Broadly speaking, however, the facts may be ranged under two great headings, Vital and Economic. Even in

these the overlap is considerable, for in considering human life as affected by age or by disease, the vital element is a necessary measure of the economic. Hence, the statistical matter will fall under one or the other category, according to the dominant purpose of the inquiry, and this must be understood in all that follows.

Vital Statistics (A).

2. *Population and its Variation.*—The increase of population and its variations are ordinarily the *crude* results, and as already indicated are not immediately comparable. In young countries where the flux of population, owing to migration differences, is essentially different from that of old populations, the distribution according to sex and age differs materially from those of older countries. It follows from this that apart from racial, climatological, economic, and traditional differences, the following rates are immediately influenced, viz.:—

(i.) Total birth rate and ratio of illegitimate to legitimate births.
(ii.) Total fertility rates or rates of births to total number of women of each age within the child-bearing period.
(iii.) Total death rate and sex-ratio of deaths.
(iv.) Infantile mortality rate.
(v.) Effect of infantile mortality on birth rate.
(vi.) Death rates of each sex for particular diseases.
(vii.) Marriage rates, and distribution according to age.
(viii.) Disease and its duration, having regard to sex, and age of incidence.

With a single exception,* the discussion of the reduction of these to what may be called their normal form has not yet been made for Australian data, nor, indeed, for the data of the world generally; hence, at the present time, we have to be content mainly with comparisons of crude results.

Suppose, however, that results for birth, death, or marriage rates were so corrected as to conform to identity of age distribution, they would not even then be necessarily comparable for all purposes. The average period of life and the climaterics vary in different climates, and perhaps also from age to age; hence, identity or similarity in the characteristic features of human life may be properly seen only through comparisons of "*corresponding states*," analogous for example, to the states defined by that term in the physical theory of the behaviour of gases.

To attain to a deeper understanding of the significance of our statistical results requires solutions of the type suggested, but they have not yet been made.

3. *Oscillatory Character of Population Phenomena.*—For many purposes one may substitute for actual phenomena certain concepts of them. For example, the annual increase of population may be supposed to conform to the idea of regular and continuous growth of population. Actually, however, increase by birth and diminution by death is essentially oscillatory or periodic. It is so in virtue of the

* See "On the Influence of Infantile Morality on Birthrate." Journ. Roy. Soc. N. S. Wales, 1908-9, by G. H. Knibbs.

nature of the case.† In other words, the numerical solution of a formula, which, starting with a given number of people, and assuming any simple law for births and deaths, gives values which are non-uniform in their progression with time. That appreciable oscillations actually exist is shown in the birth and death rates of all countries, and I have found that these follow sensibly the normal law of frequency.

This oscillation must have been repeated on a larger scale in secular history. For example, if we suppose the rate of population increase for the decade 1881-1901 for several countries to apply continuously we find that, starting even with a single couple, only a relatively small number of years are necessary to attain to the world's total existing population. Hence, the characteristic rates of increase of last century may be merely a phase-value in a secular cycle of changes.

It is evident that for a complete theory of population we shall need to know what are the amplitudes of the oscillations of all periods, mensual, annual, and secular. The science of statistics is too recent for a sufficient accumulation of data, but enough has been obtained to draft the first outline of an adequate theory.

4. *Regression towards Average Values.*—Quetelet, a man of versatile attainments and able as a mathematician, was practically the first to apply rigorous methods to the study of man and his faculties. More recently Mr. Francis Galton, in his "Hereditary Genius" (1869) and his "Natural Inheritance" (1887) made a beginning in the statistical treatment of the phenomena of variation, a field in which so much brilliant work has been done by Professor Karl Pearson, and some of his co-workers in the Philosophical Transactions of the Royal Society and in "Biometrika." This latter journal and the "Archiv für Rassen und Gesellschafts-Biologie" of Berlin, are devoted to the publication of investigations of the type under consideration.

Some of the well-ascertained results are as important as they are striking. For example, if one take any variable character, its "average value in offspring" can be related to its value in a parent by a simple linear equation.‡ This equation really expresses what has been called *filial regression.* In general terms, this may be described as the tendency observed by Mr. Francis Galton for offspring to approximate to the mean or average of the stock—that is, towards mediocrity. For example, the average height of sons of fathers below average height will approximate more closely to such average; or, again, the average for the intelligence of sons of exceptionally talented fathers will more closely approximate to the general average. Galton examined data relating to stature, eye colour, temper, artistic faculty, and some forms of disease. He supplemented his observations on human beings by others on sweet-peas and moths, obtaining confirmatory evidence. One may describe the law by saying that any peculiarity in an individual is shared by his kinsfolk, but in

† I shall show in another place that the oscillations or deviations follow the ordinary law of frequency.

‡ For example, if y_0 be its average value in the offspring, and x the value in a parent

$$y_0 = \alpha + \beta x$$

hence, if x^1 has the value $\alpha/(1-\beta)$; y^1_0 will equal x^1; that is, in that case alone the average for the offspring will equal the value for the parent.

a less degree.* Professor Karl Pearson has shown, however, that the Galton regression value holds good only for certain cases,† a point to which we shall later recur.

This fact of regression implies, on the one hand, that the full hereditary transmission of any gift is ordinarily highly improbable, and, on the other hand, that imperfection or disease is also likely to be inherited only partially.‡

5. *Ancestral Inheritance.*—Although regression toward average values is a tendency expressed with great precision when many cases are considered, it in no way limits what has been called by Galton *ancestral inheritance*, a generalisation of considerable value. Galton's observation is to the effect that in regard to any inherited character, the two parents contribute *on the average* one-half of the inherited faculty, each thus contributing one-fourth: the four grand-parents contribute among them one-quarter, thus each one-sixteenth, and so on. Hence, we get the series—

$$\tfrac{1}{2} + \tfrac{1}{4} + \tfrac{1}{8} + \tfrac{1}{16} + \text{etc.} \ldots\ldots\ldots = 1,$$

as is necessary. Professor Karl Pearson found, however, that while a series of this type holds good, the series as just given probably requires modification, as hereunder, viz.:—

Galton's co-efficients	...	0·5	0·25	0·125	&c.
Pearson's co-efficients	...	0·6244	0·1988	0·0630	&c.

It is further to be noted that modification through reduction of the number of ancestors may affect the result. Brooks, for example, pointed out that if a definite population had for ten generations married first cousins, the total ancestry of any person would be thirty-eight instead of an otherwise possible total of 2,048, and in the case of the present ruler of Germany, the probable number of his ancestors in the twelfth generation back were not more than 533, though the theoretical total possible was 4,096.

Professor Karl Pearson also points out that in the existing state of our knowledge we can hope only to reach the *probable character* regarding offspring of any given ancestry by the application of the statistical method, since the causes, a, b, c, &c., which have been isolated are not followed by a single effect x, but by any one of the effects x, y, z, &c., hence, a determination of the *frequency* with which each of these follow is an essential of the problem.

6. *The Mendelian Theory.*—One of the most interesting of recent applications of the statistical method is its use in testing the Mendelian Theory. In fact, in interpreting the whole series of facts relating to reproduction, the application of the statistical method has been productive of results of great importance. In 1866, Mendel published what is now widely regarded as one of the greatest of biological discoveries. His work was overlooked till his doctrine was rediscovered independently in 1900 by the botanists Correns, De Vries,

* Stated more rigorously, the fact may be thus expressed. If the frequency of any particular character be unimodal, the average value of the character for the sons of fathers of any definite measure of peculiarity exhibit it in less degree. If the frequency be not unimodal the statement is much more complex and the question of the dominant element comes in.

† See Phil. Trans. A., vol. 203, pp. 53-86, in particular pp. 82-3.

‡ Fathers with a mean stature of 72 inches had sons of the average height of 70·8 inches, while those of 66 inches had sons of the height of 68·3, that is, one set regressed *downward*, the other *upward* toward the mean.

and Tschermak. His theory may be thus stated:—In any cross or hybrid, one of the contrasted characters of the parents will in certain cases appear to the apparent exclusion of the other. This prevailing character may be called the *dominant* character, and the apparently suppressed character, the *recessive.* If reproduction be from the dominant forms alone it is found that in the offspring there are *apparently* three dominant forms to one recessive form.* These recessives breed true. The dominants, on the other hand, consist of one-third of true-breeding dominants and two-thirds with suppressed recessive characters, since in the next generation the latter again produce the mixture of dominants and recessives in the proportion three to one. The pure dominants and pure recessives are virtually pure stock again, breeding true for an unlimited number of generations.

From these illustrations it is easy to see how essential is the statistical method for the investigation of all important human phenomena, and it is also evident how hopelessly invalid is what may be called the popular dilution conception of such phenomena as we are considering.†

7. *Unit Characters.*—The facts are often not so simple as is implied in the last illustration. Some characteristics or "characters" of an organism behave in inheritance as if they were transmissible only *en bloc,* and like a radicle in chemistry, can be completely replaced by another radicle, but cannot be invaded as regards their individual integrity. This notion of unit characters is quite consistent with Weismann's theory of sets of determinants or primary constituents, each corresponding to an independently heritable structure. It goes far to explain what the close examination of Mendelian phenomena has confirmed—viz., that the percentage of relationship may be far more elaborate than as instanced above. The subject has been mathematically developed by Professor Karl Pearson, who shows that while the Mendelian and Galtonian doctrines are reconcileable, the full statement of the nature of the phenomena is very complex.‡ This complexity may be in part due to the fact that some characters are analogous to atoms or simple radicles (allelomorphs), while others may consist of several components (compound allelomorphs), and may enter into new combinations like the more complex molecules of organic chemistry.

8. *Theory of Disease.*—Among what are called transmissible characters is predisposition to certain diseases. Persons who are unsatisfied until the economic significance of any natural truth is disclosed, will at once recognise the value of statistical deductions as to the frequency of transmission of such adverse predispositions. It is hopeless to attempt, in any adequate way, to refer to this subject,

* The actual numbers, in the case of 1,064 hybrids of the tall and dwarf pea, were 787 tall, 277 dwarf, instead of the theoretical 798 tall and 266 dwarf, or 74·0 and 26·0 per cent., instead of 75·0 and 25·0 per cent. Toyama with Siamese silk moths got 74·96 and 25·04. With the *Lina lapponica*, a Californian beetle, Miss McCracken got 74·75 and 25·25 per cent. With rabbits, Hurst got 76 and 24 per cent., and in another case 77 and 23 per cent.

† Recent embryological investigations go far to explain the physical mechanism of this—viz., the chromosomes and their elimination.

‡ See, "On a generalised theory of Alternative inheritance, with special reference to Mendel's laws," by Karl Pearson, F.R.S., Phil. Trans. A., vol. 203, pp. 82-86.

but there are one or two matters of such peculiar importance as to be specially worthy of mention. One is the theory of the mode of appearance and duration of disease. Some diseases, pulmonary tuberculosis, for example, have a kind of double incidence on the human race—that is, are dimodal in the frequency of death with age. The infantile phase shows the greatest death-frequency at under twelve months, while the adult phase has its death-maximum at twenty-five to thirty-five years of age. Both in the Commonwealth and the United Kingdom the frequency curve for deaths of males is characteristically different to that for females.

Statistics of the frequency of the duration of disease can scarcely be said yet to exist, though such statistics would undoubtedly be valuable generally, and would be of great economic importance.

9. *Theory of Epidemics.*—In the theory of epidemics, the application of the statistical method has indicated results of great value. The late Dr. Farr, the eminent English statistician, had long ago recognised that the distributions of death from epidemics follow ordinary curve types, and in 1866, when a cattle plague was making great havoc, and public fears were acute as to the limitless damage it might do, Dr. Farr wrote a letter showing that from a proper examination of the data the acme and decline of the plague might soon be expected.*

Recently Dr. Brownlee has shown from the statistical results of epidemics that its course seems to depend on the reception of an organism, which, at the point of time when the epidemic starts, has a high degree of infectivity, but that this degree of infectivity is steadily lost till the end of the epidemic, at a rate approximately increasing in geometrical progression. The increase of infectivity may have an annual period, or (apparently) be without definite period. The cessation of the epidemic depends upon the decline of infectivity of the invading germ rather than upon any constitutional peculiarity in the persons affected.

In connection with the subject of epidemics and immunity therefrom, a recent study on phagocytosis as affected by antiseptics, &c., only disclosed its full significance on the application of the statistical method.†

10. *Economic Aspect of Vital Phenomena.*—One of the most fundamental problems of economics is that which proposes to investigate the economic efficiency of the human unit under given conditions—in fact, any attempt to ascertain the population-carrying power of our earth must attack this question as one element of the solution. The energy expended in the nurture, education, and general maintenance of the human unit appears on one side of the ledger, his productive activity on the other. Through disease, however, man's activity as a productive unit is reduced by total or partial incapacitation; and one of the measures of this would be the extent to which he is affected on the average during his life by various diseases. Statistics of this character have not yet been adequately developed, but would be valuable, and could be obtained by what may be called an occasional census.

* He virtually used the curve $y = e^{-ax^2 + bx + c}$

† Manwaring and Ruh, Rockfeller Institute VIII., 1908, pp. 473-486.

But, besides the loss of efficiency, the direct cost of disease also needs to be estimated. This demands the consideration of the effect of transfers of accumulations of wealth, and also the total cost of general and preventive medicine to a community.

The variation of efficiency with age is a question of importance, which can be resolved by appropriate statistical treatment, and also the variation with natural and acquired endowments both physical and mental.

Attempts have recently been made, so far with very partial success, to ascertain the cost of various forms of education, both general and special, designed to qualify for the various occupations of life. And it is evident that the consideration of any equitable adjustment of the social system must take account of such matters to an extent which hitherto has not been attempted.

11. *Hygiene.*—Every year recently has brought into consciousness a clearer recognition of the value of public hygiene. Here the statistical method furnishes the evidence of that value. Collaterally with improvement in systems of water-supply and sewerage, and improvement in milk-supply, there has been an improvement in city death rates; and especially in rates of infantile mortality. Notwithstanding this, the complete analysis of the total economic effect has yet to be made.

12. *Eugenics.*—The statistical and biological study of the laws of transmission of qualities has given birth to what has been called Eugenics. On the abstract side of this subject, statistics have proved of singular value, while on the practical side, it is becoming increasingly manifest that the systematic study of racial development is of the highest order of importance. This study must embrace both physical and psychical elements. On the physical side it has recently been proposed to obtain measurements of school children of the Australian States, and to have these analysed at one centre. If this work be done systematically and accurately, the drift of the variable measurements of our community will be disclosed long before it can be popularly recognised. A similar remark applies to the psychical aspects of our development. In the greater matters of human conduct, response to instincts may perhaps be regarded as a safer guide than the counsels of systematised eugenics; nevertheless, there is every reason to believe that with advancing knowledge and improved education, eugenic considerations will enter more largely into the formation of that powerful and ever-operative influence upon human conduct—viz., public opinion. Thus, the instinctive response to public opinion will tend to conform to what can be learnt through statistical investigation of the trend of human life. It is in the trend of masses, not in the idiosyncrasies of units, that the well-being or disaster of the community will be foreshadowed.

13. *The Reach of Eugenics.*—How far-reaching is the matter of a statistical study of the human being is disclosed by such results as show the importance of the hereditary factor in evolution. "Definite characters for good or ill, whether dominant or recessive, do not disappear in Mendelian inheritance. They persistently appear in their original 'purity'," says Professor Thomson, of Aberdeen,* and he

* Heredity, 1908, p. 376.

quotes Mr. Punnett to the effect that "Permanent progress is a question of breeding rather than of pedagogics; a matter of gametes, not of training. As our knowledge of heredity clears and the mists of superstition are dispelled, there grows upon us with an ever-increasing and relentless force the conviction that the creature is not made, but born."† Thus race, and reproduction from its best elements, are, according to the students of eugenics, matters of even more transcending importance than formal education. If it be known that faculty comes by birth rather than by education, it will naturally greatly affect public policy and public opinion.

Two remarks will confirm the significance of the ideals of the advocates of practical eugenics. Professor Pearson points out that 25 per cent. of the married couples of Great Britain produce 50 per cent. of the next generation, and that consequently much depends upon the physical and psychical character of that 25 per cent. And he states also that there is no escape from the general result that the ratio of defectives, including deaf and dumb, lunatics, epileptics, paralytics, crippled and deformed, debilitated and infirm has increased of late.

It will be evident, on reflection, that we shall do well in this young country, where we have the British race transplanted, to watch the evolution of the people in an appropriate manner, and a beginning, it is hoped, will shortly be made by the systematic examination of school children from an anthropometric and hygienic point of view.

Economic Statistics (B).

14. *Productive Activities.*—Turning now to the economic side of our subject, it may be remarked that a sound estimate of the measure of productive activity of any people is a desideratum of the first order in this branch of statistics. For obvious reasons, this should be measured, where possible, both in quantity and in value, since for the resolution of certain questions the one element, say quantity, is of the first order of importance, while for the resolution of other questions, money value is the important element. To attain a sufficient precision in statistics of this kind, in the pastoral, agricultural, or manufacturing industries, is, of course, no easy task, but is worthy of considerable effort.

15. *Political Aspects of Productive Activity.*—The relative scale of development of the pastoral, agricultural, and manufacturing activity of any people and changes therein, using these terms in their widest sense, must engage the attention of any statistician who recognises the real nature of his function. And it is evident, therefore, that the mode of occupation of land, and changes in the mode of occupation, should constitute part of the complete data.

Satisfactory statistics would embrace the following or analogous items in all industries, viz.:—

- (*a*) Numbers permanently and numbers partially occupied in the industry grouped as to sex and age, with the total time devoted thereto;
- (*b*) Capital outlay involved (land, buildings, plant, machinery, &c.);

---

† Heredity, 1908, p. 60.

(c) Administration expenses;
(d) Maintenance and general working expenses, including depreciation;
(e) Wages;
(f) Quantity and cost of raw material;
(g) Quantity and value of output.

In the occupation of lands, it would require the following, viz.:—Number of persons holding lands arranged according to kind of tenures and areas, and according to values.

In regard to occupation and wages and salaries, the following is desirable, viz.:—

(a) Extent to which one is employed during year;
(b) Non-employment through incapacitation and through absence of work;
(c) What emoluments received, arranged according to amounts;
(d) Cost of housing, and of food and clothing.

The value of property should be grouped under the following headings, viz.:—(a) Land; (b) Dwelling-houses; (c) Business Houses for Retail and for Wholesale Trade; (d) Manufacturing Establishments; (e) Plant and Machinery; (f) Goods, *i.e.*, commodities.

With such statistics as have been suggested it would be easy to determine whether the government and general administration of a country's affairs tended to the general material well-being or not. It could be seen, for example, whether the aggregate and distribution of efficiency were increasingly satisfactory or otherwise, whether wealth and control of land was concentrating or becoming distributed, whether employment was steady or precarious—in short, whether the economic conditions were healthy or otherwise.

16. *Statistics of Distribution.*—Another important question on the economic side is the relation between production and distribution, since when distributing charges are unduly high production may be non-economic to the producer, and material of value actually produced may have to be destroyed. To secure statistics of this character, all distributing agencies would require to render complete returns of quantities and value of material handled, amounts paid and received for same, capital, outlay, administrative and current expenses, losses and depreciation, &c.

In this connection all equipment for distributing (*e.g.*, carrying agencies, &c.) would come under review, and in this connection also State railways.

17. *Agents of Production and Distribution.*—Among important agents of production and distribution, railways in such a country as Australia hold a high place. In all developing countries too strict an adoption of the commercial principle may be detrimental to the general interest of the community, since for developmental reasons it may be wise to run a railway system at a loss, when estimated from the point of view of a paying concern, and it is easily seen that a community might advance, and be well able to pay taxes generally through the adoption in certain cases of a non-commercial policy in running its railways. A statistical examination, while it could not resolve this matter, would throw light thereon, provided the railway

statistics are kept on suitable lines to disclose fully the real nature of the railway business. It is always a great advantage when a common scheme is adopted in regard to railway statistics of a series of States between whom there is railway traffic.

18. *Analysis of Trade and Commerce.*—Possibly on few economic subjects has there been more confusion of thought than concerning the nature of value, of which there are at least four kinds—viz., use, esteem, cost, and exchange value. In the majority of economic questions, it is the last which is most frequently under consideration. The mathematical formulation and general theory of the subject has somewhat recently been worked out with great thoroughness by Walsh. Time will not permit of more than the briefest reference to the matter, but it may be pointed out that in analysing exchange value relations, the possible errors of arithmetic, harmonic, and geometric averaging, all need to be considered. The difficulty about price relations may be seen by a very simple illustration. We propose, let us say, to analyse the significance of imports of two years, expressed in pounds sterling. If we take the ruling prices of the former year and apply them to the quantities of the latter year, the ratio of the deduced and actual value is in general different from what is obtained by taking the ruling prices of the latter year and applying them to the quantities of the former year. The method followed by the Commonwealth Bureau is that adopted by the Board of Trade, and has been employed not because of its validity from the standpoint of theory, but simply because it places the Australian comparison on the same basis, however imperfect, as the British, and it certainly gives a result of some value.

This is one of the matters in which international agreement as to method is a desideratum. Dutot's, Carli's, Scrope's, Young's, Drobisch's, Lehr's, Nicholson's, and other methods have all been thoroughly analysed, and the adoption of a universal method has been ably discussed by Walsh.

IV.—THE PRESENT ASPECT OF STATISTICAL PROBLEMS.

1. *Return to Original Conception of Statistics.*—What has been very roughly indicated in the preceding remarks discloses the fact that by virtue of its inherent nature the science of statistics is not merely resuming its original range and dignity, but transcending that range. The wide reach of statistical method, and the demands it makes in regard to the necessary mathematical equipment, mark it out as on the broadest planes of human knowledge. It concerns itself with the totality of human affairs. No longer can mere tabulations of information be regarded as statistic, nor compilers of and commentators on statistical tables as statisticians. Much of the meaningless tabulation which in the past has passed current for statistics will in the near future be dispensed with, while penetrating investigations, such, for example, as those with which the founders of "Biometrika" and similar publications are associated, will take their place.

Not only will statistics become more incisive, not only will mere voluminous and increasing detail be abandoned, not only will inquiries be intelligently directed toward intelligently conceived ends, but even the field embraced will be enlarged. In a word, it may already be said that the original field has been fully resumed.

2. *Scope of Statistical Problems.*—The original field is again embraced. Geography, for example, of any value, is not merely a multitude of names, nor confined to a morphological description of a region; it recounts the trade and commerce and the productive activities of aggregations of human beings. Roads, railways, and waterways become significant because of the extent of their traffic, or because of their volume and potentialities for carriage or production. Towns are centres of human activity; the country, fields of less concentrated activity; territories are aggregates of effort expressing itself under some dominating political and social ideals, and all these are analysed and measured by the statistician to the end that their meaning may become manifest.

He is concerned with the efficiency of the human unit and the mode by which that efficiency is expressed; with the term of his life, and the way in which that term actualises itself; with the interferences of disease with man's activities or happiness; with the way in which the various diseases cut short the human career. He is concerned with the nature of man's evolution; with the expression of his character in life; with his ancestral endowment; with the whole range of his heredities; with his mode of expressing his social or antisocial qualities; with his relations in peace and war.

The statistician must also analyse the situations which human relationships bring into being, the mode of his productive activities; the exchanges of his productions. Hence he must grasp the principles of economics and finance, the theory of money, of exchange value in general, and of price.

On the mathematical side, the theory of probability is an essential instrument. The symbolic expression of frequencies of various kinds must constitute one of his instruments for attacking great practical questions. Differential relationships, their expression and analysis, are his instruments, though these do not appear in the popular publications which are submitted for ordinary information.

The multiplication of flocks and herds, the yields of agriculture, the extent of manufacture, the volume of commerce, the securities for human endeavour, and for human relationships, the bases upon which rest all forms of human effort—these are the matters which call for the professional attention of the real statistician.

3. *Essentials of a Statistical Review.*—We can now see that what should be aimed at in a complete statistical review of any community is the presentation, in a series of panoramic views, of the features of the life-conditions and life-relations of the human units of which the community is made up, treating such features, however, not as the circumstances affecting individuals, but as those operating to produce the growth and development of the sociological masses of which the human units are the components.

With this object in view we should have a review of the population itself, its composition as regards race, sex, age, &c., its fluctuations, whether natural or by migration, and its aggregations to form towns and villages. Associated with particulars of fluctuations of population we require details of the births, the marriages, and the deaths of the people, with all the wealth of information which the investigation of these vital phenomena involve. We then require particulars as to the means by which the community sustains life and comfort, and this opens up two large fields of statistical inquiry, that of production on the one hand, and that of trade on the other. Under the head of production, inquiry must be made as to the relation of the human unit to the various primary sources of wealth, thus furnishing particulars concerning such industries as—

Pastoral,	Mining,
Agricultural,	Forestry, and
Dairying,	Fisheries.

Associated with these are the various manufacturing industries in which the raw materials are worked up into the form suitable for use.

The exchange of surplus articles of production constitutes trade, and the investigation of its bearing on the human unit involves the consideration of details of imports and exports.

For many purposes connected with production and trade, means of transport and communication are required, and the necessities of our human units in this respect are mainly supplied by means of railways, tramways, and shipping, as regards transport; and postal, telegraphic, and telephonic facilities as regards communication. We thus need details concerning roads, railways, tramways, shipping, &c., as well as statistics of posts, telegraphs, and telephones.

Further, for the economical carrying out of his many functions, man required the intervention of a medium of exchange, or money, and the record of his dealings therewith furnish statistics of private finance, including banking, insurance, coinage, &c.

For the due control of the community as a whole, systems of government, Federal, State, and municipal are required, and an examination of the functions of these institutions furnish two sets of statistical results, legislative and financial, the former dealing with the scheme laid down for regulating the conduct of the community, and the latter with the levies made upon the community to secure the means for enforcing those regulations, and with the manner in which the sums so raised are disbursed.

The investigation of the formal application of these regulations, and of the penalties which their breach involves, provides the basis for the legal and criminal statistics of the community, while the records of the provision made by the more affluent members of the community for the destitute and the afflicted furnish statistics of charity.

We thus see how intimately related are the various branches of statistical knowledge, how dependent each is upon some phase of the life, conditions, or relations of the human unit, and how essential it is for a comprehensive treatment of the matter that the professional statistician's outlook should be as wide as that of human activity itself. His high aim should be that of understanding the inter-relations and inter-dependencies of man with his fellow-man, and, from his position of professional expert in statecraft, assisting the administrative statesman with his counsel and advice.

4. *Conclusion.*—The field of statistics is, however, so vast that any attempt to compress within the limits of a single address more than a cursory view of its many ramifications would be futile. What I have endeavoured to do has been to present as clearly as possible the manner in which the science of statistics has grown and developed, and to indicate, though briefly, the enormous statistical harvest still

awaiting the sickle. With these objects in view, I have traced the growth of our science from the remote past, the diminution and subsequent expansion of its recognised scope, and the modern developments in consequence of which the statistician has become not the mere recorder of numerical facts and mechanical keeper of the national ledger, but has united, with those eminently useful though not very lofty functions, the interpretation of recorded facts on the one hand and the scientific investigation of methods of record, analysis, and presentation of facts on the other, requiring for the one all those qualities of clearness of vision, extent of knowledge, and breadth of view which go to make the genuine statesman, whether his sphere of action be that of administrator or of expert in statecraft (otherwise statistician), and for the other an acquaintance of no mean order with the application to statistical science of the various branches of mathematics. In his threefold capacity as recorder of facts, interpreter of facts, and investigator of methods of presentation of facts, the statistician occupies an important position in the community, and one which, it is essential, should be of a judicial character, requiring of its occupant those qualities of unbiased impartiality usually associated with occupants of the judicial bench.

The official side of statistics is not its only side. In many countries, non-official statistics assume large proportions, and are of the highest value. Where man governs himself, as in democratic countries, he is the direct recipient of the benefits that in olden times belonged to the monarch, and it cannot be too vividly realised that the utility of the effort of the statistician will and must depend greatly upon cordial co-operation and ready supply of information by the public generally, for whom he labours.

The course of public finance, the cost of government, the development of the people, their ability to bear the strain of administrative demands, these are all under his oversight. If each individual and each body of men will discharge their statistical duty to the body politic, official statistics will be supplemented by the results of a host of special inquiries. Then, given the imagination and the necessary mathematical ability to pierce the often apparently impenetrable results which constitute the crude data or material on which one has to operate, the meaning of these can be resolved.

As we have seen, statistics had its origin in the practical needs of administration, and its scope was bounded by the horizon of the time. To-day it is no less practical, but our conception of what is essential for wise administration of human affairs has deepened and broadened. We see more clearly the sweep of each influence, and the extent and force of the action of one thing on another. A larger outlook, and greater range of knowledge, has enlightened our view as to what things are of really practical value. Thus, with a better grasp of the complexity of human affairs, the consciousness of what is needed for administrative guidance has been correspondingly elaborated, and has called for the exercise of a higher order of abilities than was demanded even a decade ago.

Finally, the day is, let us hope, not far distant, when, thanks to the International Institute of Statistics and its splendid labours, all international effort will be guided into common lines by the highest and ablest of those who are devoted to unfolding the meaning and resolving the problems of statistics.

PAPERS READ IN SECTION G1.

1.—THE LIMIT OF STATE ACTION.

BY MAX HIRSCH.

Two causes combine to foster the belief in the omnipotence of the State and to extend governmental functions in every modern community. One is the advent to political power of what are termed the working classes. Dissatisfied with the conditions in which they have to carry on their lives, they, not unnaturally, look to the only power visible to them, the State, to improve these conditions, and Socialism has crystallised their vague expectations into a system which places scarcely any limit on State functions. This, the more active force is supported, on the part of other classes, by a growth in altruism, which also, with more or less intensity, looks to the State to improve the condition of the mass of the people. Hence results a tendency, temporarily irresistible, to extend governmental functions, and every such additional function circumscribes the functions of some or all individuals. Individual freedom is thus being confined to ever narrowing limits, the power of the State and the number of its officials is constantly being extended, and with it goes of necessity a constantly increasing transfer of expenditure from the individual citizen to the State. The question whether there are any limits to this transfer of functions and wealth to the State, and where the line of demarcation between the legitimate functions of State and of individuals lies, is therefore becoming one urgently calling for solution.

Two schools confront each other. One postulates that every demand for an extension of governmental activities may and must be judged by "the balance of advantages" which it confers upon the community. Though it includes many persons who do not favour the governmental organisation at which Socialism aims—it nevertheless may fairly be termed the socialistic school of thought, because it does not postulate any limit in principle to such extension.

The other school of thought denies the possibility of any such empiric determination of "the balance of advantages" arising from any addition to the activities of the State. It teaches that certain functions naturally belong to the State, while others naturally belong to individuals; that the line of demarcation separating the functions of the one from those of the other can be clearly established from known and admitted principles, and that any encroachment by either on the functions of the other must be detrimental to the community. This school, though materially differing in its conceptions from the individualism taught in the first half of the last century, nevertheless may be termed individualistic, because it teaches that there are rights of the individual with which the State may not interfere.

The object of this paper is to criticise the teaching of the former school of thought, and to support that of the latter.

Both these widely diverging schools of thought hold one conception in common. They agree that the State exists for a particular purpose, and that this purpose is to enable the persons composing the community to lead happier lives than otherwise would be possible. This common conception may therefore be fitly taken as the starting point of this inquiry.

The object of State action being the happiness of the individuals forming the community, the first question to be examined is, can the State possibly achieve this object by actions determined upon empirically—*i.e.*, by weighing "the balance of advantages" resulting from such actions? This very conception admits that State action may be disadvantageous as well as advantageous—*i.e.*, that its results do not depend upon chance, nor upon the intentions of the State, but are determined by the universal and unalterable causal relation between acts and their results. It is, however, equally clear that if such causal relations exist, the result of every State action may be deduced from these unalterable causal relations.

It may, however, be contended that it is easier to pursue the balance of advantages resulting from any action of the State—*i.e.*, its immediate as well as its remote sequences, than to recognise the law of causal relation which determines the sequences of such acts. The slightest examination, however, establishes the fact that the former course, far from being more easy, is actually impossible. It is admittedly difficult for a single individual to estimate the conduct which will ensure the greatest happiness to himself and his immediate family. Hence individuals, more and more, allow their conduct to be guided by principles, in the sure expectation that conduct so guided is more conducive to their happiness and that of their dependents than conduct based on considerations of expediency. This difficulty of the individual is, however, infinitesimal compared with that of the State. For the State deals with millions of individuals, all differing in innumerable ways from each other and from the persons composing the governmental agencies which enact and administer the laws that are to ensure their happiness. Nevertheless, the persons enacting and administering the laws have no other guidance than their own feelings to determine the kinds, degrees, and sequences of the countless acts, the totality of which constitutes the happiness of the innumerable persons, all differently constituted, from them and from each other, the happiness of whom and of their descendants they endeavour to ensure. The object, individual happiness, and the agencies by which it can be attained are thus simple when compared with the infinite complexity of the object, general happiness, and the agencies by which it can be attained. Yet, if individual conduct aiming at the former cannot be usefully guided by merely empirical considerations, it must be obvious that such considerations cannot possibly furnish a reliable guide to conduct aiming at general happiness.

The State, guided by purely empirical considerations, can thus obtain no certainty that any one of its acts will add to the happiness of the individuals composing the community. The contrary conception, moreover, recognising no limit to the interference of the State, tends, in favourable circumstances, to the transference of innumerable functions from individuals to the State. Yet every such transference tends to counteract its object—the increase of general happiness. For happiness is a state dependent upon the satisfaction arising from a due performance of functions—*i.e.*, the normal discharge of all its functions constitutes the happiness of any organism. Yet every additional function performed by the State restricts the number of functions which can be normally discharged by individuals, and thus reduces their happiness.

Moreover, the greatest measure of happiness of which men are capable arises from perfect adaptation to the requirements of social life. Suffering is the inevitable concomitant of man's as yet imperfact adjustment to social requirements, and the only means by which a more perfect adjustment, and consequent increase of happiness, can be obtained. For, if maladjustment were not productive of unhappiness, or if it produced happiness, man's nature could not evolve into greater congruity with the requirements of social life. Hence, it follows that every function transferred from individuals to the State, lessening, as it must, the evolution towards greater congruity, must tend to reduce the happiness of which men otherwise would be capable.

The foregoing examination, limited as it naturally must be, has established the fact that there are principles—*i.e.*, natural laws—which determine, apart from individual induction or from empirical balancing of advantages, whether any action of the State will have beneficent or maleficent sequences—*i.e.*, whether it will increase or induce general happiness. Fortunately, such proof was not needed, for no one, not even the advocates of empirical balancing of advantages, doubted it when confronted by particular acts. That disorder increases when violence goes unpunished; that contracts are broken lightly and frequently when justice is expensive or uncertain; that production is checked where taxation is uncertain or unjustly apportioned; that wealth declines where property is insecure; that it concentrates in the hands of a few where monopolies abound—are propositions which are assented to without any balancing of advantages. What, then, are the principles which determine the sequences of State actions, and, hence, the line of demarcation between the action of the State and of individuals? It must now be attempted to answer this question.

For in the social state the happiness of every individual is affected by the conduct of all other individuals. Dishonesty, by causing expense in supervision, tends to a reduction in the production of wealth; incapacity does the same, besides reducing the happiness of the incapable and of their children; licentiousness and over-indulgence, while having similar results, cause useless expenditure on hospitals, prisons, and lunatic asylums; selfishness tends to aggression on the rights of others, and thus reduces happiness directly. The greatest measure of happiness, therefore, arises when all individuals, being guided by ethical considerations, have adapted their conduct to the requirements of social life. In order that such conduct may become general all adults must receive benefits according to their capacity, capacity being measured by fitness for the conditions of social life. On no other plan could the evolution of higher social types from lower social types have taken place in the past, and on no other plan can it proceed further. To realise the absolute truth of this proposition one has but to imagine a society in which benefits were proportional to inefficiency. In such case inferior would naturally survive superior, and have a greater number of children of similar unfitness. A gradual retrogression would result, until the society, becoming less and less adjusted to the conditions under which the lives of its members must be carried on, would be exposed to universal suffering, ending in extinction.

The admitted object of every action of the State being general happiness, it follows that the State must abstain from any action which disturbs the relation between efficiency and reward. It must neither increase the reward of the more capable at the expense of the less capable, nor must it increase the reward of the latter at the expense of the former—*i.e.*, it must not confer special privileges on any individual. General rights and equal opportunities for all citizens, regardless of their capacity or fitness, therefore must be the foremost object to which every action of the State should be directed.

And, further, as adaptation to the social state and the highest state of happiness depends for its evolution upon the exercise by all individuals of all their functions, it follows that the State shall not limit their freedom by more than is necessary to secure the maintenance of equal rights and opportunities. The greatest measure of general happiness thus arises from the fullest freedom compatible with equality of rights and opportunities—*i.e.*, from "the freedom of each to do as he wills, provided he encroaches not upon the equal freedom of all others."

These considerations show not only that there are ethical principles limiting the activity of the State, but also define the ethical line of demarcation, separating State action from individual action. The State not only may but must perform all those acts which establish and maintain equality of rights and opportunities for all its citizens, and cannot beneficially affect the community by any act not necessitated by this object.

If these considerations are applied to the conduct of modern States, it will be seen at once that the State not only assumes numerous functions which lie outside the limits of its legitimate activities, but leaves unfulfilled many other functions which fall within this limit. Nothing need be said here as to the former, but a short exposition of the principal functions neglected by the modern State may be justified on account of their transcendent importance.

The first object of man, as of any organism, is to maintain his life. But the maintenance of life depends upon the use of the earth. In modern societies this use of the earth assumes many and varied aspects. The farmer uses its fertility; the miner, its mineral treasures; merchants, bankers, manufacturers, and professional men use its products; and all these, as well as every other man, must use the earth as dwellers thereon. To all men, therefore, the use of the earth is the basis of their existence, the indispensable opportunity for the maintenance of their lives. It follows that equal right to the use of the earth is the indispensable condition for equality of rights and opportunities, the establishment and maintenance of which we found to be the primary duty of the State. Yet, the modern State has not only neglected to establish and maintain the equal right of all to the use of the earth, but has established and maintains by force the opposite condition. Private ownership of land, unlimited by any condition which compels owners of more valuable lots of land to compensate the community for the special privilege which they enjoy, compelling non-owners to hand over to others part of the wealth which they produce for mere permission to live, is thus the fundamental infringement of the equal rights of all and its abolition—*i.e.*, the collection of the rental value of the land for common use is the principal function of the State which it leaves unperformed.

Other functions, the neglect of which similarly abrogates the equal rights of all, consist of special privileges of an industrial character. While the great mass of industries by which men maintain their lives in tiring service to their fellowmen are naturally free to all, certain industries, arising in highly developed societies, are not so free, but depend for their establishment and increase upon the grant of a special privilege by the State to one or to a limited number of persons—*i.e.*, upon the transfer to them of part of the sovereign power of the State.

In order that private persons may hold and operate a railway, the State, by special legislation, must transfer to them some of its power of eminent domain—*i.e.*, power to forcibly dispossess other persons of land, and must secure to them the right of way over a narrow but long plot of land. Such privileges cannot be granted indiscriminately, and the grant of such privileges to a few, creating a monopoly in transportation, seriously diminishes the rights of all others, and establishes a condition of inequality of rights. Similarly privileged industrial undertakings are privately-owned tramways, and the supply of gas, water, electricity, hydraulic and pneumatic power to modern cities. Such privileges are of the nature of monopolies, and all of them, therefore, form part of the natural functions of the State, which it neglects to perform.

As already stated, space does not permit to enter upon the consideration of the numerous interferences with equal rights which arise from functions unjustly assumed by the modern State. But it may be pointed out that little reflection will establish the fact that this unjust assumption of functions by the State, and the sentiments which compel such action, are the corollaries of the unjust transfer of governmental functions to private persons. Because the State neglects to perform functions naturally belonging to it, it is forced to assume functions which do not belong to it, freedom being thus hemmed in and reduced from both sides. In no other way than by following the dictates of justice, through a strict regard of the ethical line of demarcation between State and private functions, and not by any balancing of advantages, can human beings reach the highest state of general happiness of which their nature is capable.

2.—COMPARATIVE LEGISLATION RELATING TO THE INDUSTRIAL CLASSES.

By JOHN B. TRIVETT, F.R.A.S., F.S.S., Government Statistician of New South Wales.

A retrospect of the course of legislation in civilised countries during the last fifty years affords an almost limitless field for reflection as to the multitudinous influences which dominate the nations in their actions respecting the welfare of the people.

When we regard the current work of the Parliaments, we are apt to lose sight of the sustained controlling spirit which the perspective of long years of legislative history clearly shows, and which in the event unfailingly asserts itself.

After witnessing in England the stirring events of the periods of the Chartists, of the Corn laws, of the Factory and Trade Union Emancipation; or, on the Continent, the fierce struggles for liberty and liberalism which found their vent in the revolutionary outbreaks which upset dynasties, who would have dreamed of the possibility within fifty or sixty years of the realisation of practically all that was demanded in those unhappy times?

Taking the history of England, whether we view the development as the work of Whigs or of Tories, of Conservatives or of Liberals, of the New Unionist Party or of the Ultra Radical, it will be evident that with the procession of the years the degree of progress has not been marked to any material extent by the name of the party in power at any given time. Rather it may be measured by the extent of the awakening of the popular mind as to the ideals which should control legislation; and, in fine, the advance of legislation at any stage may be regarded as indicative of the growth of the national mind in the humanities.

The same statement may be made with equal force in considering the legislative enactments of all other civilised nations.

I propose to take a brief review of the course of legislation in New South Wales during the last twenty years, in order to ascertain the trend of our laws; and with more especial reference to the industrial classes, who form the great bulk of the population, and who may, therefore, be expected to exercise a very distinct influence in moulding national sentiment.

In order to obtain an enlightened view of the application of the industrial legislation, I have analysed the list of enactments, and subdivided the subjects treated under different headings, corresponding to the several stages of life; and thus have obtained the means of observing in what respects, and to what extent, the interests of the people have been fostered with regard to each period.

The stages of life resolve themselves as follows:—

I. Infancy.
II. Youth.
III. Manhood Specifically—Agriculture.
IV. ,, ,, Pastoral.
V. ,, ,, Mining.
VI. ,, ,, Shipping.
VII. ,, ,, Shopkeeping.

VIII. Manhood Generally—Health, Food, Drink, &c.
IX. ,, ,, Industrial Conditions and Safeguards in Trade.
X. ,, ,, General Welfare and Protection.
XI. Decline of Life, Sickness, and Old Age.

The details of the above classification are to be seen in the following synoptical statement, information regarding the Acts being amplified where necessary:—

I.—Infancy (10 Enactments).

(1.) *Protection of Children Act*, 1892.

Unlawful to accept premium for adoption of children except by periodical payments not exceeding 20s. per week. Adopted child to be registered. Inspections to be made. Penalties for neglect of child. Death of adopted child to be reported to the police. Persons having custody of child to be registered annually. Records to be kept of lying-in homes. Child not to be taken from lying-in home without express authority. Child under 14 years of age not to be engaged in dangerous performances. Protection generally.

(2.) *Custody of Children and Children's Settlements*, 1894.

When a parent has deserted or neglected his child, or allowed his child to be brought up at the expense of the State, or of another person, the Supreme Court shall not make an order for delivery of the child to such parent except under certain conditions.

(3.) *Children's Protection Amendment Act*, 1900.

Protection from assault. Removal to safety when offence has been committed. May be dealt with under Industrial Schools' Act. Penalties for causing children to solicit alms, or perform at public entertainments for profit.

(4.) *Destitute Children's Society Act*, 1901.

Consolidation of Society's Laws. Objects: Protection, support, and religious instruction of deserted children. Directors to provide for maintenance, &c., with power to apprentice children. Parents' liability for contributions.

(5.) *State Children's Relief*, 1901 *(Consolidation)*.

Consolidation of Acts relating to the boarding-out of children. Appointment of Relief Board. Powers and duties of the Board and Boarding-out officers. Cottage homes for sick children. Own children may be boarded-out to deserted wife or widow. Parents' liability for contributions.

(6.) *Legitimation Act*, 1902.

Legitimation of illegitimate children automatically, on registration after marriage of parents.

(7.) *Children's Protection (Consolidation)*, 1902.

(8.) *Juvenile Smoking Suppression*, 1903.

Prohibiting supply of tobacco, cigars, or cigarettes to persons under 16 years of age.

(9.) *Infant Protection*, 1904.

Further and better provision for protection, maintenance, education, and care of infants, and for supervision of places established for their reception.

(10.) *Neglected Children and Juvenile Offenders*, 1905.

Provision for protection, control, education, maintenance, and reformation of neglected children and juvenile offenders. For the establishment and control of institutions, and for contributions by near relatives towards the support of children in institutions. Constitution of children's courts. Provision for licensing of children trading in streets.

II.—Youth (5 Enactments).

(1.) *Apprentices Act*, 1894.

Care and supervision of orphan apprentices.

(2.) *State Children's Relief*, 1896.

Extended protection and control of apprentices and other children, and a subvention to deserted wives and widows in respect of their children.

(3.) *Deserted Wives and Children*, 1901.

Orders made against husbands deserting wives or children, and against mother deserting illegitimate child. Seizure of goods or attachment of annuities under orders. Education of neglected children. Protection of property acquired by wife after desertion by husband.

(4.) *Reformatory and Industrial Schools*, 1901.

Consolidation of Acts. Reformatories and industrial schools for the employment, education, correction, and restraint of children. Private industrial schools subject to inspection. Vagrant or destitute children, or offenders under 16 years sent to schools. Religious training. Apprenticing of children. Parents' liability for contributions. Punishment of absconders, and of persons assisting them.

(5.) *Apprentices*, 1901 *(Consolidation)*.

No child under 14 to be bound. Courts to settle disputes between master and apprentice. Apprentice absenting himself without leave. Penalty where master transfers or discharges apprentice who does not consent.

III.—Manhood Specifically, Agriculture (5 Enactments).

(1.) *Advances to Settlers*, 1899.

Up to £200 on security at 4 per cent. interest, payable in 10 years.

(2.) *Advances to Settlers*, 1902.

Amount of advance increased from £200 to £500.

(3.) *Advances to Settlers*, 1902.

Amount of advance increased to £1,500.

(4.) *Vine and Vegetation Diseases*, 1906.

Precautions against fruit pests. Infected fruit, whether local or imported, to be destroyed.

(5.) *Government Savings Bank*, 1906.

Loans and mortgage of lands, and to make improvements on lands under purchase from Crown, to facilitate closer settlement, agriculture, and general production.

IV.—Manhood Specifically, Pastoral (4 Enactments).

(1.) *Closer Settlement*, 1902.

Acquisition of private lands. Division of land into farms sufficiently large to maintain home thereon. Rent equal to 5 per cent. of capital value.

(2.) *Closer Settlement*, 1904.

To acquire private lands, and to provide for closer settlement. Owner may offer land and proposal then reported upon by Closer Settlement Board, and if approved by Parliament Minister may make contract.

Land compulsorily resumed where value exceeds £20,000. Land acquired, together with adjacent Crown lands, to be a settlement purchase area for agriculture, grazing, and township settlement. Residential and improvement conditions. Provisions against transfers, excepting ordinary distribution under will.

(3.) *Closer Settlement Amendment*, 1906.

Lessees of land acquired by Crown to become Crown tenants, who shall have preferential right in applying for a settlement purchase.

(4.) *Closer Settlement Amendment*, 1907.

Constitution of Advisory Boards. Land within 15 miles of proposed railway open to resumption.

V.—Manhood Specifically, Mining (8 Enactments).

(1.) *Mining on Private Lands*, 1894.

To legalise mining on private lands, and to make better provision for mining on Crown lands. Holders of miner's right allowed to enter private lands. Owner not entitled to preferential right to mining lease. Rents payable to owner twenty shillings per acre.

(2.) *No Liability Mining Companies Act*, 1896.

Registration of companies. Shareholders not liable to calls or contributions. Balance-sheet compulsory. Inspection of books. Winding-up, distribution of assets.

(3.) *Mining Amendment*, 1896.

Authority to enter private lands. Power of Crown to resume lands.

(4.) *Miners' Accident Relief Act*, 1900.

Allowances to persons injured by mining accidents, and to the relations of persons killed or injured, contributions by owners of mines, by persons employed in or about mines, and from Consolidated Revenue.

(5.) *Mines Inspection*, 1901.

Qualifications and duties of managers, and engine-drivers' wages and restrictions and employment. Inspection and management. Drainage and other safeguarding provisions.

(6.) *Coal Mines Regulation*, 1902 *(Consolidation).*

Managers, under-managers, and engine-drivers to hold certificates. Inspection of mines. Returns of operations to be furnished annually. Notification of accidents. Boys under fourteen, and females, not to be employed. Wages. Check weighers. Two shafts to be provided with communication to all parts of workings. Ventilation. Precautions. Use of safety lamps. Regulations as to use and storage of explosives. Periodical inspection.

(7.) *Mines Inspection*, 1904.

Payment of check weighmen.

(8.) *Mining Act*, 1906 *(Consolidation).*

General provisions regulating mining on both Crown and private lands.

VI.—Manhood Specifically, Shipping (1 Enactment).

Seamen's Act, 1898.

Apprenticeship. Engagement of seamen, discharges, wages. Property of deceased seamen. Duties of masters.

VII.—Manhood Specifically, Shopkeeping (3 Enactments).

(1.) *Early Closing of Shops*, 1899.

Hours of closing for all shops in proclaimed districts. Shops closed for one half-day each week. Half-holiday each week for all shop-assistants, fresh meat-carters and milk-carters, and monthly holiday to bakers' employees. Shop-assistants not to be detained beyond one half-hour of closing time.

(2.) *Early Closing Amendment*, 1900.

Closing of shops in country districts. Any area may be proclaimed. Poll may be taken in country districts as to alteration of the one-o'clock closing day.

(3.) *Early Closing, Hairdressers*, 1906.

Hairdressers' shops. Hours of closing. Hairdressers' assistants to be included amongst shop-assistants, and to have weekly half-holiday.

VIII.—Manhood Generally, Health, Food, Drink, &c.

(15 Enactments).

(1.) *Diseased Animals and Meat Act*, 1892.

Penalty on selling, conveying, or exposing diseased animals for sale. Powers of inspection, seizing, and destruction.

(2.) *Noxious Trades and Cattle Slaughtering*, 1894.

Duties and powers of local authorities and Board of Health.

(3.) *Municipal Baths Act*, 1896.

Municipalities empowered to erect or lease baths. Power to charge tolls for admission thereto.

(4.) *Public Health*, 1896.

A most comprehensive Act.

(5.) *Liquor Act*, 1898.

Licensing Courts instituted for granting publicans' and other licenses. Rights, duties, and liabilities of licensees. Sly grog-selling. Local option. Appointment of inspectors. Right of entry, day or night, by inspectors or police. Cancellation of licenses. Disqualification of licensees. Adulterated liquor.

(6.) *Adulteration of Liquor*, 1899.

Penalty on brewers for adultering liquors, and on persons selling such liquors. Inspection of brewers' premises.

(7.) *Noxious Microbes*, 1900.

To prevent introduction of infectious and noxious micro-organisms.

(8.) *Inebriates Act of* 1900.

Care, control, and treatment of inebriates.

(9.) *Bread Act*, 1901.

Standards of quality and quantity to prevent adulteration and short weight.

(10.) *Dairies Supervision*, 1901 *(Consolidation)*.

Regulation of the production, manufacture, and distribution of milk, cream, butter, and cheese. Dairymen, milk-vendors, butter and cheese manufacturers to be registered. Premises to be inspected at reasonable times. Infectious diseases in dairy premises, &c., to be reported immediately. Persons suffering from infectious diseases not to take part in dairy operations. Cancellation of registration if premises deemed insanitary. Sale or supply of unwholesome milk forbidden. Powers of Board of Health and local authorities.

(11.) *Public Health and Prevention of Spread of Diseases*, 1902 *(Consolidation)*.

Compulsory notification of infectious diseases, and prevention of the spread thereof. Custody and treatment of lepers. Buildings not allowed on land deemed to be unsuitable. Demolition of condemned dwellings. Abatement and prevention of nuisances. Pollution of water supply. Penalties for selling adulterated foods, or food not of the nature demanded.

(12.) *Cattle Slaughtering and Diseased Animals and Meat,* 1902.

Provisions as to cattle slaughtering. Inspection of licensed slaughter-houses. Cancellation of licenses in case of premises unsuitable, or of insanitary condition. Diseased cattle dying in slaughter-house to be removed and destroyed. Penalty for slaughtering diseased cattle. Penalty for selling diseased meat. Seizure of condemned animals by inspector.

(13.) *Sydney Abattoir and Nuisances Prevention,* 1902.

Public Health Board to make regulations as to cleanliness and control of abattoir. Nuisances prevention. Breeding of swine in city forbidden. Cattle driving permitted only within certain hours.

(14.) *Poisons Act,* 1902.

Particulars to be kept as to poison sold and purchaser. Witness required if purchaser under 18. Precautions.

(15.) *Noxious Trades,* 1902.

Compulsory registration. Inspection of premises.

IX.—Manhood Generally, Industrial Conditions and Safeguards in Trade (19 Enactments).

(1.) *Chinese Restriction and Regulation Act,* 1888.

Naturalisation not allowed. Masters to give list of Chinese on board. Number to be brought by any vessel restricted to 1 to every 300 tons of tonnage of vessel. Tax of £100 on each Chinese arriving by land or sea, except crews of vessels. Chinese not to be allowed to engage in mining; exemption in respect of Chinese who are British subjects.

(2.) *Trades Disputes Conciliation and Arbitration Act,* 1892.

Industrial districts. Clerk of awards for each district to receive application from employers and employees for reference to a council of conciliation for district, or to council of arbitration, of any dispute or claim to convene council; to keep records of references and settlements of council of conciliation, or of references and awards of council of arbitration; and generally to supervise machinery of Act in his district.

Council of conciliation for each district elected for 2 years; 2 members elected by employees registered under the Trade Unions Act, and 2 elected by employers' bodies similarly registered.

Until State divided into industrial districts, there shall be a council of conciliation for the whole State, 12 to 18 in number, one-half to be elected by each of the recommending authorities as above.

Special conciliators may be appointed by the parties to a dispute apart from the ordinary district council.

Procedure—

(1) Parties may jointly agree to a reference;

(2) Either party may lodge application with clerk of awards asking for reference to council;

(3) Either party may appoint persons (not more than 3) to represent them;

(4) Clerk will present applications to council of conciliation;

(5) Decision of council to be transmitted to president of council of arbitration;

(6) Council to report failures to agree, whereupon clerk will notify parties, and either party may then require clerk to refer dispute to council of arbitration.

Council of Arbitration: 1 for whole State; 3 members, 1 each selected by employers and employees, the third to be mutually agreed upon by the other two. Council chosen for 2 years. The council of conciliation may sit as assessors to council of arbitration if parties agree.

Reference to Arbitration—

(1) By reference from conciliation council in case of failure to agree;

(2) Direct without first referring to council.

Council of arbitration to sit as open court and decide by the principles of equity and good conscience; no representation by attorney. Award to be made in one month after completion of sitting. Award enforced by legal process if parties agree to be bound before award is made. Power of enforcing attendance of witnesses, and of entry for purposes of inspection. Claims may deal with the wages, workmanship, condition of work, quality of food supplied to employees, and sanitation of workshops.

(3.) *Employers' Liability Amendment Act*, 1893.

Protection of principal Act extended to seamen.

(4.) *Coal Mines Regulation Act*, 1896.

Certificate of competence of managers. Inspection. Coroner's inquests. Returns of owner, agent, or manager. Notices of accidents. Employment of boys and females. Wages payments. Prohibition of single shafts. Safety rules.

(5.) *Factories and Shops Act*, 1896.

Supervision and regulation of factories and shops. Limitation of hours of working. Extension of owner's liability for injuries suffered by employees. Registration of factories. Inspection. Sanitary arrangements, painting, lime-washing, &c. Safeguards against dangerous machinery. Protection from fire.

(6.) *Coloured Races Restriction and Regulation Act*, 1896.

Extension of provisions of Chinese Restriction Act to other coloured races.

(7.) *Employers' Liability (Consolidation) Act*, 1897.

Compensation for personal injury to a workman through defect in ways, works, plant, &c., or through negligence on part of any person in service of employer. Similar provisions in regard to seamen when a ship is at anchor, receiving or discharging cargo, &c. Sum limited to estimated earnings during the three years preceding. Penalties under other Acts to be deducted.

(8.) *Compensation to Relatives of Persons Killed by Accidents*, 1897.

Where death of a person is caused by wrongful act, neglect or default, action taken for the benefit of the wife, husband, parent, or child of deceased by executor of deceased. Action to be commenced within twelve months after death.

(9.) *Immigration Restriction Act*, 1898.

A prohibited immigrant is a person who cannot write an application for exemption in some European language.

(10.) *Conciliation and Arbitration Act of* 1899.

Minister may direct inquiry, and failing settlement, direct public inquiry under a Judge. Application to be made by employer, or a majority of employees.

(11.) *Truck Act of* 1900.

All wages to be paid in money.

(12.) *Coal Lumpers' Baskets Act*, 1900.

Baskets not to exceed 30 lb. in weight.

(13.) *Industrial Arbitration Act*, 1901.

Provision for registration of industrial unions, making of industrial agreements, and for a court of arbitration. Industrial agreements may be made and are binding same as award of court. Court of arbitration consisting of Judge and one representative from each of the two bodies interested. Jurisdiction and powers of court—to hear and determine disputes, to make awards or to vary same, &c. Reference to the court only by union or person aggrieved. Prohibition of strikes pending settlement of dispute. Court may prescribe minimum wages, and direct that preference be given to unionists. Awards given may be made common rules in industries affected. Agreements, &c., exempt from stamp duty.

(14.) *Shearers' Accommodation Act*, 1901.

Where six or more shearers are employed, proper and sufficient accommodation must be provided at least fifty yards from shearing-shed. Exemption in certain cases. Asiatics to be accommodated in separate buildings Two hundred and forty cubic feet of air space to each person sleeping in building. Drinking water, proper cooking, and washing vessels and necessary conveniences to be provided. Shearers to keep premises clean, and be responsible for damages. Inspection of sheds authorised. Penalties.

(15.) *Butcher's Shop Sunday Closing Act*, 1902.

Compulsory closing of butchers' shops on Sunday. Sale of meat forbidden on that day.

(16.) *Masters and Servants Act*, 1902.

Remedies against servants breaking agreements, &c. Remedies against masters. Differences to be settled by award of stipendiary or police magistrate; or two justices.

(17.) *Scaffolding and Lifts Act*, 1902.

Inspection of scaffolding. Scaffolding, engines, and gear to be in accordance with regulations. Inspection of lifts. Driver of steam crane to hold certificate.

(18.) *Industrial Disputes Act*, 1908.

Constitution of boards to determine the conditions of employment in industries. Lock-outs and strikes prohibited. Registered trade union with membership not less than twenty, or twenty employees, may apply for constitution of board. Board to consist of chairman and not less than two nor more than ten other members, half to be employees and half employers. Board to decide all disputes, fix wages, hours, &c. Industrial Court instituted to which appeals may be taken against board's award. Decision of court *final*.

(19.) *Scaffolding and Lifts Amending Act*, 1908.

Extending scope of previous Act. Defining terms used in previous Act. Power of Governor to make regulations relating to proper construction of scaffolding, lifts, &c.

X.—Manhood Generally, General Welfare and Protection (29 Enactments).

(1.) *Trades Hall Institute Act*, 1893.

Empowering trustees to borrow.

(2.) *Labour Settlements Act*, 1893.

Loans by Crown to found settlements under a board of control. After four years, repayable by instalments of 8 per cent. per annum, including interest at 4 per cent.

(3.) *Trades Hall, Newcastle, Vesting Act*, 1893.

Vesting land in trustees for erection of a hall for friendly societies, and other land for erection of trades hall.

(4.) *Labour Settlements Amendment Act*, 1894.

Power to grant loans to boards of amounts ranging up to £50 per member enrolled.

(5.) *Municipal Council of Sydney Electric Lighting Act*, 1896.

To enable the Municipal Council of Sydney to raise £250,000 for the generating and supply of electric light and power.

(6.) *Contractors' Debts' Act*, 1897.

Protecting the wages of workmen.

(7.) *Broken Hill Trades Hall Site*, 1898.

Vesting land in trustees of the Barrier District Council of the Australian Labour Federation, conditionally on the erection of building thereon for the purposes of a trades hall.

(8.) *Small Debts Recovery Act*, 1899.

Jurisdiction in cases of Debt up to £30 outside, and £10 within, metropolitan district.

(9.) *Attachment for Wages Limitation Act*, 1900.

No attachment to be made where salary is not more than £2 per week, and where more than £2, then only for amount of wages exceeding that amount. In other words, the amounts up to £2 are free of attachment.

(10.) *Sydney Coal Delivery Act*, 1901.

Coal to be sold by weight. Penalty for selling one sort of coal for another, and for selling wet coal. Coal to be delivered in sacks, if required. Carters to have weighing machine on cart. Penalty for refusal by carter to weigh coal. All coal to be weighed, if purchaser desires. Penalty for using improper weighing machine and for light weights.

(11.) *Block Holders Act*, 1901.

Setting apart Crown lands for working men's blocks. Providing loans to lessees of such blocks.

(12.) *Games, Wagers, and Betting Houses Act*, 1902.

Powers to enter and search gaming-houses. Penalty on persons found therein. Cheating at cards. Powers to enter and search betting-houses. Penalty if found on premises. Advertisements relating to betting forbidden.

(13.) *Labour Settlement (Consolidated)*, 1902.

Lease of land for labour settlements. Loans to boards of control. Repayment over extended periods.

(14.) *Women's Franchise Act*, 1902.

Extending the parliamentary franchise to women.

(15.) *Pawnbrokers Act*, 1902.

Compulsory licensing of pawnbrokers. Entries of pledged goods. Period for sale of pledges. Pawnbroker not to purchase. Certain pledges forbidden. Stolen articles to be delivered to owner.

(16.) *Vagrancy Act*, 1902.

Punishment of idle and disorderly persons, rogues, and vagabonds. Penalties for obscene or threatening language. Goods in possession of offenders.

(17.) *Smoke Nuisance Prevention Act*, 1902.

Furnaces to be so constructed as to prevent smoke. Extension of Act to certain suburbs.

(18.) *Influx of Criminals Prevention Act*, 1903.

To prevent the influx of criminals into New South Wales. Liability of masters of ships conveying criminals. Convicted persons not admitted to State.

(19.) *Habitual Criminals Act*, 1905.

Detention and control of habitual criminals. Judge may declare convicted person an habitual criminal. Habitual criminals at expiration of sentence to be detained in confinement during His Majesty's pleasure, and to work at some trade, receiving half the proceeds. Reformed criminals on release to report address and occupation once in every three months.

(20.) *Local Government (Shires) Act*, 1905.

Local government of rural districts. Division of State into classified shires. Endowment from Consolidated Revenue. Powers of Shire Councils. Government of shires. Elections. Qualifications of voters. All land rateable unless used for certain public or charitable purposes, or unoccupied Crown land. Appeals. Rating on unimproved value. General rate not less than one penny, and not more than twopence in the pound on unimproved value. Recovery of rates. Accounts. Audit.

(21.) *Small Debts Recovery Amending Act*, 1905.

Jurisdiction of court extended to include debts not exceeding fifty pounds instead of ten pounds Service of default summons and judgment in default. Attachment of debts. Garnishee orders.

(22.) *Money Lenders and Infants Loans Act*, 1905.

To render penal the inciting of infants to borrow money. Registration of money-lenders. Court may set aside agreement if interest or charges are excessive.

(23.) *Newcastle Friendly Societies and Trades Hall Site*, 1905.

To vest land for trades hall in trustees elected under the rules of Newcastle Eight Hours' Committee.

(24.) *Gaming and Betting Act*, 1906.

Regulation and suppression of gaming, betting, and wagering. To restrict the holding of race meetings. For the licensing of racecourses, &c. Betting prohibited, except on racecourses.

(25.) *Second-hand Dealers and Collectors Act*, 1906.

Second-hand dealers and collectors to be licensed. Name to be painted on outside of premises. Book to be kept showing wares purchased or received. Form of old wares not to be changed for five days. Collectors' addresses to be left at police station.

(26.) *Local Government Extension Act*, 1906.

For the better government of municipalities and shires. Provisions similar to those of Shires Act of 1905. Limits of rating.

(27.) *Parliamentary Elections*, 1906.

Preparation and revision of electoral rolls. Alteration of rolls. Removal of names. Nomination of candidates. Their qualifications. Ballot papers to be provided. Vote, how given. Informal votes. Penalty for obstructing elector from access to booth. Member's allowances to be reckoned from the day of election.

(28.) *Careless Use of Fire Amendment Act*, 1906.

Protection of corn or hay stacks, &c., growing crops or grass lands. Punishment of persons igniting inflammable adjacent material.

(29.) *Local Government Act*, 1906 *(Consolidation).*

To consolidate and amend the law relating to the local government of shires and municipalities.

XI.—Decline of Life, Sickness and Old Age (10 Enactments)

(1.) *Friendly Societies Act*, 1899.

Appointment of Registrar. Societies which may be registered. Conditions of registration. Societies with branches. Registered societies may recover subscriptions. Authority of Registrar to inspect books. Audit. Annual returns. Quinquennial valuation. Privileges of registered societies. Rights of members. Investment of funds. Payment on death. Disputes. Registrar's powers of inspection. Cancelling and suspension of registry. Penalties.

(2.) *Friendly Societies Amendment Act*, 1900.

Extension of privileges. Settlement of disputes.

(3.) *Old-age Pensions Act*, 1900.

Providing pensions for aged. Qualifications—twenty-five years' continuous residence, good character, and limited means. Pensions not exceeding twenty-six pounds per annum.

(4.) *Friendly Societies Amendment Act*, 1901.

Existing societies may be registered for five years under certain conditions, although uncertified by actuary.

(5.) *Building and Co-operative Societies Act*, 1902.

Establishment of societies. Compulsory registration. Rules for control. Returns. Dividends and bonuses. Responsibility of trustees.

(6.) *Life, Fire, and Marine Insurance Act*, 1902.

Encouragement of life assurance. Policy and premiums protected on bankruptcy and against court process. Protection of endowments and annuities.

(7.) *Friendly Societies Amending Act*, 1903.

Separate and distinct accounts to be kept of contributions to and payments from the funds in respect of members who joined before and after the 1st January, 1903.

(8.) *Friendly Societies Amendment Act*, 1906.

Registration compulsory on all friendly societies. Rules inoperative if unregistered. Moneys for different funds to be kept separate. After valuation, Registrar may make recommendations and require societies to submit proposals for improving financial position. Disputes may be heard by Registrar.

(9.) *Invalidity and Accident Pensions Act*, 1907.

Persons over sixteen years of age, permanently incapacitated for any work, and not receiving old-age pension, entitled to pension not exceeding twenty-six pounds a year.

(10.) *Subventions to Friendly Societies Act*, 1908.

On application by registered societies subventions will be paid towards the cost of sick-pay, medical attendance, and funeral benefits as follows:—Sick-pay subvention equal to half the cost of sick-pay on account of extended sickness of male members under sixty-five and females under sixty, and the whole cost in connection with sick-pay of older members. Limited to five shillings per week for any individual claim. Subvention equal to total contributions chargeable for medical attendance and medicines in respect of male members aged sixty-five and over, and of females aged sixty years and over. Subvention equal to total contributions chargeable to assure payment of funeral donations in respect of members over stated ages.

RELEVANCY OF THE EPITOMISED ACTS.

It is interesting to compare the conditions existent in England at the beginning of the nineteenth century with those in New South Wales at the present time. During the earlier period a number of enactments were in force known as "Combination Laws," which were mainly devised to prevent the industrial classes from combining to secure amelioration of the conditions affecting their trade interests.

In the year 1824 an Act was passed entitled "Combination of Workmen," the schedule to which affords a vivid insight into the severity of the laws which affected the working men prior to that period. In that schedule appear the titles of thirty-four Acts which were to be repealed, the first of them having been passed 500 years previously, in the reign of Edward I. These repealed Acts had authorised penalties of the utmost severity for offences in the way of combinations of workmen, which now are not only permissible, but are even encouraged by Statute.

It is beside the purpose of this review to recapitulate the dark history of the prolonged struggle of working men to secure the right of uniting for their common welfare, and to render their conditions of existence happier and more wholesome, but the above brief reference serves to show by way of contrast the vast advance made during the nineteenth century in the humane direction of emancipation from a condition of practical serfdom. When we study the detailed provisions enumerated in the list of enactments of recent years in New South Wales, we may well experience profound surprise at the short-sightedness of 100 years ago, when men were repressed by Draconian laws, whilst it was possible to "allure them to brighter worlds, and lead the way" by means of beneficent, thrift-encouraging, and humanitarian measures, such as are embodied in my synopsis of enactments.

The mere title of an Act might be completely delusive, and while the name might suggest an advance in the direction of reform, the provisions enacted under this specious and attractive coating might be reactionary and repressive. Hence, I have taken the trouble to indicate in the above analysis the cardinal principles contained in our recent legislation.

Returning to the codified system of laws which I have presented, I shall now examine the sequence which has been followed in the introduction of the new laws; or, in other words, ascertain the trend of the desires of our legislators (representing the State) as evinced in the order of attention given to the various interests treated.

First, as to General Aspects.—Taking the order of legislation in respect of the broad general interests of the industrial classes, we find that the earliest subjects for treatment were those relating to industrial conditions and safeguards in trade This would very naturally be expected as the most pressing of the requirements of the working classes.

Next in order from the general point of view, the health interests and matters relating to food, drink, and bodily welfare received attention: and, finally, the miscellaneous matters concerning the general welfare and protection of the people obtained legislative notice.

Secondly, as to Special Aspects.—In this connection we find that the several trades or occupations involving industrial interests during the manhood stages of life were treated in the following sequence:—

(1) Shipping,
(2) Shopkeeping,
(3) Mining,
(4) Agricultural,
(5) Pastoral.

Thirdly, as to the Helpless Stages of Life.—Youth was the first to receive attention, and then age and infancy, the two extremes of life, were cared for at about the same time.

The attached graph enables a ready insight to be obtained as to the years in which legislation was enacted affecting the interests grouped under the several sub-headings.

Divided into quinquennial periods, the following table shows the progression in the number of laws enacted:—

Period.	Number of Laws.	Number Per cent.	Number Per cent. to End of Each Period.
Before 1893	8	7	7
1894-1898	21	19	26
1899-1903	54	50	76
1904-1908	26	24	100
	109	100	...

Another view is obtained by taking the numbers of the laws passed, respectively, prior to and since the date of the federating of the States. Up to the end of 1900 there had been forty-five laws, or 41 per cent. of the total industrial laws, and since that date sixty-four have been enacted, equivalent to 59 per cent. No doubt there are two reasons for the acceleration in the treatment of these subjects since the anti-federation period—viz., the growing interest and popularity as to measures of amelioration of the working classes, and the large additional opportunity for attending to subjects of social reform which has been afforded by the translation of many affairs of government to the Federal authorities.

Reforms Effected by the New Laws.—The following résumé indicates the scope of the reforms effected by the new laws:—

I.—Infancy: Much care has been bestowed on the protection and nurture of infants, in view of the evils which previously existed in connection with baby-farming, and considerable aid is rendered in cases where, through neglect, the children of worthless parents would otherwise swell the mortality list. By the agency of these Acts, illegitimate children receive close attention, and the death list in this class, although still very high in comparison with that of the legitimate, has been reduced during recent years.

Means are provided for coping with juvenile offenders, and thus nipping in the bud that which would otherwise blossom into vice and crime. One of the most merciful measures is to be noted in the "Legitimation Act," which renders it easy to avoid the terrible effects in a child's life which result from the stigma of illegitimacy.

II.—Youth: As to the period between infancy and manhood, when character is in the formative stage, although there are only five laws, yet the provisions affirmed by them are far-reaching, and of great value. Thus, the care and supervision of apprentices, and wise conditions attaching to that part of a man's career, are fully secured.

Women who unfortunately have wedded worthless husbands, also widows, receive subventions in aid from the State, and on the other hand, the mother of an illegitimate child is surrounded with restrictions to safeguard the child's life.

The later stages of this part of life are also cared for by means of reformatories and industrial schools.

Summed up, it may safely be asserted that the citizen is tended carefully up to adult age, and that as a result there have been deterrent forces at work in our midst for some years past, which have diminished crime, and laid the foundations of useful citizenship in numerous instances.

III.—Manhood, from Stated Specific View Points: The mere recapitulation of the titles of the various Acts would be sufficient to indicate the vast advancement afforded in this context.

From the agricultural aspect, we see that in the endeavour to secure a sturdy yeomanry on our lands, the State has proffered means of financial aid, which come within the reach of most of our citizens; and it could not be extended much further unless the ultimate step be taken of advancing money without security.

In pastoral matters the State is now pursuing the vigorous policy of acquiring suitable extensive areas from private holders, and subdividing them with a view to the settlement of people on moderate areas sufficient to afford a livelihood.

In the mining industry the best means which could be conceived have been taken to free the miner from burdensome restrictions, to encourage enterprise, and to safeguard the lives of men, by regulations as to inspection, competency, and general duties. And, as a crowning feature in relation to this class of labour, we have a compassionate and humane institution in the Miners' Accident Relief Fund, whereby provision of a substantial nature is made in respect of all the ill-effects to the miner, and to his dependents, which result from mining accidents and disasters.

With regard to the seafaring class, although there is but one Act, it is completely effective in fulfilling requirements. The sailor is amply protected thereby in the whole of the surroundings of his career.

As to shopkeepers, although they were not specifically noticed until 1899, yet the three laws on their behalf which have since been passed in connection with early closing have already resulted in an immense betterment of the conditions of their existence, and the present life and future prospects of this class have been rendered distinctly brighter and more hopeful as a consequence.

IV.—Manhood from a General Point of View—Health: Never in the history of mankind has the health of the people been so tenderly regarded as at the present time. The best efforts procurable by means of legislation have been devoted to the avoidance of disease, and this is shown in the powers of inspection, of seizure, and of destruction of diseased meat, also in the measure to prevent the introduction of infectious and noxious micro-organisms. Further, the most rigorous precautions are exercised under the "Dairies Supervision Act" to preserve the public from infectious diseases which may be communicated through an ill-regulated or unregulated milk supply. The beneficial results plainly apparent in the lower infantile mortality, and in the diminution of the death-roll from tuberculosis, speak volumes as to the efficacy of this type of legislation.

Again, if unfortunately disease succeeds in passing the advance guard of the protective Acts, it is met by, and succumbs to, that splendid measure "The Public Health Act," under the provisions of which ample means are available for actively combating and eradicating disease.

Likewise having regard to the weaknesses and cupidity of men, we find enactments for saving us from the wrongdoing of our fellows and of ourselves. For instance, there are laws concerning noxious trades and the adulteration of liquor; also we have the Bread Act; and, from a personal aspect, we may regard the Municipal Baths Act, the Liquor, Inebriates, and the Poisons Acts as social boons.

V.—Manhood—Industrial Conditions and Safeguards in Trade: On this subject a volume might be written. The industrial classes are preserved from unequal competition in trade which would necessarily arise from the presence of inferior races, by means of the Chinese

Restriction, Coloured Race Restriction, and Immigration Restriction Acts, the severity of the provisions of which effectively prevents any material competition from such persons. Men are protected at their work through the agency of the Acts relating to Employers' Liability, Coal Mines Regulation, Factories and Shops, Accidents Compensation, Coal Lumpers' Baskets, Masters and Servants, and Scaffolding and Lifts. They are protected both as to their personal well being and as to their pecuniary interests by the Truck Act, Shearers' Accommodation Act, and Butchers' Shop Sunday Closing Act.

But the great central consideration in this branch of our subject is encountered when we regard the successive steps which have been taken during the last twenty years to solve the problem of securing an enlightened method of settling industrial disputes.

So long as there are two distinct parties, interested from different points of view in monetary concerns, so long will there be a liability to differences of opinion and to disputes. In the past there have been two such parties, and they still exist as employer and employee. But in the early days the employee was unorganised, and was consequently helpless to secure the discussion of his grievances. As time proceeded and the worker began to emerge from his individuality by forming considerable coteries or unions, he was able in his collective capacity to assert his claims more effectively, and developed the crude and inefficient weapon of the strike, by which he wrought disaster both on himself and on the employer, but with far more deadly effect in his own case.

The futility of the strike method was soon perceived by the worker, and the disastrous loss occasioned was in every instance realised by both parties.

The first essential to a peaceful solution of disputes is naturally a common plane of discussion, in order clearly to define grievances; and the merit of hearing two sides of a question need scarcely be asserted.

The need for conferences and arbitrament in disputes gradually forced public opinion to a decision which secured the passage of a tentative measure in 1892 entitled "Trade Disputes Conciliation and Arbitration Act," the details of which have been given in my analysis. The conceptions in that Act were excellent, but as so much depended on voluntary acceptance of the awards of the Arbitration Tribunal created by the Act, and as awards were enforceable only when the parties agreed beforehand to be bound thereby, it very naturally happened that the Act remained inoperative for practical results. Nine years of agitation and endeavour passed away before the "Industrial Arbitration Act of 1901" was placed on the Statute-book, with the provisions as detailed in my analysis. This measure was regarded as purely experimental, and its operation was made terminable on the 30th June, 1908.

As the time of expiry of the Act approached, the Government introduced a measure in Parliament dealing with industrial disputes in a different manner to that which had been instituted under the Act of 1901.

Under the system provided in the measure of 1901 it was found that the court had become congested with business, and that intolerable delays arose for several reasons, the main being:—

1. Only one tribunal.
2. Absence of expert members, there being only three fixed arbitrators (members of the court), whilst there were disputes relating to multifarious trades.
3. The presence of the legal fraternity, which involved ruinously heavy law costs.

These delays were highly detrimental to the usefulness of the court, inasmuch as the essential value of an Industrial Tribunal is found in the rapidity and ease with which the aggrieved persons can obtain redress; for if a strike be imminent, and the position become acute, it is necessary to proceed to a hearing at once before graver dangers ensue.

Moreover, in the course of time it was found that even where an award was obtained, there was a want of finality in that award, it having been ruled by the High Court of Australia that there was the right of reversing the decision by way of prohibition.

On account of these objections the new "Industrial Disputes Act of 1908" was passed, and replaces the previous temporary and experimental Act.

The Act now in force provides for the creation of separate boards as tribunals for every industry. These boards are composed of an equal number of representatives of each party to the dispute, who may be summoned without vexatious delay, and who, from their knowledge of the particular business or trade involved, may decide technical points, and give an enlightened opinion on matters at issue. They may proceed without formalities, and their decision is final. An Industrial Court is instituted under the Act with plenary powers of direction and enforcement of awards.

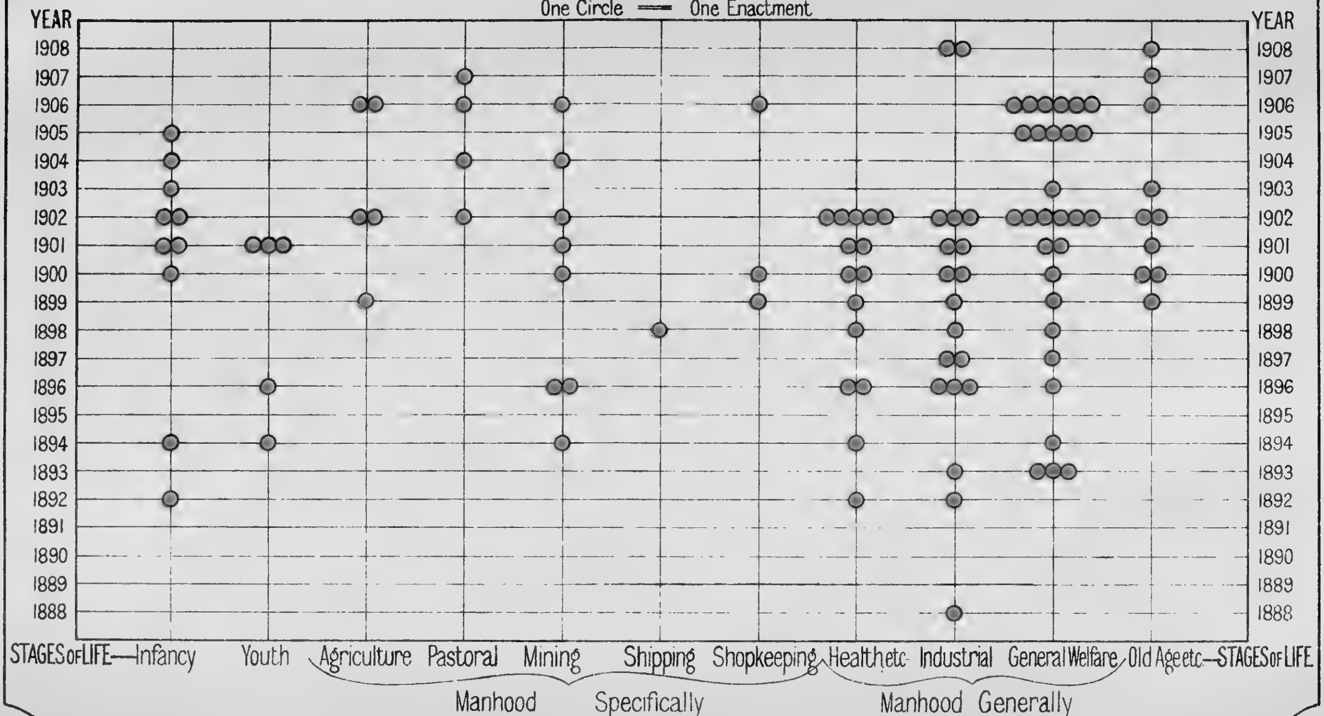
It is not within the scope of this review to educe the controversial points which naturally have arisen concerning this law. My sole object is to show that in the evolution of industrial legislation earnest and sustained attempts have been made to obtain some practical means of avoiding the unrest, bitterness, and misery which prevailed when no machinery whatever existed whereby disputes could be settled. And it must be conceded, whatever the defects of the laws I have enumerated, that an immense advance has been made towards the desired goal.

VI.—Manhood—General Welfare and Protection: In this category, as the heading indicates, we find a number of miscellaneous measures which administer to the well being of the workman. Thus, we have laws relating to his moral and social welfare, and aiding him as to his material advancement.

As to his means of advancement in life, I may cite the various Trades Hall Acts which appear in my schedule, also Contractors' Debts, Small Debts Recovery, Attachment for Wages Limitation, Coal Delivery, and Block Holders.

INDUSTRIAL LEGISLATION

One Circle = One Enactment



From a social point of view we have the Electric Lighting Act, Women's Franchise, Smoke Prevention, Local Government, Second-hand Dealers, Parliamentary Elections, and Careless Use of Fire enactments.

Lastly, in the realm of morals, we find the Games and Betting-houses Act, Pawnbrokers, Vagrancy, Influx of Criminals, Habitual Criminals, Money Lenders and Infants' Loans Acts.

Of the laws comprised in the above list much might be stated in terms of the highest praise, but space precludes.

VII.—Decline of Life: We befittingly close our list of beneficent laws by referring to those which appear at the close of our analytical schedule, some of which have wrought incalculable blessings in the past, and, in conjunction with the others of more recent date, will bestow priceless boons on suffering humanity in the future.

The friendly societies supply succour during sickness and in the hour of death, and the Old Age Pensions Act affords ease and comfort after a well-spent life of toil and usefulness.

Industrial Legislation as a Whole.

With respect to the industrial laws viewed in bulk, it may be stated, as in all mundane affairs, that they consist of three experimental classes, viz.:—

1. Proved failures.
2. Those still in the tentative stage.
3. Proved successes.

Prominent examples of these may be noted—

As to the first class ...	Labour Settlements.
As to the second class	Industrial Disputes.
As to the third class ...	Early-closing of Shops.

Failure may be attributable to various causes, such as misconception of the true ideal; unripeness of time as to the experiment under notice, or, most fatal of all, maladministration. With respect to these governing factors it is best to defer to the individual judgment, but in every case the obvious lesson should be laid to heart in the interests of our common welfare.

The types of laws which may be regarded as still in the nature of experiments should be closely studied by the sociologist; and the future developments should be watched, so that in the fullness of time we may evolve the desires of the great heart of the State.

The successes will readily speak for themselves, and require no argument. And it must be confessed, looking down the vista of twenty years, that, in securing their intended objects, there are many of our statutes for which we should be profoundly thankful.

Taking the sequence of the lists enumerated, we find that a continuous and increasing attention has been paid to the needs of the industrial classes, and to the uplifting of humanity in respect of their mental, moral, and physical conditions.

I might mention parenthetically that it is curious to observe amidst the long series of legislative endeavours to lighten the load of life, there are two striking gaps in the list. I allude to the absence of a measure legalising eight hours as the extent of a day's work, and of an Act on modern lines dealing with the formation and regulation of trade unions.

As to the former, I would remark that on all occasions when attempts have been made to secure formal enactments on the subject, serious difficulties have presented themselves; but in striking contrast to this want of success, we find in certain directions that forty-four hours constitute a week's work, thus giving even less than eight hours per day for a six-day week. Moreover, the question is being seriously discussed in recent years whether the working day should not be measured by a still smaller number of hours.

As to the new Trade Union Act, which seems to be desirable, it is instructive to note that the present law is remarkable mainly for its negative nature, and is noteworthy more for what it withholds than for any boon which it confers.

In conclusion, it may safely be stated as a result of our introspection that the protection of the industrial interests, and the attainment of salutary conditions throughout life have been secured to the working man. The standard of living has been perceptibly raised, means have been tried to settle disputes, to prevent the distraction of the economic relations of the great bulk of the population, and a large advance has been made toward the solution of the problem of work and wages.

Unionism on sound, national lines will prove the salvation of the working man, and the best means of raising him to higher ideals. But unionism on an unsound basis, where selfishness and disregard of responsibility and of the rights of his fellows are allowed to prevail, will reap an inevitable harvest of sorrow and disaster.

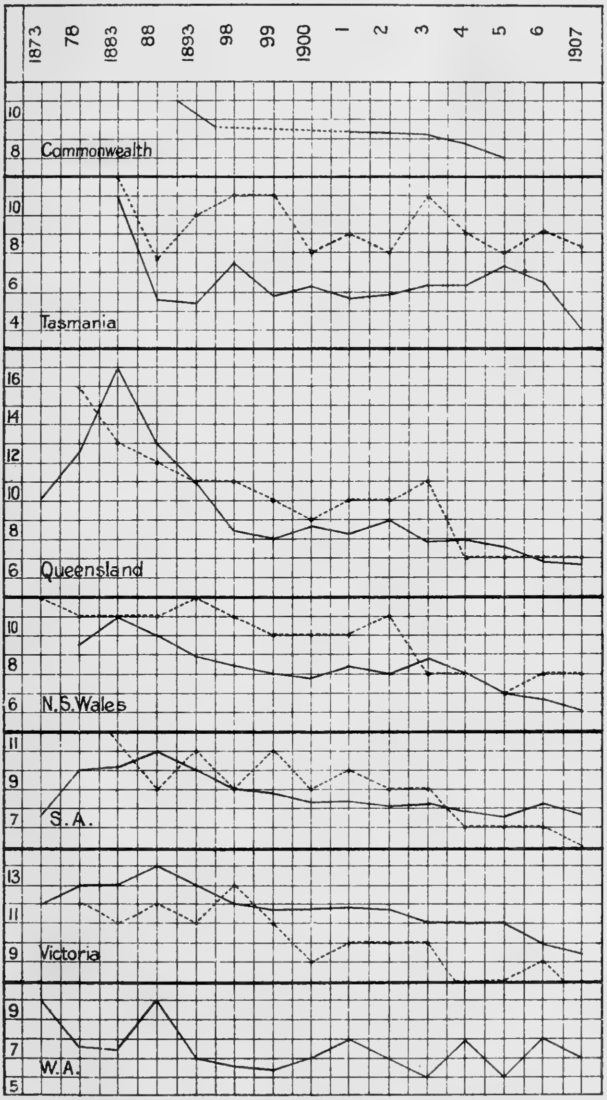
The outlook is bright, and auspicious of the peaceful determination of the difficulties to be found in our industrial life. The spirit of independence and fair play of our race will in due course enable us to reach the ultimate Utopia of peace and contentment.

3.—STATISTICAL INQUIRY INTO PULMONARY TUBERCULOSIS IN AUSTRALIA.

By J. L. CUMPSTON, Medical Officer for Schools, W.A.

Reference to Table I. will reveal a steady increase in the actual number of deaths from phthisis in West Australia. The fact, brought into prominence by the discovery of tuberculosis amongst dairy cows, has lead to considerable feeling of alarm amongst the people in this State. This superficial view of the subject, however, takes no account of the very rapid increase in the total population of the State within recent years. In order that a correct estimate of the position should be obtained, the death-rates per 1,000 of the population must be taken into consideration. This is done in Table II., where the death-rate per 1,000 of the mean population in each year for a number of years is set out for each State in Australia, and,

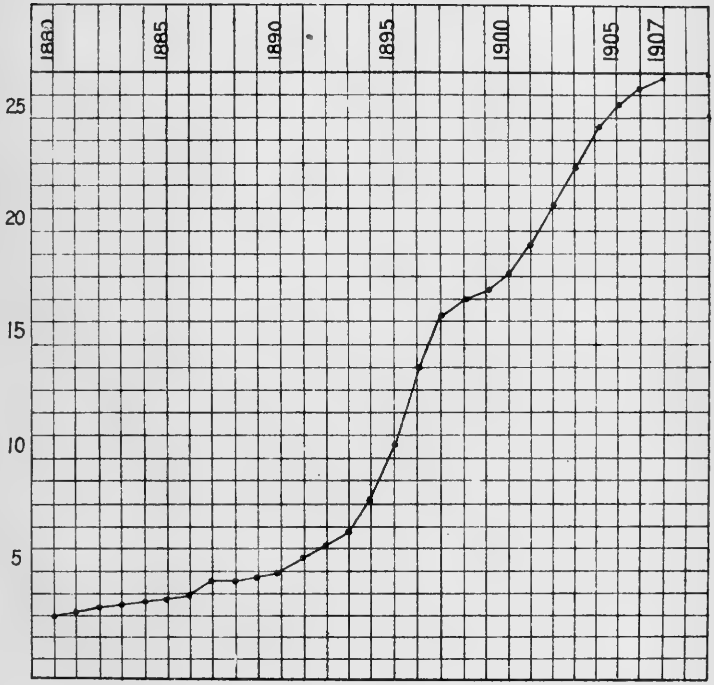
Fig. 1.



Death-rates per 10,000 of total estimated population from Phthisis ————

Infantile mortality figures. ----------

FIG. 2.



Estimated mean population of W.A. each year. Each square is Equivalent to 10,000 people

since 1901, for the whole of the Commonwealth. The figures for each year are given from 1898 onwards, and for every fifth year from 1873-1898. These figures are set out graphically in Figure 1. Table II. and Figure 1 show that there has been a progressive decline in the death-rate from phthisis in every State, except West Australia. Somewhere between 1883 and 1888 each State, except West Australia, seems to have attained its maximum, and from that time onwards the decline has been progressive and uniform (with the slight exceptions of New South Wales, which in 1903, and Tasmania, which in 1905 showed slight subsidiary rises). The single exception to this satisfactory progress is West Australia, in which the phthisis death-rate declined until 1899, rose again until 1901, and since has remained practically stationary. It will be demonstrated later in this paper that West Australia is, so to speak, bearing the burdens of others in this respect, and some at least of her disability should be debited to the other States.

The order in which the States are arranged according to their phthisis death-rate for 1907 is Tasmania, New South Wales, Queensland, South Australia, West Australia, Victoria—the order being from the lowest to the highest. Table III. shows how these rates compare with those of other countries; from these it will readily be seen that all of the States and the Commonwealth as a whole occupy very favourable positions in the phthisis rates of the world.

While the phthisis death-rate in Australia is low compared with that of other countries, it is not to be considered that the decline in the phthisis rate is an exceptional feature in which Australian mortality returns particularly excel.

Dr. Bulstrode says:—"It will be seen by the accompanying chart that in practically every county in England there has been a substantial fall in the death-rate from pulmonary tuberculosis" between 1871-1900 (35th Annual Report, Local Government Board (1905-6). Chart facing p. 38).

Dr. Newsholme:—"In recent years, in many but not in all countries, the death-rate from phthisis has declined." ("The Relative Importance of the Constituent Factors Involved in the Control of Pulmonary Tuberculosis," read before Epidemiological Society, 15-12-05.)

Although the actual number of deaths from phthisis in Western Australia has increased, the total population also of the State has increased in an extraordinary degree (Figure 2), and the net result, as has been pointed out, is that the increase in the number of phthisis deaths means simply that the amount of phthisis in the State has only increased with the population, *and it cannot, therefore be said that phthisis is on the increase in this State.* This aspect is further supported by a reference to Figure 3, which shows the percentage of deaths from phthisis to total deaths from all causes during the 20 years ending 1906. As the figure shows, the percentage fell steadily until 1896-7, and then rose slowly till it arrived at its original 1887 level.

Reverting to Figure 1, it will be seen that between 1893-1900 a distinct depression in the curve is present. The significance of these two depressions will be discussed later on in this paper.

While, however, throughout Australia the death-rates from phthisis are diminishing, and, therefore, the position in regard to this troublesome disease is improving, when the actual total loss of life is considered, it becomes evident that no measures for its prevention can be considered too stringent.

During 1907 the Commonwealth suffered a loss from phthisis alone of 2,863 deaths, and during the 5 years 1903-7 a total of 16,603 deaths.

Age and Sex Distribution of Deaths from Phthisis.—Figure 4 shows the average number of deaths from phthisis at each age-group shown, for the ten years 1897-1906. This figure refers only to West Australia, and the figures for that State prior to 1897 are not available. It is seen also that the maximum is reached for females in the 25-30 age-group, and for males in the 30-35 age-group. The Figure also shows that the liability of females to die from phthisis is less than that of males up to the age of 15 years, exceeds that of males till the twenty-fifth year, and from the twenty-fifth year onwards males are much more liable to die from phthisis than females.

To compare these facts with those for England and Wales—

"In England and Wales, as a whole, the age of highest mortality is at ages from 45-55 for males and at 35-45 for females. In the rural group of counties it is from 25-35 for both sexes." (Bulstrode, 55th Annual Local Government Board Report, 1905-6, p. 42.)

The experience of West Australia is thus seen to be in accord with that of the rural group of counties in England and Wales.

To quote the same report again, p. 44:—" . . the liability of females to die of pulmonary tuberculosis at ages under 5 is less than that of males, while between the ages of 5-25 females are more liable thus to die than males; after this age the liability is decidedly greater among males."

This shows that in West Australia females enjoy comparative immunity for 10 years longer than in England—that is, they begin to exceed males at 15 years of age instead of at 5, so that the period during which their phthisis mortality is greater than that of males is 10 years shorter than in England.

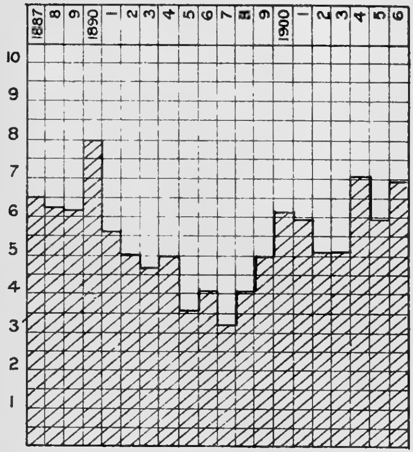
Dr. Bulstrode discusses the reason why girls suffer from phthisis more than boys in England at ages 5-25, in which discussion he says:—"It is, in his (Beevor's) view, the full-grown lung of the girl of 15 years of age which, having lost its resistance to the tubercle bacillus, leads to the death-rate of the 15-year-old girl from phthisis being equal to that of the boy of 17."

It is interesting that the Australian tables show that it is at the 15-year period that the phthisis rate among girls begins to exceed that among boys.

Figure 4 shows us further that the age-group when phthisis is markedly prevalent are those between 20-50 in both sexes—*i.e.*, the ages when persons of both sexes have the greatest economic value in the community.

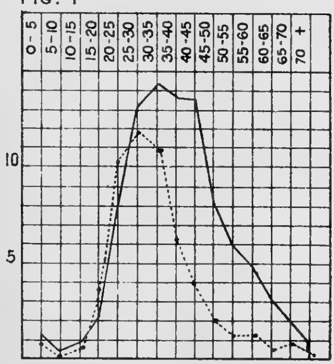
Further, we see that the number of deaths under 15 is especially small, being the lowest points on the curve up to 70 years of age.

Fig. 3



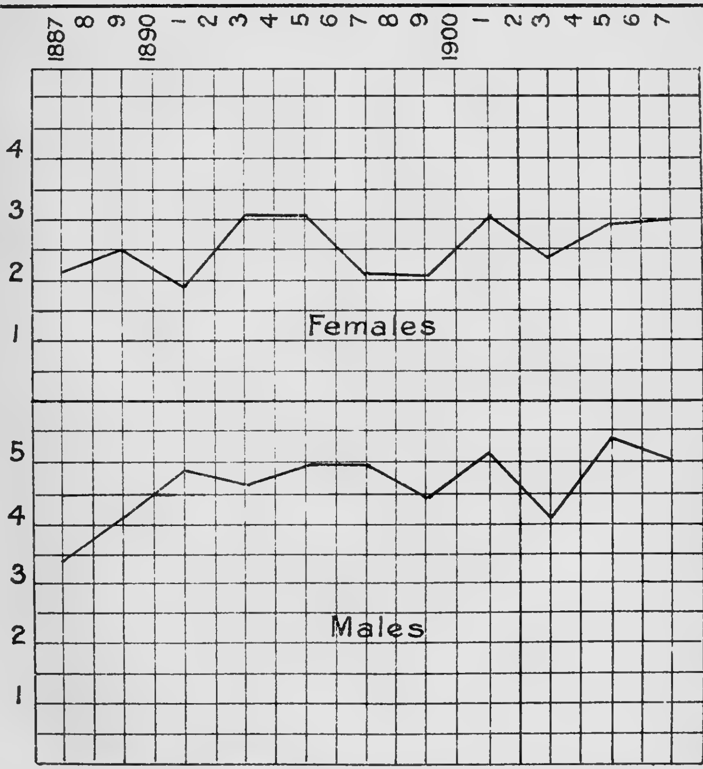
Deaths from phthisis expressed as a percentage of the total deaths from all causes.
Each square = 0·5 per cent

Fig. 4



Ages at Death from Phthisis Males ——
Females ·········
Average at each age group for 10 years 1897–1906.
Each Square represents an average of one death.

FIG. 5



Death-rate per 10,000 of males and females.

Each square = one death per 10,000 of total living population

Of a total of 206 deaths during 1907, 4 were under 5 years and 9 were under 15 years, so that the incidence on the very young population is extremely low. At the present time in England and Wales males suffer more than females to the extent of some 4 deaths per 10,000 (*vide* Bulstrode, *loc. cit.* p. 43). In Australia the male rate exceeds the female by 1·2 per 10,000. Table IV. shows the average figures for 10 years, 1897-1906, representing the percentage of deaths from phthisis in each age-group of the total deaths from all causes in the respective groups. In each five-yearly age-group between 25-45, one death in every seven or eight is caused by phthisis. Figure 5 and the accompanying table show the progress during eleven years, 1897-1907, of the male and female death-rates per 10,000 of population. The male rate has advanced slightly; the female rate has remained stationary since 1893.

Monthly Distribution of Deaths in various States.—Table V. shows the monthly distribution of deaths in mean numbers for the States and years specified. August seems to be the most prominent month, with September as the next in order. These two months represent the close of winter and the beginning of spring, which may account for the fact that more deaths are to be placed to their credit than to that of other months.

An important point in the question of phthisis in Australia is a determination of how much of the phthisis is of local production, and how much is imported, so to speak, for local consumption. Consideration of the data supplied from the other States reveals a want of uniformity which makes such a determination very difficult. For Victoria and South Australia no figures are available. In Queensland, of a total of 4,539 deaths from phthisis during 11 years, 1893 and 1898-1907, 27·6 per cent. were of people born in Australia or New Zealand, and 72·4 per cent. born elsewhere. In New South Wales, of 11,974 deaths of persons whose birthplace was ascertained and recorded during the same 11 years, a minimum of 50·8 per cent. were Australian born (129 others were not stated). Further, during 10 years, 1893, 1898-1906,* of 11,126 from phthisis, in which the birthplace was stated, 48·8 per cent. were born in New South Wales (another 116 were "not stated").

In West Australia, during 5 years, 1903-1907, 12·6 per cent. were born in West Australia out of a total of 923 deaths.

The above data represent all that can be gathered as to the incidence of phthisis on the Australian-born or the immigrant sections of the community. It is obvious that it is not even possible to say how many deaths throughout Australia occur in the Australian-born portion of the population. It may provisionally be said, perhaps, that, taking the New South Wales figures as a basis, 50-55 per cent. of phthisis are among Australian-born. In Western Australia, however, the length of residence within the State expressed in years prior to death has been tabulated since 1903, and this information is available.

It is seen from Table VI. that 73·02 per cent. of the total number of deaths from phthisis during the years 1903-7 were of persons born

*After 1906 deaths are recorded as "Australian born"—prior to that "as born in New South Wales."

elsewhere than in West Australia, and whose time of residence within that State was ascertained, recorded, and tabulated. Another 12·6 per cent. were born in West Australia, so that it can be claimed that Figure 6 is sufficiently representative of the introduced phthisis to enable deductions to be drawn from it.

Figure 6 sets out for each year under consideration the deaths from phthisis of people not born in Western Australia according to the number of years' residence in that State. The curves show a definite sequence.

In 1903 the maximum point is during the ninth year of residence—that is, the greatest number of deaths took place among these people who entered the State during the year 1895-6.

In 1904, 1905, and 1906 similarly the greatest number of deaths took place among those who entered the State in the years 1895-1896. In 1907 the maximum was among those who entered the State in the year 1896-7.

Reference to Figure 2.—The curve of the mean total population in each year shows that during the years 1894-1897 a sudden rise in population occurred, and then, after steadying a little for 3 years, another rapid rise began. From 1894-7 the sudden increase was due to the rush of people attracted by the discovery of goldfields. The later rise has been due partly to the discovery of fresh goldfields, and partly to an energetic policy of importing agricultural settlers pursued by the authorities. The effect of such an increase of population can be seen in many ways. Its effect on the incidence of diphtheria has already been pointed out by the writer in a previous paper ("Public Health," July, 1908).

Figure 3 shows that the curve was at its lowest, 1895-8, and similarly Figure 1 for West Australia shows a marked depression in the curve between 1893-1900. Both these are due to the sudden large increase in population. It can be asserted without hesitation that much of the increase in population in Western Australia was obtained at the expense of the other Australian States, and in view of Figure 6 the deduction that some at least of the people that died from phthisis in West Australia during 1903-7 came from the other States in Australia is reasonable. In this connection the remark of Dr. Bulstrode, after a full consideration of the experience of the various authors, may be quoted:—"Obviously a considerable number of persons with phthisis lived and worked for many years after the recognition of their ailment, and this, independently of treatment in sanatoria (*loc. cit.* p. 115). But, irrespectively of whether the people under discussion were affected with either recognised or unrecognised pulmonary tuberculosis on their arrival in this State, it may be assumed that had the unusually large migration not taken place between 1894-1897, some at least of these cases might have died from phthisis in the States from which they originally came, and so the incidence of phthisis would have been more evenly distributed, and the decline in phthisis death-rate have included West Australia, and so have been uniform throughout all of the Australian States.

A consideration of why it is that the phthisis death-rate is showing a marked tendency to decline affords a fascinating problem, the

FIG. 6.

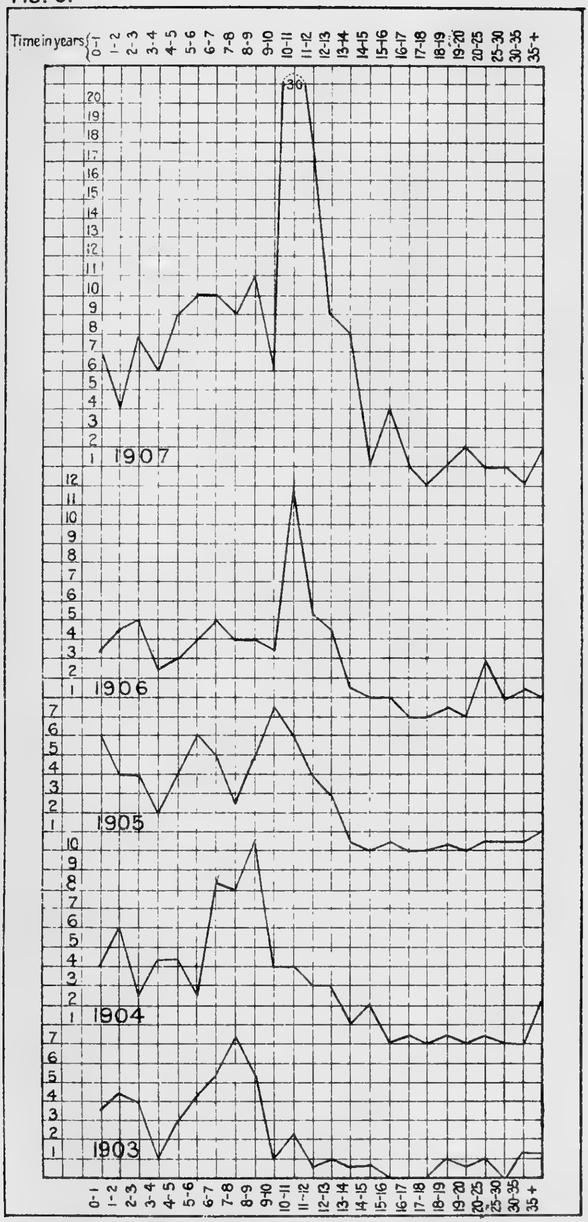


Fig. 6. Shewing the time of residence in Western Australia of cases that died from Phthisis in each of the years 1903–7.

solution of which is somewhat elusive. The question is discussed at length by Dr. Bulstrode in his monumental report (and the writer takes this opportunity of gratefully acknowledging a very free use of the material contained therein), where the following factors are discussed in turn. Change in the type of the disease, poverty, alcoholism, occupation, *qua* dust, overcrowding, soil dampness, insanity, the passing of the Public Health Act, the discovery of the tubercle bacillus, Housing of the Working Classes Act, commencement of notification of phthisis and sanatoria; and, as a result of a very exhaustive considerations, he arrives at the following very guarded conclusion:—"The precise value of each factor must depend largely upon the importance which science eventually attaches to bovine tuberculosis and to case-to-case infection" (*loc. cit.*, p. 99).

Newsholme discusses the same question with especial reference to—Improved sanitation, improved nutrition of the people in general, education and isolation, and improvement in the purity of the milk supply. Newsholme's conclusion is very definite. He says:—"The conclusion to be drawn from these facts is that institutional segregation, notably of advanced cases, is the most powerful single means available for controlling phthisis" (*loc. cit.*, proof p. 27). How will these various factors apply in Australia? Poverty, alcoholism, occupation, *qua* dust, overcrowding, soil dampness, Housing of the Working Classes Act, commencement of notification of phthisis, improved nutrition of the people, will hardly be thought to apply at all in Australia. Change in the type of the disease and insanity may have some influence, but they cannot statistically be put in evidence.

The advent of a Public Health Act and its theoretical corollary, improved sanitation, cannot have had any influence, as the commencement of the decline in phthisis death-rate was uniformly between 1883-1888 in the various States, and the dates of passing of effective Health Acts vary from 1890 in Victoria to 1904 in Tasmania. Improvement in the purity of the milk supply: This, *per se*, is difficult to demonstrate statistically, but Newsholme has arrived at a result indirectly. "We have seen that he (von Behring) claims that infection by cow's milk in infancy is the chief source of adult tuberculosis." If this be so, then the total death-rate from phthisis ought to be high in different countries, in accordance with the proportion of infants in each country who are fed on cow's milk, and not suckled by their mothers. There are no figures directly dealing with this point, but it is a well-established law that infantile mortality is low in accordance with the number of mothers who perform their natural duty to their infants. Hence, there should, if von Behring's views are correct, be an inverse† relationship between infantile mortality and phthisis death-rate.

Newsholme then gives a table of phthisis death-rates and infantile mortality in various countries, and says:—"There is, in fact, no such relationship between the magnitude of infantile mortality and that of the phthisis death-rate" (Newsholme, *loc. cit.*, proof p. 12). On Fig. 1 are set out the curves of the infantile mortality figures and phthisis death-rate for the past 20 years in various States. The

† It is so stated in the proof-sheets of Newsholme's article; but it would seem that the relationship should be a direct one rather than inverse.

curves for the infantile mortality are shown on Figure 1. It is evident from this figure that the infantile mortality curves in all the States have declined in harmony with the phthisis death-rate. As, however, the phthisis mortality is at its maximum between 25-35 years of age, in order to substantiate von Behring's views of infantile milk infection as a cause of adult phthisis, and, according to Newsholme's theory of infantile mortality figure as a statistical index of possible milk infection, the infantile mortality figure should have been low during the seventies and early eighties to conform to the low phthisis rates in the first decade of the twentieth century. It is obvious from the chart that this is not so. There remains the factor of isolation and education,* on which Newsholme lays so much stress.

Table VII. shows the percentage of total deaths from phthisis represented by the phthisis deaths that occurred in Government-subsidised hospitals (the majority of Australian hospitals receive some subsidy from the State Governments). This table shows conclusively that there is not in Australia any relationship between the percentage of total deaths that occur in hospitals (and the stay of patients is often very prolonged) and the decline in the phthisis death-rate.

While hesitating to criticise two such authorities as Newsholme and Bulstrode, I yet venture to suggest that neither of these authorities has gone far enough in the search for an explanation.

Figure 9 is a reproduction of Figure 7 in "The Prevention of Tuberculosis" (1908), p. 34. This shows that the curve for phthisis death-rate, while falling from 1850, yet began to fall markedly in the quinquennium 1865-1869, and has not since modified its regular decline.

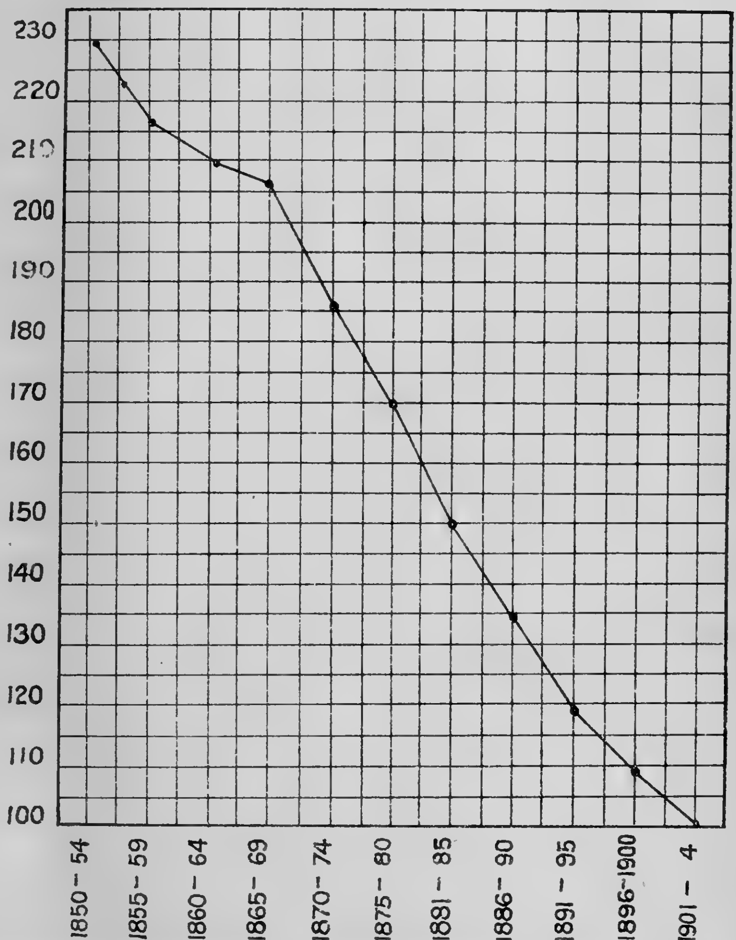
Bulstrode (*loc. cit.*, p. 37) shows a chart of the fall of the phthisis death-rate since 1850, with four points marked as follow:—Public Health Act, 1875; Discovery of the Tubercle Bacillus, 1882; Housing of the Working Classes Act, 1890; Commencement of Notification and of Sanatoria, 1899; and points out that none of these has had any marked influence in producing a decline in the phthisis death-rate. In Australia it has been shown that the curve in phthisis death-rate began to fall uniformly after 1883-1885—*i.e.*, soon after the discovery of tubercle bacillus. The fall in England and Wales began in 1865-9 quinquennium—*i.e.*, shortly before education became compulsory. One is inclined to think that Dr. Bulstrode might have included in his chart "Elementary Education Act, 1871." In short, it is not unlikely that the real explanation of the diminution in the phthisis death-rate is to be found in the rapid enlightenment of the people in general, which began in the early sixties, led up to compulsory education in 1871, and has continued so rapidly since.

In thus singling out the Elementary Education Act, it is not intended that this is to be considered as itself an important factor, but rather as an indication of the spirit of the period which saw its enactment.

This decade, 1860-69, may be regarded as a landmark in the career of the English "working classes." Trades unionism became

* Education, *i.e.*, as far as phthisis and its method of spread is concerned. In this sense the word "education" is used throughout the succeeding remarks.

FIG. 9



Relative Death rates from Phthisis from 1850-1904 – the death-rate in the most recent period being taken as 100

Copied from "The prevention of Tuberculosis," Newsholme, 1908, p. 34.

active, the Reform Bill was seriously introduced, and the whole decade culminated in what Justice McCarthy calls "Reformation in a flood," which reformation included the Elementary Education Act. It may fairly be said that about this time there was a great awakening of intelligence among the lower classes—the classes chiefly affected by phthisis—and this awakening brought with it a complete change in the social system of England. Men of all classes began to grapple with many evils which they had previously passively regarded as the "will of God." I have put my idea very inaptly; but what is intended to be conveyed is that the same fundamental cause—the awakening intelligence of the English nation as a whole—is responsible for the rapid progress that England had made in internal affairs, including sanitary reform as a whole, the institution of sanatoria, the lessened incidence of phthisis, and, possibly, even the rapid diminution of typhus. As Sir Shirley Murphy has stated concisely in his Annual Report for 1904:—"Phthisis in large degree is a disease of poverty, and in so far as the social condition of the people is improved, the risk of being attacked by phthisis is lessened for all."

"Dr. Niven, in his Annual Report for 1906, after analysis of the principal causes which are likely to have promoted a remarkable decline in pulmonary tuberculosis in England and Wales, regards as the chief factors the great advance in material well-being of the working classes, extending over the whole country, and producing increased resistance of the disease." (Bulstrode, *loc. cit.*, p. 103.)

The marked exception to the happy unanimity in this record of falling phthisis death-rate is Ireland, where there is as yet no awakening intelligence, but merely a dull lethargy. In Australia apparently the improvement coincides in its beginnings with the discovery of the tubercle bacillus. I am inclined to think that this coincidence is not merely fortuitous, but that a definite relationship exists, and that the experience of Australia coincides with that of Germany in this respect. As a practical point, there can be no question that Newsholme's concluding remark, quoted above, "that institutional segregation, notably of advanced cases, is the most powerful single means available for controlling phthisis" must be adopted, but I should prefer to see added some extension of the dogma providing for the persistent and widespread education of the community at large. The necessity of such measures is well recognised by the Countess of Aberdeen and her advisers in Ireland. Dr. Newsholme has, of course, realised the need for such education, as his procedure when medical officer of health at Brighton fully shows. It is certainly by sympathetic administration, but always through the people, that effective sanitary progress is obtained. The economic aspect of phthisis is a grave one. Dr. Herman Biggs (1903) places the expense of tuberculosis to the people of the United States at £66,000,000 annually.

Newsholme ("The Prevention of Tuberculosis," p. 20).—If, however, we assume that only one year's disablement is caused by every fatal case of consumption, then the direct loss per annum in England and Wales produced by the death of men aged twenty to sixty-five from consumption, reckoning wages at £50 per annum, judging by the experience of 1904, amounts to £1,015,400. This is the loss in wages, reckoned at the above rate. No allowance is made for the cost of illness, for the interference which every sickness involves with the work of others, or for the infection of others and resultant further loss of work and money."

The total revenue for West Australia for 1907 was £3,401,353 —the estimated mean population 263,749—the revenue per head was thus £12 18s., approximately. The number of deaths from phthisis was 206. Thus, roughly assuming each individual to be worth £12 18s. to the State, the loss to the State would be £2,657 8s. for 1907 alone. Mr. E. T. Owen, the Government Actuary for Western Australia, in his report to the Royal Commission on Immigration, assesses the value to the State of every immigrant of thirty years of age at £309. To quote from his report:—

"On that basis every immigrant of thirty years of age is, when the annual sums are capitalised, worth to the State Government £295, and to the local government authorities £14; he is, therefore, under that assumption, worth to the State the total sum of £309."

During 1907, 172 persons between twenty and fifty years of age died from phthisis in West Australia. Assuming each person to be worth only half the above estimate, there occurred in one year a capital loss to the State of £26,574.

Any of these financial methods of arriving at an individual's value to the State is unsatisfactory, but whichever point of view be chosen, the loss in one year of 206 individuals to the State or of 2,863 to the Commonwealth, the majority of whom are in the prime of life, is a very serious matter, and any expenditure that would prevent the spread of this disease would be more than justified.

The following table shows the number of people in each year who died from phthisis after ten years' or less residence in Western Australia:—

1903 ...	... 80	1906 ...	... 78
1904 ...	... 110	1907 ...	... 80
1905 ...	... 92		

This table in itself is sufficient reason for the introduction of strict supervisory measures for the prevention of fresh cases, which become a charge upon public funds and serious centres of fresh infection.

The measures to be adopted are obvious. They include all known precautions, the supervision of the meat and food supply, the careful and repeated inspection of dairy herds, the notification of cases, the cleansing and disinfection of infected premises, and particularly the strict isolation of "open cases." In this Commonwealth, also, strong measures should be taken with a view to prevent the landing of phthisis cases, or their strict supervision if allowed to land.

Throughout this paper I have made free use of the statistical returns published by Mr. Fraser, the Registrar-General for West Australia, who also kindly obtained for me, through the courtesy of the respective statisticians, the necessary statistics from the other States. I take this opportunity of thanking him for his kindness, not only in furnishing data, but for many useful suggestions.

Table 1.

1873	26	1901	151
1878	22	1902	146
1883	24	1903	144
1888	42	1904	198
1893	44	1905	162
1898	113	1906	213
1899	114	1907	206
1900	137		

Actual number of deaths from phthisis in W.A.

Table 2.

—	West Australia.	Victoria.	South Australia.	New South Wales.	Queensland.	Tasmania.	Commonwealth.
1907	·781	·958	·763	·628	·652	·418	...
1906	·820	·989	·815	·665	·678	·659	...
1905	·647	1·110	·753	·701	·755	·748	·808
1904	·837	1·114	·791	·812	·790	·632	·897
1903	·651	1·110	·818	·870	·784	·631	·912
1902	·710	1·166	·813	·805	·892	·580	·921
1901	·802	1·176	·845	·830	·844	·576	·938
1900	·774	1·162	·844	·780	·871	·620	...
1899	·676	1·154	·887	·808	·800	·592	...
1898	·669	1·295	·914	·841	·855	·750	...
1893	·720	1·343	1·011	·888	1·115	·579	...
1888	·993	1·448	1·175	1·010	1·304	·583	...
1883	·768	1·332	1·027	1·123	1·758	1·102	...
1878	·786	1·368	1·099	·978	1·272	...	...
1873	1·009	1·210	·772	...	1·035	...	...

Death rates from phthisis per 1,000 of estimated mean population.

Table 3.

Deaths from Phthisis—Various Countries.

Country.	Year.	Deaths per Million Inhabitants.	Country.	Year.	Deaths per Million Inhabitants.
New Zealand ...	1905	570	Spain	1904	1,509
Commonwealth ...	1905	808	Jamaica	1905	1,522
Ceylon	1905	957	German Empire ...	1904	1,796
Belgium	1904	1,091	Switzerland ...	1904	1,882
England and Wales	1905	1,144	Norway	1904	1,964
Italy	1905	1,182	Chile	1905	2,017
Netherlands ...	1905	1,357	Ireland	1905	2,099
United Kingdom ...	1904	1,365	Servia	1905	3,325
Japan	1903	1,449	Austria	1903	3,362
Scotland	1904	1,456	Hungary	1905	4,415

From Official Year Book, Commonwealth, 1901-7, p. 209.

MALE AND FEMALE PHTHISIS DEATH RATES.

Year.	Estimated Mean Population.	Total Deaths from Phthisis.	Male Deaths from Phthisis.	Male Death Rate per 10,000 of total population.	Female Deaths from Phthisis	Female Death Rate per 10,000.
1907	263,749	206	132	5·04	74	2·8
1906	259,811	213	142	5·4	71	2·7
1905	250,207	162	102	4·1	60	2·4
1904	236,516	198	124	5·2	74	3·1
1903	221,278	144	99	4·4	45	2·03
1902	205,755	146	101	4·9	45	2·2
1901	188,313	151	93	4·9	58	3·1
1900	176,905	137	81	4·6	56	3·1
1899	168,528	114	81	4·8	33	1·9
1898	168,999	113	71	4·2	42	2·5
1897	155,563	87	53	3·4	34	2·2

(To accompany Fig 5)

Table 5.

MONTHLY INCIDENCE OF DEATHS FROM PHTHISIS.—AVERAGE OF ACTUAL NUMBER OF DEATHS IN EACH MONTH.

Month.	WEST AUSTRALIA.	TASMANIA.	NEW SOUTH WALES.	QUEENSLAND.	SOUTH AUSTRALIA.
	Average of 5 years, 1903-1907.	Average of 13 years ending 1907.	Average of 5 years, 1903-1907.	Average of 15 years ending 1907.	Average of 15 years ending 1907.
January ...	17·6	8·7	86	34	26·5
February ...	13·4	7·4	71	28	21·5
March ...	13·8	9·1	85·6	31	24·3
April ..	17·6	9·1	82·2	29	23·7
May ...	14·6	8·6	94·8	32	26·01
June ...	13·6	10·0	94·4	32	25·9
July ...	15·2	9·5	106·0	35	28·8
August ...	19·6	11·2	105·4	35	24·8
September ...	16·8	10·7	99·8	35	27·1
October ...	16·0	11·4	101·2	34	26·2
November ...	15·0	11·3	88·6	33	24·9
December ...	11·4	9·5	78·2	34	24·8

Table 6.

Year.	Total Deaths from Phthisis.	Number Born in West Australia.	Born Elsewhere. Length of Residence in West Australia Not Stated.	Born Elsewhere. Length of Residence Specified.	Born Elsewhere. Last Column expressed as Percentage of Total Phthisis Deaths.
1907 ...	206	19	30	157	76·2
1906 ...	213	29	35	149	69·9
1905 ..	162	18	17	127	78·4
1904 ...	198	27	27	144	72·7
1903 ...	144	24	22	98	68·0
Totals ...	923	117	131	675	73·02

Table showing percentage of introduced phthisis in West Australia, in which length of residence is specified.

Table 7.

NUMBER OF DEATHS FROM PHTHISIS IN GOVERNMENT SUBSIDISED HOSPITALS EXPRESSED AS A PERCENTAGE OF TOTAL DEATHS FROM PHTHISIS IN EACH STATE.

Year.	Tasmania.	New South Wales.	Victoria.	West Australia.
1907	34·6	33·8	20·4	37·8
1906	16·8	31·7	16·7	32·4
1905	20·9	32·6	19·1	46·3
1904	15·9	28·7	17·0	28·3
1903	14·3	31·4	14·7	40·9
1902	16·6	30·4	17·9	37·6
1901	24·0	27·1	18·8	35·1
1900	27·2	30·4	16·0	...
1899	22·0	29·8	17·0	...
1898	11·1	28·9	14·6	...
1893	17·9	27·6	17·6	...
1888	36·2	...	19·2	...
1883	8·8	...	19·3	...

5.—THE PROXY VOTE.

By PROFESSOR E. J. NANSON.

After a general election we frequently see in the Press tabular statements of the votes polled and the number of members elected by the several parties. In the case of two parties whose candidates are denoted respectively by the earlier and later letters of the alphabet the statement for ten districts each returning one member might be as follows:—

Elected	A	101	Q	100	Defeated
	B	102	R	99	
	C	103	S	98	
	D	101	T	100	
	E	104	U	97	
	F	101	V	100	
Defeated	G	80	W	121	Elected
	H	79	X	122	
	I	81	Y	120	
	J	80	Z	121	
Votes ...		932		1,078	
Seats ...		6		4	

In the case of three parties whose candidates are denoted respectively by the earlier, the middle, and the later letters of the alphabet the statement for six districts, each returning one member, might be as follows:—

	A	102	L	101	U	97
	B	102	M	99	V	99
	C	101	N	100	W	99
	D	104	P	102	X	94
	E	66	Q	148	Y	86
	F	65	R	148	Z	87
Votes ...		540		698		562
Seats ...		4		2		0

In each of these cases there is electoral injustice. In the first case the minority party, with 932 votes, secures six of the ten seats, whilst the majority party only gets four. In the second case no one of the three parties has an absolute majority. But the weakest of the three parties, with 540 votes, secures four of the six seats; the strongest party gets two only, whilst the party with the second largest number of votes gets no representation whatever.

Such are the results which can be brought about by the existing electoral system. The merest tyro can see that these results are untrue, and he can also see that there is considerable force in the process by which the results are shown to be untrue. It is proposed in this paper to show that this process, which even a child can understand, may, by the aid of some simple changes in the electoral law, be made to give the true results of the election.

The most casual inspection of the figures above given shows that the existing system errs in two distinct ways. In the first place it absolutely ignores the scores of all unsuccessful candidates. In the second place it takes no account whatsoever of the *differences* in the scores of the successful candidates.

The remedy, then, is plain and two-fold. In the first place, every member must have in *parliament* a voting power proportionate to the votes he polls in the election. In the second place, every vote polled must be represented in parliament.

The first part of the remedy is quite simple in practice. Furnish every member with an "ingot" weighing one gram for every thousand votes polled by the member. In a "division" in parliament every ingot would be cast by its owner on the "aye" or the "no" balance. The number of popular votes for and against every measure before parliament would then be quickly and automatically found, and the tellers could compile the division list at their leisure.

The second part of the remedy leads to a most important feature. Since every vote is to be represented, it follows that in each district there must be as many seats as there are parties. Nothing short of this can secure to each party its proper share of representation, be the parties few or many. This feature is the stumbling-block for every member of parliament at present. Members will not give up the one-member districts. Yet no true electoral reform can be got till this is done.

One other simple feature remains to be mentioned. Each elector is to have one vote as at present, but to heal party splits it is necessary to use the contingent or single transferable vote. The extensive experience of the Political Labour Council in Victoria and elsewhere places beyond all doubt or cavil the fact that the single transferable vote does simply, satisfactorily, and completely heal all splits within the party, no matter how ineffective it may be as a means of bringing together two *different* parties.

There are, then, three simple reforms necessary. First, the ingot, or vote by weight. Second, the enlarged district, so many parties, so many seats for the district. Finally, the single transferable vote to heal all party splits.

Let us now see how these reforms would work in the two cases already cited.

In the case of two parties, suppose the ten single-member districts replaced by five two-member districts. In the first of these larger districts one party runs the two candidates A and B. The other party runs the two candidates Q, R. As there are four candidates for two seats the lowest candidate, R, is excluded. Then, party loyalty being assumed, the ninety-nine votes cast for R now go, by means of the transferable vote, to Q. The poll now stands:—

Q	199	B	102	A	101

As there are now three candidates for two seats the lowest, A, is rejected, and his 102 votes go to B, so that the poll stands:—

B	203	Q	199

Similar treatment of the other four districts gives the following result:—

	B	203	Q	199
	C	204	T	198
	E	205	V	197
	G	159	X	243
	I	161	Z	241
Votes	...	932		1,078

Thus each party gets five seats, but one party has a voting power of ·932 grams, and the other a voting power of 1·078 grams in parliament.

Again, in the case of three parties, suppose the six single-member districts replaced by two districts each returning three members. In the first of these larger districts the three parties run the candidates A, B, C; L, M, N; U, V, W. After three counts or scrutinies, in which U, M, C are successively rejected, the poll might stand—

A	152	L	151	V	147
B	153	N	149	W	148

These results are obtained, as before, by use of the transferable vote. For example, U is first rejected. The 97 votes so set free go partly to V, and partly to W.

After three more counts, in which V, N, A are successively rejected, the poll might stand as in the first line of the following table:—

	B	305	L	300	W	295
	E	235	Q	398	X	267
Votes ...		540		698		575

the second line in the table being got by a similar treatment of the second three-member district. Thus, each party gets two seats, but their voting powers in parliament are in grams ·540, ·698, ·575 respectively.

It has, then, been shown that, by three simple reforms, each quite simple in the practical working out, glaring electoral inequalities can be cured, and results generally accepted as fair can be attained. But this does not bring us to the solution of the three-party problem. It remains to be shown how the proxy vote may enable us to get over this difficulty.

The effects of the scheme proposed so far are merely to allow each elector to annex himself, body and soul, to one of the three parties, and to enable him to give a truly effective vote for his party. The result may be, as we have seen *ad nauseam* in practical politics, merely "three elevens." The only way out is by compromise. But, as our legislators are not good at this, it is now time for the electors themselves to take a hand, and the proxy vote will enable them to do so effectually.

The existence of three general policies has in the past divided the electors into three parties, each in favour of one of the three policies, and against the other two. This position has been forced on politicians and electors by an electoral system in which there is not room for more than two parties. But, in reality, three policies divide the electors into *six* parties. There are three parties of the type already stated. But there are also three of another type, each in favour of two of the policies, and against the third policy. These are the "compromise" parties, which alone can help us out of our present dilemma. To enable them to do so, all that is necessary is to have districts returning six members apiece.

Let us now see how this idea will deal with the three-party problem in the three-party case already discussed. Let the three parties be Government, Opposition, and Third party.

Let an elector in favour of Government policy and against the other two be said to be of type G. Also, let an elector in favour of Opposition and Third party policies but against Government policy be said to be of type OT; and so in other cases. Then the electors and candidates already dealt with in the three-party case might be further classified as follows:—

G.	O.	T.	O.T.	T.G.	G.O.
...	L 101	U 97	...	A 102	...
...	P 102	X 94	...	...	D 104
B 102	...	V 99	...	...	M 99
E 66	...	Y 86	Q 148	...	...
C 101	N 100	...	W 99	...	...
F 65	R 148	...	...	Z 87	..
334	451	376	247	189	203

Thus it has been assumed that A and his 102 supporters were in favour of Government and Third party policies, and that B and his 102 supporters were against Opposition and Third party policies, and similarly in other cases.

Assuming this classification in a six-member district, two important consequences follow. First, if an election was held in this district, one candidate of each type would be elected. The successful candidates of the second type would be Q, A, D, with 247, 189, 203 votes respectively. Those of the first type would have respectively 334, 451, 376 votes, but who the successful candidates are would depend on the way in which the secondary and subsequent votes were cast.

Next, from this classification we can deduce the mind of the whole district for and against each of the three policies. From it we at once get the following statement:—

GOVERNMENT.		OPPOSITION.		THIRD PARTY.	
For.	Against.	For.	Against.	For.	Against.
334	451	451	334	376	334
189	376	247	376	247	451
203	247	203	189	189	203
726	1,074	901	899	812	988

Thus we see that the policy of the Opposition is carried, and that the policies of the Government and Third party are defeated, the decision in each of the three cases being by an absolute majority of the whole of the electors in the six-member district considered.

But, as the figures in the preceding statement represent, in milligrams, the weights of the ingots which would be cast into the scales on the three divisions contemplated, it follows that by the proxy vote a parliament can be elected which is bound to give effect to the will of the electors as regards *each* of the three party policies.

For simplicity, the case of one six-member district alone has been considered. But the results already stated would apply to the aggregate of the results in several six-member districts.

To apply the scheme to the election of Representatives, it would be sufficient to divide each State into six-member districts. The number of such districts is not a matter of great importance. For the weight of each State in the House would depend not on the number of its members but on the weight of its ingots. Thus one great incidental advantage of the scheme would be continuous automatic adjustment of the weight of each State without any need whatsoever for frequent periodical readjustments of electoral boundaries.

But in the election of Senators a slight modification would be necessary. Inasmuch as the Federal Constitution requires each State to have the same amount of representation in the Senate, it would be sufficient to make the total weight of ingots for each State the same.

To make the scheme theoretically perfect it would be necessary to apply the contingent vote *within* each type only. Unless this be done, one of the types might get no representatives. For instance, if in the latter stages of the election just discussed two Opposition candidates had 251, 200 votes respectively, the "TG" candidate would be at the bottom of the poll, and would therefore be rejected unless the restrictions suggested were made. But the introduction of this restriction might well be postponed till actual experience showed that it was really necessary.

To those familiar with the electoral reform movement of the present day it is merely necessary to say that what is here proposed is practically the Hare scheme without the quota and without the tedious process of surplus distribution. It is, in fact, the Hare scheme shorn of all its tedious complicated details. But, at the same time, it is but right to claim for the scheme now proposed that it furnishes a much more refined and accurate representation of the weights of parties than can possibly be obtained by any scheme of quota representatives with districts returning not more than six members.

6.—PROGRESS OF ARBITRATION FOR THE PREVENTION AND SETTLEMENT OF INTERNATIONAL DISPUTES.

By HENRY A. TARDENT.

Section GII.

AGRICULTURE.

ADDRESS BY THE PRESIDENT,

H. W. POTTS, F.C.S., F.L.S.,

Principal, Hawkesbury Agricultural College, Richmond, N.S.W.

THE AGRARIAN INDUSTRIES: THEIR DEVELOPMENT AND PRESENT CONDITION WITH SPECIAL REFERENCE TO THE OUTLOOK FOR THE COMMONWEALTH OF AUSTRALIA.

John Naismith, a noted agriculturist in the latter part of the eighteenth century, wrote:—" Agriculture has been regarded by the wisest men of all ages as the most important employment of mankind, and the firmest support of a State; and, being of the most laborious kind, and attended with uncommon hazard and difficulty, seems not only to merit, but demand, every possible degree of public patronage."

Quaint as may be the mode of expression, the main principle is as urgent to-day. Indeed, more so, seeing applied science has relieved many phases of the laborious aspect of agriculture and its allied industries.

Without assenting to the doctrines of such an extremist in social economics as the late author of "Progress and Poverty," we may admit that there is much force in his assertion, when in answer to the hackneyed objection "we cannot all be farmers," he emphatically rejoins: "Why, that is just what we all could be." Why indigence and material advance seem to be so inseparable, and why, with an enormously increased production, so small a share falls to the lot of vast numbers of toiling bread-winners, is not the subject I now propose to deal with, but in the opinion of many it is intimately connected therewith. There is a steadily growing conviction in many minds that systems of government and of land tenure which drive population off the land in old countries, and fail to settle them on it in new, are largely responsible for such an unequal condition of things. While in many places dire need is rampant, we nevertheless hear of "over-production." In reality this is frequently only another term for imperfect and ill-regulated distribution. When we see no deserving person unemployed; when man, woman, and child are well fed, comfortably housed, and decently clad, then it will be time enough to speak of over-production; but the time has not yet arrived when the plough or the loom may be idle for want of needs to supply, and I shall endeavour to show what activity and progress in the primary industries are awaiting development in the continent of Australia.

In newly-settled and comparatively undeveloped countries like Australia, one would naturally suppose that the preponderance of population would be in the rural districts, but the tendency is to accumulate to a surprising extent in the capital cities. Mr. G. H. Knibbs, the Federal Statistician, points out in his Commonwealth Year Book that this metropolitan aggregation is so remarkable that it ranges from 19 to 46 per cent. of the total population of the respective States.

In South Australia the Adelaide population is 46 per cent. of the whole State; in Victoria, the Melbourne population is 43 per cent.; the population of Sydney is 35 per cent. of the whole State; of Brisbane, 24 per cent.; Perth, 20 per cent.; and Hobart over 19 per cent.

Taking the whole Commonwealth, the six capital cities have a population equivalent to 35 per cent. of that of the entire Commonwealth.

That so large a proportion of our Australian population should crowd into the capital cities is hardly a satisfactory condition of things. It cannot be explained as the result of abnormal expansion of manufacturing industries, as is the case with older countries where the same social phenomenon is experienced; consequently, we may derive some satisfaction from the apparent fact that the production from primary sources in this land is so great and valuable as to admit of a very large proportion of its population who are engaged in distribution and secondary production living in urban centres. But surely it is this very evidence of the great value of our primary products which should be the strongest incentive to the following of agrarian pursuits. In America the increased town population has been accompanied by a corresponding increase in agrarian settlement.

In what measure the tendency in Australia may be attributed either to a disinclination to country work and life, or to an actual difficulty in getting on the land, I am not prepared to say, but most likely both are contributing factors.

To what extent we can revert more to agrarian occupations or at least maintain a reasonable balance between the primary and secondary industries is the problem before us.

In Australia pastoral pursuits were for a long period the paramount agrarian industry. Agriculture, until recent times, was of little account, but it has now reached a stage of such importance, and is expanding so rapidly, that it bids fair ere long to rival and surpass the older industry.

Just 120 years ago Captain Phillip started us with 7 horses, 6 head of cattle, 29 sheep, 12 pigs, and a few goats. In 1800 we had 203 horses, 1,044 cattle, 6,124 sheep, and 4,017 pigs. In 1850 such rapid advance had been made that the records were, in round numbers:—

Horses	160,000	Sheep	16,000,000
Cattle	1,895,000	Pigs	114,000

The following table shows the live stock of each State, and for the whole Commonwealth, at the end of 1907:—

State.	Horses.	Cattle.	Sheep.	Swine.
New South Wales ...	578,326	2,749,193	44,461,839	216,145
Victoria	424,648	1,842,805	14,146,734	211,012
Queensland	488,486	3,892,232	16,738,047	133,246
South Australia	224,447	680,095	6,661,217	112,277
West Australia	113,330	785,566	3,684,974	53,399
Tasmania	38,299	211,117	1,729,394	42,985
Commonwealth	1,867,536	10,161,008	87,422,205	769,064

The first start in agriculture was made with 8 acres planted with wheat and barley by Captain Phillip in 1788. Nine years later the total area under crops was nearly 5,000 acres, and 53 years afterwards (in 1850) it was close on 500,000 acres.

The area under crop in each State and the whole Commonwealth for the year 1907 is given hereunder:—

State.	Area under Crops.
New South Wales	2,570,137 acres
Victoria	3,232,523 ,,
Queensland	532,624 ,,
South Australia	2,265,017 ,,
Western Australia	494,987 ,,
Tasmania	244,744 ,,
Commonwealth	9,340,032 acres

It will be seen that about one-third of the total crop area of the Commonwealth is in the State of Victoria; rather more than one-fourth is in New South Wales; and rather less than one-fourth in South Australia.

The development of both pastoral and agricultural industries of the Commonwealth has been frequently dealt with, and I shall here only draw attention to the fact that in regard to crops the area has during the past 20 years advanced from 5,585,622 acres to 9,340,032 acres, representing a total increase of 3,754,410 acres, or at the rate of 67 per cent.

The following table gives a comparative statement for each State and for the Commonwealth. The New South Wales area has trebled, and that of Queensland has increased in very nearly the same proportion, while the West Australian area has advanced seven-fold. Victoria, which has the largest area under cultivation, does not increase at anything like the rate of New South Wales. Tasmania's progress in cultivation is at a slower rate than that of Victoria, and the South Australian area is practically stationary.

State.	Area Cultivated.		Increase.	
	Year ended March, 1888.	Year ended March, 1908.	Total.	Per cent.
	Acres	Acres.	Acres.	
New South Wales ...	855,627	2,570,137	1,714,510	200
Victoria	2,054,004	3,232,523	1,178,519	57
Queensland	192,987	532,624	339,637	176
South Australia	2,245,114	2,265,017	19,903	1
West Australia	65,701	494,987	429,286	653
Tasmania	172,189	244,744	72,555	42
Commonwealth	5,585,622	9,340,032	3,754,410	67

But what I am more concerned with in this paper are the capabilities of extension and improvement—the future outlook. And, without taking into account any probable improvement in the direction of higher results from better methods, it will be at once apparent from the following table that we have only touched the fringe of cultivation. In order to make it an Australasian matter, I have included New Zealand—

Country.	Total Area.	Area Alienated.	Area under Crops.	Proportion of Cultivated Area to—	
				Total Area.	Alienated Area.
	Acres.	Acres.	Acres.	1 Acre out of every—	1 Acre out of every—
New South Wales ...	198,638,080	51,000,000	2,570,137	77	20
Victoria	56,245,760	27,417,091	3,232,523	17	8
Queensland	429,120,000	19,703,325	532,634	804	37
South Australia ...	578,361,600	9,604,863	2,265,017	255	4
West Australia ...	624,588,800	13,306,495	494,987	1,261	27
Tasmania	16,777,600	5,479,538	244,744	68	22
Commonwealth ..	1,903,731,840	126,511,312	9,340,032	202	13
New Zealand ...	66,861,440	26,462,809	1,824,363	366	15
Australasia	1,970,593,280	152,974,121	11,164,395	176	14

Taking the whole area of the Commonwealth, the proportion cultivated is only 1 acre out of every 202 acres. Out of an alienated area of 126,511,312 acres only 9,340,032 acres are cultivated—that is to say, 1 out of every 13. In New South Wales only one-twentieth of the alienated area is cultivated, or one seventy-seventh of the total area of the State. In Victoria one-eighth of the alienated area, or one-seventeenth of the total area. Of the Queensland alienated area only 1 acre out of every 37 is cultivated; and of the total area of the State only 1 out of every 504. In South Australia the alienated area is small, and one-fourth of it is under crop. But, taking the whole area of the State, only 1 out of every 255. Of the alienated area of West Australia only one twenty-seventh is cultivated; and of the total area of the State only 1 out of every 1,261 acres. Even in Tasmania only 1 out of every 22 acres alienated is under crop; and only 1 out of every 68 of the whole State. In New Zealand only 1 out of every 15 acres of the alienated area is cultivated; and of the whole Dominion only 1 out of every 366.

The total area of Australasia—*i.e.*, the Australian Commonwealth and New Zealand—is 1,970,593.280 acres, of which 152,974.121 acres are alienated. The area under crops is 11,164,395, representing only 1 out of every 176 acres of the whole area, and 1 out of every 14 acres alienated. Apart from the fact that only a small portion of the alienated area of Australasia is under the plough, there is in each State of the Commonwealth a very large area of Crown lands under occupation by lease. It is certain that some of this also is suitable for cultivation.

The area of Crown lands under lease in each State is as follows:—

	Acres.
New South Wales	124,237,000
Victoria	16,637,000
Queensland	247,059,000
South Australia	204,696,000
West Australia	155,528,000
Tasmania	1,344,320
Commonwealth	746,501,320

The following table shows for each State and for the whole Commonwealth (1) what proportion of the total area is alienated or in process of alienation, (2) what proportion of it is under Crown lands occupany, and (3) what proportion of it is unoccupied:—

—	New South Wales.	Victoria.	Queensland.	South Australia.	Western Australia.	Tasmania.	Commonwealth.
	%	%	%	%	%	%	%
Area alienated and in process of alienation	25	48	4	4	2	33	6
Crown lands occupied under lease	63	29	58	39	24	8	39
Unoccupied	12	23	38	57	74	59	55

The estimated value of the production from agrarian industries for the Commonwealth of Australia for the year 1906 is given by Mr. Knibbs as follows:—

	£
Agricultural	25,349,000
Pastoral	45,389,000
Dairying, poultry, bees, &c.	13,611,000
Total	£84,349,000

Figures for comparison over a series of years are not available for the Commonwealth, but a ten-years' comparison for New South Wales shows as follows:—

	Year 1897.		Year 1907.
	£		£
Pastoral	11,823,000	...	22,750,000
Agricultural ...	6,250,000*	...	6,587,000
Dairying	2,653,000	...	3,400,000
Poultry, bees, &c. ...	...	...	1,845,000
Total	£20,726,000	...	£34,582,000

The production of butter for the Commonwealth and each State is given for the year 1897 and the year 1907:—

	Year 1897.		Year 1907.
	Lb.		Lb.
New South Wales ...	29,410,000	...	60,031,000
Victoria	34,561,000	...	63,746,000
Queensland ...	5,686,000	...	22,789,000
South Australia ...	4,831,000	...	8,519,000
West Australia ...	270,000	...	437,000
Tasmania	600,000	...	905,000
	75,358,000	...	156,427,000

The statement of the president of the Pastoralists' Union (Mr. W. E. Abbott) at the annual meeting in 1905 is worth repeating, as indicating what the potentialities are even in one portion of this State alone. He said:—"By the application of capital to the land and the use of the plough instead of depending on the natural growth of grass as we have hitherto done, the eastern division, which is only one-third of the State, can be made to easily and safely carry more than 40,000,000 sheep, besides leaving room for other stock and all kinds of farming; and it would then maintain in comfort and prosperity a population ten times as large as it carries now."

It has been predicted by some recent writers that the day is approaching when all the lands suitable or available for wheat growing will be in use, and when the annual consumption will overtake production. Professor Sylvanus P. Thompson stated last year that this would happen as early as the year 1910. Sir William Crooke, in a presidential address to the British Association about 10 years ago, placed the time somewhere about the year 1931. In view of the foregoing figures for this continent I do not think there is any cause for alarm, even in the present conditions.

Moreover, the vast resources of the United States are only in a comparatively early stage of utilisation, so much so that whatever may be true in particular regions, cultivation as a whole is not so scientifically advanced, and not so productive per acre, as in the United Kingdom. According to the 12th census of the United States the farm acreage represented only 44 per cent. of the total area of the States; and only one-half the farm acreage is returned as "Improved land"—*i.e.*, under crops, bare fallow, or sown grasses.

* 1897 was an exceptionally good year for prices—agriculturally.

In 1900 less than 6 per cent. of the area of New Mexico was farm land, and only 7 per cent. of the farm area was returned as "improved."

This helps us to understand why, in spite of the fact that many of the States have a greater percentage of improved land than some of the densely settled European countries, the proportion for the whole republic is so low.

While it would be difficult to estimate the value to agriculturists of the scientific services of eminent men like Sir William Crooke, their statistical calculations and prophecies, from a social economic point of view, do not necessarily carry the same weight as the results of their scientific labours and investigations. The complete utilisation or partial exhaustion of what is estimated to be all the available or suitable wheat land is a matter very difficult to determine. Statistics showing decreased areas, or stagnant operations, in various countries, do not indicate it by any means. Modern farming is very largely dependent on physical and social conditions, which are subject to variations. The farmer has to study commercial conditions, and to consider the prices which his different products will realise. Why has the cultivated area of New South Wales increased at so slow a rate during the last seven years as compared with the astonishing leaps and bounds it took during the preceding septennial period? Most assuredly not for want of available land, and not even so much on account of physical conditions. The truth lies in the fact that very many landholders cultivating big areas, as well as others with small holdings, have found sheep temporarily more profitable. A big slump in wool prices would make all the difference.

On the other hand, South Australia has, by reason of climatic and other conditions, found it advantageous to foster the wheat industry.

Of late years a marked improvement in yield is shown, and is mainly due to improved methods of cultivation, careful selection of seed, and the proper use of manures.

The folowing table gives the average yield per acre:—

Year.	Bushels.	Year.	Bushels.
1891 ...	... 5·6	1901 ..	... 5·9
1892 ...	... 4·3	1902 ...	... 4·6
1893 ...	... 6·1	1903 ...	... 3·6
1894 ...	... 7·9	1904 ...	... 7·7
1895 ...	... 4·9	1905 ...	... 6·5
1896 ...	... 4·2	1906 ...	... 11·5
1897 ...	... 1·7	1907 ...	... 10·2
1898 ...	... 2·6	1908 ...	... 10·9
1899 ...	... 4·9	1909 ...	... 11·6
1900 ...	... 4·6		

In England we know that a serious decline has taken place in agriculture, but it is certainly not due to the exhaustion of the soil. It is quite within the bounds of reasonable possibility that a reaction may set in. Notwithstanding the remarkable fertility of its soil, no other country in the world shows so small a proportion of its population engaged in agrarian pursuits. This is a matter for grave reflection when it is considered how entirely dependent on foreign supplies the whole nation is. Will this condition of things necessarily always remain? Allowing for the disadvantages of climate and of land laws, the British Isles possess many advantages for farming not enjoyed by less favoured countries of much greater area; and many persons who have studied the subject are convinced that the 20th century will see a considerable reversion to agriculture in the United Kingdom.

Mr. Parker, of the Minnesota Experiment Station, in dealing with the question of future wheat supply, combats the opinion that wheat is only a pioneer crop. Even if it be, there are still vast areas to be pioneered; but the world is not so dependent on the pioneer lands for wheat. In America, he says, not a few of the oldest States are producing more wheat to-day than they did 40 years ago, and that as soon as the virgin lands of the West cease yielding spring wheat they will follow the example of the older States and maintain their yields by taking to the less exhausting winter wheats.

All these considerations suggest to the Australian that, while we should make the most of outside markets, the ultimate destiny of our country is—like America—to supply the needs of a big population within our own borders, and henceforth all our efforts should be directed towards the establishment of this social condition.

The following is a list of some of the principal items of food imported annually into the United Kingdom, and alongside it, for purposes of comparison, are given the quantities of similar produce exported from the Commonwealth to all places:—

	Imported into the United Kingdom.	Exported from Australia.
	£	£
Wheat	30,000,000	4,801,700
Flour	10,000,000	1,296,000
Maize	12,000,000	5,850
Oats	4,000,000	60,000
Barley	7,000,000	5,500
Butter	12,000,000	2,890,000
Bacon and ham	16,000,000	17,350
Cheese	7,000,000	12,700
Mutton	8,000,000	1,377,500
Beef	10,000,000	575,700
Fruit	12,000,000	334,000
Sugar	16,000,000	13,400
Wine	5,000,000	15,300
Tobacco	4,000,000	66,800
Lard	3,000,000	8,500

An estimate of the world's wheat harvest for this season, published by the Hungarian Agricultural Ministry, gives the crop as 3,128,720,000 bushels. On the 25th August an estimate in "Dornbusch's List" placed the quantity at 3,090,000,000 bushels. We may fairly assume that it will not be less than 3,000,000,000 bushels.

The Australian Commonwealth will produce about the fiftieth part of this.

The estimate of the live stock of the world, together with the figures for the Australian Commonwealth, is as follows:—

	The World.	Australia.
Horses ...	77,191,000 ...	1,868,000
Cattle ...	343,483,000 ...	10,161,000
Sheep ...	496,557,000 ...	87,422,000
Swine ...	121,287,000 ...	769,000

It will be seen that while one-sixth of the sheep of the world are depastured in Australia we have only an insignificant proportion of the other stock.

It would be difficult to enumerate or even approximately attach a value to the benefits which science has conferred upon the agrarian industries. Where in former times many operations were carried out by more or less haphazard rules science has established rational methods. Biological research gave us in 1887 the scientific explanation for the well-known method of preceding a crop of wheat with clover as the best preparation. Such has been practised from the time of the Romans.

We are constantly reminded that the conditions of modern agricultural practice must be harmonised with the facts of pure science. The benefit of applying farmyard manure was proven long before science showed how certain chemical constituents are essential to plant life. So, also, simple observation, prior to scientific confirmation, taught the benefits derivable from feeding live stock on the more concentrated foods.

Attention was first called by Liebig nearly 80 years ago to the gradual deterioration of arable soils in his "Chemistry in its Relation to Agriculture." Science has afforded the essential stimulus in the establishment of new industries. The first attempts at extracting beet sugar were failures; now more than half the sugar production of the world is obtained from this source.

Scientific direction is required to combat insect and fungus pests as well as noxious vegetation.

The geologist and the chemist have classified our soils, and assisted us in determining conditions for effective fertilisation. Probably the greatest service to the man on the land has been afforded by the study of bacterial life in soils. The fixation of atmospheric nitrogen by leguminous crops and the liberation of plant food in soils through bacterial action have explained obscure phenomena of intense interest.

The concern created by the possibility of exhausting our stores of nitrates in Chili has been relieved by the production of fertilising nitrates from the atmosphere at Notodden, in Norway. The nitrate of lime thus produced is found in practice to be quite equal to the fertilising power of commercial Chili saltpetre, and the manufacturing cost of this scientific product is not much more than half.

Science, again, has brought our distant markets into closer touch with us for our perishable products by means of refrigeration. Science has assumed a controlling feature in every operation at the dairy.

The improvement of crops and the breeding of new varieties of plants have been brought within our reach by Burbank, Garton, and Farrer. With the labours of the last-named distinguished scientist we are familiar, and point with satisfaction to the results of his splendid work in increasing the character and yields of wheat, and extending our grain-raising areas. Burbank's labours are world-widely known. Quoting from one of his public utterances, he states, in referring to his creation—the edible thornless cactus:—"The population of the world may be doubled, and yet in the immediate food of the cactus plant itself, and in the food animals that may be raised upon it, there would be enough for all. The possibilities have an enormous scope, whether on fertile lands or on the desert. It enables the desert to be utilised without the necessity for irrigation."

Fortunately, the increasing evidences of helpfulness from applied science are coming home to the sceptical farmer. The majority of men on the land realise the need for systematic training in an avocation which is steadily emerging from one of increasing drudgery to the application of attractive and energetic skill. Real and accurate knowledge appeals to the earnest farmer, as it does to all who assist to consolidate a nation's well-being. Rivals in all countries in cultivation and production have to be met on an equal footing. Practical and profitable production is steadily improving, and depends on systematic training. Accuracy and precision must supplant the old methods of ignorance and doubt. These can only be acquired by technical education and the application of the most modern results in scientific discoveries, combined with manipulative skill. Despite the divergence of the paths which agricultural education has vigorously trodden during the past 25 years, they lead finally to one desirable goal—profitable production.

A widespread knowledge of the general principles governing our agrarian industries is becoming daily more apparent. This must of necessity increase as we are brought into closer commercial relationship with the outside world. An unmistakable and increasing demand has manifested itself during the past ten years for agricultural education. Existent facilities to meet this are insufficient. A wider scope must be given to all educational sources already available, and this will require to be originated and organised. This involves legislative inquiry and increased financial aid.

The subjects of Nature study and elementary mental training in natural sciences are being included in the curricula of our primary systems of education. The aim is being seriously undertaken to develop a child's natural taste, ambitions, and love for rural life. The introduction of the agricultural high school is undergoing all the trials of initiation.

The agricultural colleges already established, with fearless and rare forbearance, have been tactfully steered through a shoal of doubts and unfair criticism to a stage in their growth of unassailable stability and usefulness.

The time, however, has arrived when a revision of the orthodox curriculum must be discussed. Many weak phases that were tolerated in the swaddling clothes stages must be replaced by a training in unison with the outcome of scientific research and advanced pedagogic method.

It may be excusable here to quote the remarks of a prominent English agricultural scientist, Mr. P. McConnell, B.Sc., who recently stated that: "Some 17 years ago the 'Dons' of Cambridge University, when assembled in conclave, laughed at the idea of introducing the teaching of agricultural science into the university curriculum, and the undergraduates' organ ('The Granta') had a derisive article on the occasion, set off with classical quotations. A very great change has come over matters since then, and now at that seat of learning Agriculture is one of the most important departments, and the information given is likely to be of infinitely more value to those who receive it than the cramming up of Latin and Greek for an M.A. 'pass.'"

To provide agricultural education in its various stages from the primary school to the university involves two momentous problems—

1st. To define the exact scope and limitations of the subjects to be taught in these schools.

2nd. To select and train teachers possessing aptitude, enthusiasm, and teaching instincts.

The highly important work of experimentation and research demands men of specific scientific attainments. In this our Australian Universities can offer all the facilities for training.

We have expected too much from the teachers in our agricultural schools and colleges in the past in asking them to conduct experimental work whilst associated with fixed duties in teaching.

Thoroughness and exactness of detail are the mainstays of sound investigations, and teachers cannot devote proper attention to classes of work demanding such diverse characteristics.

Another point that has to be jealously guarded against is the possibility of teachers in primary schools failing to grasp the true mental expansion following on Nature study, and stultifying its real aims in their eagerness to give the teaching an industrial aspect.

In referring to the statistics prepared by Mr. Coghlan, Agent-General for New South Wales, we find that 500,000 square miles of Australian territory are considered well watered, and of the remaining 2,000,000 square miles about one-fourth is practically rainless, and the other three-fourths insufficiently supplied for agricultural purposes.

Mr. Coghlan points out in regard to the acknowledged quality of the soil that aridity and fertility, far from being accidental, are in reality cause and effect, and that analysis of the arid soils have sufficiently established their relationship of dryness and fertility.

About 300,000 square miles of this fertile but arid soil is available for reclamation in Australia. We have only 200,000 acres under the influence of irrigation in Australia. The outlook in this connection is one of profitable expansion. Contrast this small area with those under the influence of irrigation in other countries—India, 33,000,000 acres; the American Republic, 7,600,000 acres; Egypt, 6,000,000 acres; and Spain, 2,800,000 acres.

Mr. Coghlan states, in referring to benefits arising from irrigation—"It is not too much to state that millions of acres in the arid and semi-arid districts in Australia, now given over to pasturage and dependent upon precarious rainfall, will carry a large agricultural population for whom drought will have no terrors."

The Murray tributaries have together an average annual flow of 530,000 million cubic feet. The flow of the Murray itself before it is joined by its tributaries is 127,000 million cubic feet. Thus the total of the Murray basin waters is 657,000 million cubic feet.

The boldest scheme so far projected and commenced for water conservation and irrigation is the Barren Jack Reservoir, which will throw back the Murrumbidgee waters for 40 miles, the Yass River 25 miles, and the Goodradigbee for 15 miles. It will submerge 12,470 acres, and hold in reserve 33,380 million cubic feet of water. In storage capacity it will almost equal the Assouan Dam, in Egypt, and cost about £1,500,000 sterling. The complete scheme will make provision to irrigate 100,000 acres to the extent of 24 in. to 30 in. per year for the purpose of intense cultivation, and to provide enough water for stock and domestic use on 2,000,000 acres of purely pastoral land, and render it independent of the average rainfall. The system later on will include an additional area on the southern aspect of 150,000 acres for cultivation, and another 1,000,000 acres of grazing land. It is estimated that a population of at least 60,000 will be permanently settled on the area watered from the Barren Jack scheme.

There are five other projects, either in construction or definitely proposed, the success of which is regarded as quite assured. The six schemes will provide profitable land for over 300,000 people. The total cost is approximately estimated at £7,100,000. These by no means exhaust the possibilities of the economic extension of water conservation in Australia. It is not possible to fully estimate the increase in the values of irrigable lands, but estimates provided by countries already irrigated show at least three and four times the increase, always providing an intelligent, earnest, industrious, and trained class of people are encouraged to settle on it.

The research work of Mendel has indicated to the breeder to treat the animal or plant as an assemblage of distinct characters or units inherited on certain definite principles. As a result of cross-breeding, these characters may be obtained in fresh combinations, hence we have the basis of new breeds, or varieties. We are in the midst of a ceaseless flood-tide of Mendelian investigations which produce new facts of intense interest and economic importance. We are beginning to realise that the results of mating to an unexpected extent is under man's control, and, apart from its highly scientific features, the application of the recently disclosed arrangement of laws are likely to be used for man's benefit. Wiesmann asserts with assured confidence that—"The principle of selection does rule over all the categories of vital units." The complaint that there is no definite aim in breeding is not likely to prevail long.

In the large interests involved in rearing and feeding domestic stock in Australia, we have in the past overlooked the paramount importance of improving our native grasses and herbage. Much has been accomplished in raising the yields and character of our wheats, mainly through the untiring zeal and genius of Farrer. An unlimited field for usefulness lies ahead of us in the study of the life history and qualifications of our native grasses and their improvement. The hybridisation of native grasses so far has not been seriously attempted, and in this regard our Governments would confer a benefit of unknown extent by establishing farms for this purpose under competent scientific direction.

The rapid advance made in motor cultivation and motor harvesting operations brings within the range of practical operation the adoption of motor machinery in our agricultural areas. The objective is to make a perfect seed bed in one operation, and once this is accomplished the days of the plough are numbered.

In the dairy we are past the stage of looking askance at the milking machine. It has not only satisfied critical inquiries in its daily work, but is affording a wide field for further improvement and facile application.

A glance at the records now provided in allocating points of quality in butter made for export, points to the possibility of rendering further scientific aid to an industry which has sprung into existence with phenomenal activity. When we pass from the trade established in butter to the possibility of increasing our exports in cheese, we realise that quality again is the predominant factor in combination with the skill of the manufacturer. We necessarily must become exacting to satisfy a critical market.

Quite recently we have introduced E. B. Hart's (Wisconsin) simple test to rapidly estimate casein in milk at the Hawkesbury College Laboratory. We have found the results remarkably accurate in contrast with those effected by chemical analysis. It promises to be as useful an adjunct to the cheese laboratory as the Babcock tester has been in the butter factory.

The suggestions to assist those engaged in agriculture and stock-raising can be continued to a greater extent. I have indicated sufficient to show that there exists an almost limitless scope by applied science to stimulate and protect our agrarian industries.

All these facts point to the necessity for the organisation of our Departments of Agriculture and for the fostering influence of Legislatures by means of financial aid. The outlook for agriculture in Australia affords ample evidence for abiding confidence and lasting prosperity.

PAPERS READ IN SECTION GII

1.—MILK STANDARDS.

By M. A. O'CALLAGHAN, Government Dairy Expert, N.S.W.

Almost all writers and speakers of recent date have attacked the milk question from the consumer's point of view only; and statements have been made which have done more to retard than to encourage progress. It goes without saying that any judgment given which is not equitable, or any opinions expressed which have not got solid fact for their bases, must bring about that dissatisfaction which causes a reaction rather than a progressive movement. Accuse an innocent man of any charge, and repeat the accusation sufficiently often, and in time you will find a sour, disheartened person. Now, if our dairy farmers are even occasionally accused of sins which they do not commit, it goes without saying that we shall, instead of getting their best efforts towards improvement, only bring about a disbelief in the teachings and work of scientific men. For this reason it becomes absolutely necessary, if we are to make any progress towards improving the quality of our milk, to understand the position thoroughly ourselves as teachers; and then we may be able to demonstrate error, and convince the farmer of the necessity for better things.

THE PRESENT POSITION.

Let us review the position somewhat:—

The consumer or his agent purchases from the farmer cow's milk. Well, what is cow's milk? We might define it as the whole of the fluid secreted by the healthy mammary glands of the cow.

If the farmer supplies us with this in an unadulterated condition, we can have no quarrel with him, unless there is something more definite in the way of standards mentioned in the contract. If the farmer then sells his milk as drawn from the cow, and an analyst presents him with a certificate that such milk contains a certain percentage of added water, the farmer, now knowing the basis from which the analyst drew his conclusions, simply believes that the chemist does not know his business, and this belief makes it more difficult to get such a farmer to follow in any way the teachings of science.

Thus it is that in this stage of the dairying industry in Australia it is rather important that if milk standards are to be fixed, they shall not only be equitable, but shall be workable ones, and the standards on which the analyst bases his conclusions should be clearly shown on every certificate of analysis. The farmer (and frequently the presiding magistrate) does not know that the analyst does not absolutely find water in the milk apart from that yielded by the cow; and does not dream for a moment that the analyst assumes that normal milk contains a certain percentage of solids not fat, and that if the milk in question does not reach that standard the analyst concludes that water has been added. In many cases, instead of stating that the milk contains added water, the correct and educational thing to do would be to inform the farmer or milk seller that his milk is below the standard in a certain way, and point out on said certificate the probable cause of the deficiency. This is a young country, and dairying is practically a young industry here, and we must not assume that farmers and members of the general community know all about milk analytical standards and methods.

Milk Composition.

Hitherto we have been accustomed to accept, I am afraid, the old theory handed down by workers (in countries where the seasons are regular and where droughts are unknown) that the fat is, practically speaking, the only constituent of milk which varies to any extent, especially in a herd of more than two or three cattle; whereas I have reason to believe that investigation will show the solids other than fat are materially affected by continued droughts, such as experienced repeatedly in different parts of Australia. I am driven to this belief by actual results obtained from milk produced in New South Wales, and I am supported in this opinion by observations in the United States, made during a drought—or what they consider over there a drought.

About 10 years ago I made rather an exhaustive inquiry into the milk produced in New South Wales from one point of view—namely, its fat contents, and arrived at the conclusion that in New South Wales milk was up to, if not above, the average milk produced in other countries from this point of view. The actual figures worked out at 3·88 per cent. This represented the mixed milk of many thousands of cows as supplied to butter factories in New South Wales about 10 years ago. At that time I had no reason to believe our milks were not equally representative in solids not fat. In latter years, however, we have been experiencing rather persistent droughts throughout the area which generally supplies Sydney with milk for human consumption as milk; and a number of complaints have been made regarding the milk supplied by farmers who appeared from all ordinary standpoints to be above suspicion. One of these complaints was sent to a well-known farmer, of some means, in the county of Cumberland, and, as a consequence, he brought various samples of his milk to my laboratory for analysis. These proved to be so low in solids not fat, while above the ordinary standard for fat, that I decided to make further investigations, and accordingly visited the farm myself, when I found the cows to be crossbred, with a good deal of the Jersey strain through the greater number. The drought conditions were severe, and no green food had been available for months, but the animals were being hand-fed on chaff and bran, and appeared in very fair condition. Samples were taken, and, to make assurance doubly sure, I sent my chief field assistant to the dairy to take samples there himself, and see that all milk was thoroughly mixed before sampling. The results given below on the 4th and 5th September, 1906, show that even with those cases when special samples were taken the solids not fat of the milk were extremely low. In one case, that of the night's milk, solids not fat fell below 8 per cent., whereas the fat reached 4·90 per cent. Observations were continued, with varying results, right up to the end of the year 1906, as is seen in the table given below:—

MILK SAMPLES FROM COUNTY OF CUMBERLAND FARMER, NEW SOUTH WALES, ABOVE REFERRED TO.

Date.	Total Solids.	Solids Not Fat.	Fat.	Remarks.
20/7/06	13·40	8·40	5·00	Morning's milk, 16 cows, ·74 % ash.
18/8/06	11·38	8·18	3·20	
4/9/06	12·82	7·92	4·90	From milk of 55 cows. Night's milk. Sample taken by Mr. Pedersen.
5/9/06	12·02	8·27	3·75	From 8-gallon can. Morning's milk. Sample taken by Mr. Pedersen.
5/9/06	11·70	8·30	3·40	From 10 gallon can. Morning's milk. Sample taken by Mr. Pedersen.
17/10/06	12·42	8·42	4·0	Night's milk.
17/10/06	12·27	9·27	3·0	Morning's milk.
16/11/06	12·22	9·00	3·20	
16/12/06	12·36	8·16	4·20	Night's milk.
18/12/06	11·14	7·84	3·30	Morning's milk.

APPEAL TO THE COW.

When it is considered that these figures were obtained from a herd of at least fifty cows, one has to do some thinking before recommending that the solids not fat should reach 8·5 as a minimum in any legal standards that are adopted. In fact, whatever standard is adopted in any State, in my opinion it should carry with it an appeal to the cow on similar lines to the system now adopted in England.

Following the matter up, I have caused frequent observations to be made of the milk supplied by the different breeds of cattle at the State Stud Farm, near Berry, where animals of all breeds are stationed, the cattle being all the progeny of imported stock on both sides.

In the district of Berry we have had for two years now what we might term a summer drought. Rains have been heavy during the winter on each occasion, but no spring rains fell either in 1907 or 1908 on that part of the South coast, the result being that cattle have had rather a trying time; but their condition, of course, has been kept up by the aid of hand-feeding. Green feed has, however, been scarce, and the general conditions might be described during the entire summer of 1907, and the present summer so far, as abnormal.

The following figures represented the milk of the different breeds stationed at Berry last winter—namely, in July, 1908:—

	Morning's Milk.		Evening's Milk.	
	Fat.	Solids not Fat.	Fat.	Solids not Fat.
Jerseys (6)	4·70	8·96	5·16	8·83
Holsteins (8)	2·90	8·44	3·95	8·19
Guernseys (6)	3·77	8·81	4·87	8·49
Ayrshire (1 cow) ...	2·86	8·39	3·81	8·31
Shorthorn (1 cow) ...	3·45	8·13	4·00	7·84

With reference to these figures, it might be stated that, in addition to analysing the mixed milk of each breed (morning and evening), individual samples were taken from each cow and analysed, and the results, when calculated out, agree as near as possible with the actual results of the mixed milk; so that not alone is the correctness of the analytical work substantiated but the representative character of the samples also.

Looking through the breeds it was found that of the Jerseys none absolutely fell below 8·5; but two cows in the evening's milk fell as low as 8·5 solids not fat. Amongst the Holsteins, in the morning's milk, 5 out of 8 fell below the 8·5 standard, while in the evening's milk 5 also fell below 8·5 in solids not fat. Amongst the Guernseys 2 cows fell below 8·5 in solids not fat, evening's milk, notwithstanding the fact that in each of those cases the fat percentage was above 5.

During the months of June and July last, when there was fair grass, I caused samples of milk to be taken by my field officers from representative herds in several districts in New South Wales, the results of which are shown in the following table:—

Sample.	Date.	Number of Cows.	Morning.			Evening.		
			T. S.	Fat.	S. N. F.	T. S.	Fat.	S. N. F.
Bowral District ...	10-6-08	36	12·81	3·95	8·86	13·42	4·55	8·87
Denman ,, ...	23-6-08	31	13·84	4·37	9·57	14·64	5·47	9·17
,, ,, ...	25-6-08	13	13·00	3·95	9·05	13·54	4·80	8·74
,, ,, ...	28-6-08	40	13·33	4·05	9·27	14·47	5·30	9·17
Coraki ,, ...	2-7	42	11·60	3·70	7·90	12·22	4·20	8·02
Singleton ,, ...	11-7-08	50	12·66	4·10	8·56	13·50	4·90	8·60
,, ,, ...	11-7-08	72	12·54	3·80	8·74	13·20	4·57	8·63
Alstonville ,, ...	25-6-08	35	12·78	3·82	8·96	13·39	4·80	8·59

T. S. means "Total Solids."

S. N. F. means "Solids not Fat."

Looking at these figures, which are representative of some of the best herds of cattle, it is seen that in the morning's milk in only one case did the mixed milk of the herd fall below 8·5, and the cows in this herd were to a great extent half-bred Holsteins. The same herd was at fault in the evening's milking; but it is seen that three others were only slightly above the 8·5 standard, and when we consider those figures it will be also well to bear in mind that the dairy farmers represented were all butter-makers, and it will be only natural to expect that they would keep a class of cows especially adapted for the production of good butter yields, whereas the dairy farmer, who devotes his special attention to the sale of milk for town supply, selects the animal which gives a large quantity of milk as a matter of the first importance.

Later figures obtained from the cattle depastured at Berry State Stud Farm are, however, of still greater interest. They are as follows:—

SAMPLES OF MILK OBTAINED AT BERRY STUD FARM ON 7TH JANUARY, 1909, AFTER A DROUGHT OF ABOUT FOUR MONTHS.

[Analyses by Messrs. Ramsay (Chief Assistant Chemist, Department of Agriculture, N.S.W.), and M. A. O'Callaghan].

Breed and Sample Number.	Total Solids.	Fat.	Solids not Fat.	Ash.	Number of Cows.
Guernseys—					
1. Morning ...	13·52	4·45	9·07	·76	Two.
2. Evening ...	13·77	5·05	8·72	·70	
Jerseys—					
3. Morning ...	14·18	4·75	9·43	·61	Seven.
4. Evening ...	14·26	5·55	8·71	·68	
Holsteins—					
5. Morning ...	11·86	3·27	8·59	·71	Five.
6. Evening ...	11·97	3·72	8·25	·68	
Ayrshires—					
7. Morning ...	11·31	3·15	8·16	·66	Four.
8. Evening ...	11·42	3·18	8·24	·59	
Shorthorns—					
9. Morning ...	11·44	2·80	8·64	·68	Four.
10. Evening ...	11·40	3·27	8·13	·66	

The figures given in this last table are valuable because the district in which these cattle are stationed has gone through a severe summer drought, and there is no such thing as green grass at present available. It will be seen that only the Guernseys and Jerseys yielded milk which would come up to the standards in solids not fat. All the other cows supplied yielded "*adulterated*" milk, whereas only in one case, that of the four Shorthorn cows, did the milk fall below the *fat standard* of 3 per cent. All the figures given draw attention to one point—namely, that the evening's milk, though richer in fat, is as a rule lower in solids not fat than yielded by the same cows in the morning. The animal yields a certain amount of solid matter in the morning, and gives a higher proportion of solids not fat than she does in the evening. The ash figures are remarkable. They are so low that, taking them with the low solids not fat, an analyst would be justified in certifying that water had been added.

Before concluding, I should like to quote a short paragraph from Leffmann and Beam's work on Food Analysis:—

"The average of nearly 100 determinations at the University of Wisconsin Creamery *during a protracted drought* in 1895 gave but a trifle over 8·5 per cent. solids not fat. The casein was low in this milk, while the sugar was about normal in amount. Similar conditions have been observed by Van Slyke at the New York Station."

I wish it to be distinctly understood that I do not advocate a low standard for milk. If there is to be an Australian standard, it should not be lower than—fat 3 per cent., solids not fat 8·5 per cent.; but any standard fixed must be subject to a higher court of appeal, and that court should undoubtedly be the farmer's dairy herd. This appeal should be made within three or four days from the date on which the samples were taken. The farmer or his agent should be the person to demand the appeal. He will not appeal if he has adulterated his milk, knowing only too well that the cow would then confirm the analyst's opinion. Large milk-selling companies should analyse representative samples from the milk vats before offering it for sale to the public, and they should obtain a warranty from their supplying farmers that the milk supplied was *pure.* The consumers, the milk companies, and the milk producers would then (with an appeal to the cow clause) be protected.

2.—TUMOURS IN DOMESTICATED ANIMALS.

By J. DESMOND, R.V.S., G.M.V.C., F.R.M.S., Government Veterinary Surgeon, Adelaide, South Australia.

The following is a description of some of the tumours that have been forwarded for laboratory investigation:—

Specimens from Chief Inspector of Stock, received 9th October, 1901, Laboratory No. S.A. 92. These specimens were hard cystic tumours of the skin, taken from the junction of the throat and neck of some fat cattle that were seized at the city sale-yards. The cattle were in prime condition. They were bred in the North, and for a short time previous to being submitted for sale were pastured in the South-east.

The tumours were spheroid in shape, about the size of a breakfast cup, sessile, and appeared to grow outwards from the skin. The outer surface was hard and horny, and so tough that a surgical saw had to be used to bisect the specimen. (*See* Fig. No. 1.)

In the centre of these tumours small irregular cavities were found, which were lined with a thin layer of creamy pus. (*See* Fig. 2, Photo. No. 1.)

In one case only did a lesion extend deep down under the normal tissue. This was in the largest tumour, where a small cavity containing pus was found in the tissues under the skin. (*See* Fig. 2, Drawing No. 2.)

The pus from these tumours was examined with the microscope for Koch's bacillus of tuberculosis, but with negative results. Guinea pigs were inoculated, and when killed 2 months afterwards were found to be free from any disease or ill-effects of the inoculation. Bacteriological cultures were made, and a streptococcus was found.

These specimens must be classed as cutaneous horns, and in the description of the following horny growths I shall adhere to the classification given by Mr. J. Bland Sutton, F.R.C.S., in his work, "Tumours, Innocent and Malignant." Horns growing from the skin of animals are of four varieties, viz.:

1. *Sebaceous Horns*, the subject of our present study, in which a cyst is found at their base. (*See* Fig. 2, Photo. No. 1.) Sections from the base of these specimens were prepared for microscopic examination, and the following layers were found. (*See* Fig. 2, Drawing No. 2.)

2. *Wart Horns.* (*See* Figs. 3 and 4.) This specimen is from the cheek, near the angle of the mouth, of an aged cow, and has been

Fig. 1.—Sebaceous Horn.
Taken after the specimen was cut through the centre.

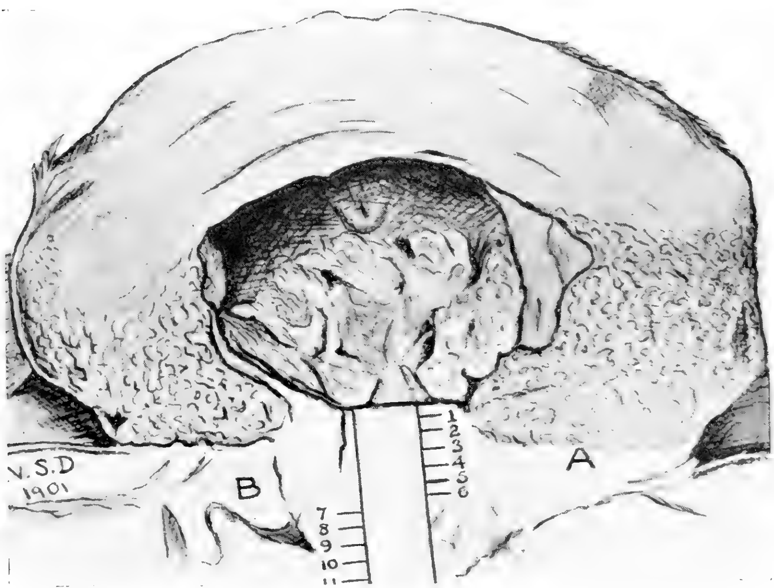


FIG. 2.—SEBACEOUS HORN.

Photo No. 1.
Drawing No. 2. A, small abscess under the skin; B, small gland; 1, pus cells and mast cells, as found in chronic inflammation; 2, dense fibrous tissue; 3, layer of loose fibrous tissue; 4, dense fibrous tissue; 5, layer of loose fibrous tissue; 6, fat; 7, fibrous tissue; 8, fat; 9, dense fibrous tissue; 10, loose fibrous tissue; 11, developing blood vessels.

Fig. 3.—Wart Horn.

Fig. 3 shows the appearance it presented on the animal, including the upper part where it was attached to the skin. On the upper third, two hard, horny outgrowths of a flaky nature are to be seen.

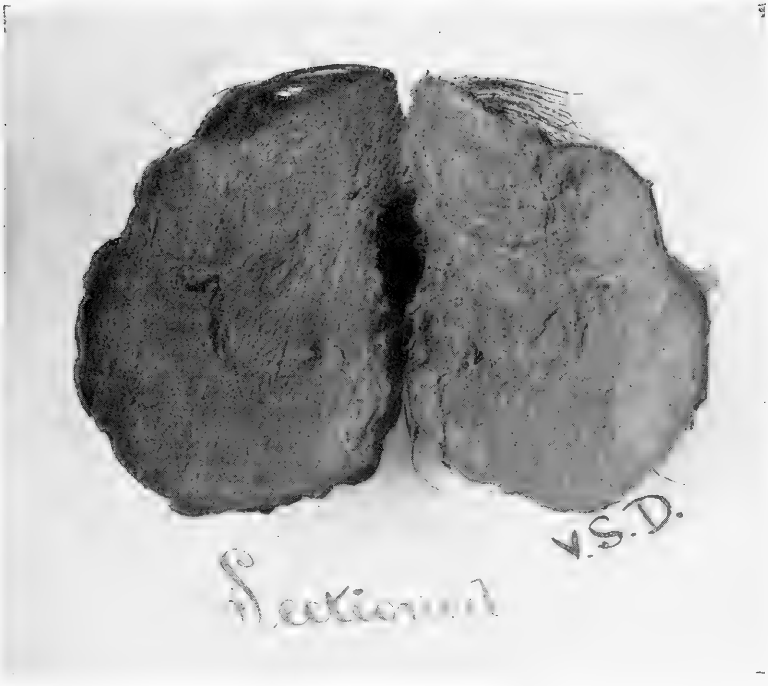


Fig. 4.—Wart Horn.

Fig. 4 is a photo. of the inner surfaces of the sectioned tumour, and demonstrates its variety, *i.e.*, the absence of a cyst at the base.

Fig. 5.—Hoof Horns.
Beginning above :—Left hindfoot ; right hindfoot.

Fig. 6.—Cicatrical Horn.
Horny growth of "Brand Scar."

Fig. 7.—Cicatrical Horn, or "Brand Cancer."
An Epithelioma.

in my collection of specimens for 13 years. These tumours are not uncommon on the skin of bovines. They are very vascular, and are commonly known as "blood warts."

3. *Hoof Horns,* from an overgrowth of the hoofs of ovine and bovine animals. These conditions are common in sheep, while they are uncommon in cattle. I have secured specimens of this abnormal condition, with the following history: An aged cow in this State, well bred, fat, and a deep milker, in which all the hoofs were affected, and of great length. (*See* Fig. 5.)

This animal did not use the sole or toe of the front feet in walking or standing; all the weight was on the heels, while the toes were turned upwards. This animal could only be moved with great difficulty, and was in great pain on account of those delicate structures, the laminæ in the hoofs, being diseased. Since the animal was otherwise healthy, I advised that she should be slaughtered.

The legs were secured for examination, and the following is their description:—

Near fore leg: Hoof, 8 in. long; the upper portion, outer view, had a deep irregular cleft, which was discharging pus. The hoof was removed, and the lamina was prepared for microscopic examination, and found to be affected with suppurating laminitis.

Off fore leg: Hoof, 8½ in. long, and in much the same condition as tho near fore foot.

Near hind foot: 6 in. long. The wall was not ruptured, still the irregularity of the hoofs denoted that great structural changes had taken place in the deep structures.

Off hind hoof: This measured 8 in., and the appearance was identical with those in the other hind foot.

4. *Cicatrical Horns,* the seat of brand scar, the result of branding the skin of cattle too deeply. In Mr. J. Bland Sutton's work, above mentioned, he says: "Horns growing in the cicatrices of burns are very rare. In Australia, where fire-branding of cattle is the rule, it is not uncommon to find horns growing in cicatrices caused by the hot branding iron.

The following is a description of a typical case:—

An aged cow was found with a fungating mass (*see* Fig. No. 7) on the left rump, the seat of a deep brand. The mass was vascular, and gave off a vile stench. These growths are known locally as "brand cancer." After careful examination, the os sacrum was found to be involved, and slaughter was advised. A *post-mortem* examination was made, and the following noted:—Os sacrum involved. (*See* Fig. 9.) Liver contained an abnormal growth, which, when examined microscopically, was found to be an angioma, while the fungating mass was found to be an epithelioma. (*See* Fig. 8.) These lesions are prone to the development of epithelial cancer, of which we have reported on many specimens during this year.

Endotheliomata.—This specimen was the enlarged left testicle, and a large nodular tumour from the pelvis of an aged stallion, the whole weighing about 30 lb. (*See* Fig. 10).

The testicle measured 5 by 10 in., and weighed 5 lb. It was nodular, and, when cut into, was found to contain a cavity, the contents of which were breaking down.

The nodular growth in the pelvis was very irregular in shape, and it involved the genito-urinary organs. This part of the specimen was found to be secondary to the disease of the testicle.

The following is a naked-eye description of the specimens:—The testicle was very nodular, and about three times the normal weight; the tunics were adherent, and enormously thickened; the blood vessels were much distended, and in the posterior extremity a cavity was found, 2 in. in diameter, with very irregular walls, containing a quantity of dark, semi-fluid, broken-down tissue. The growth from the pelvis was firm in consistency, and very nodular, the nodules varying in size from a marble to two clinched fists. When these nodules were cut into they were found to consist of a dense capsule, surrounding a firm and glistening structure, which contained paths of what appeared to the naked eye as connective tissue.

Sections were prepared for miscroscopical examination, and the following found:—Small sarcoma-like cells; epithelioid cells, resembling cells found in myeloid sarcoma; sarcomatous cells, forming the bulk of the tumour at this part; fibro-cellular trabeculæ, with round-celled infiltration.

An artery cut longitudinally showed proliferation of its endothelium, and epithelioid and sarcomatous cells in a space in the muscular coat of the wall of the artery; and sarcomatous cells occupying lymph spaces in the false capsule of the tumour.

Lymph spaces lined with endothelial cells were found in many parts of the capsule, and this gave the key to its pathological position among tumours—endotheliomata.

This is the first time this class of tumours has been found in animals. Dr. J. M. Carter, V.M.D., says, in his able article on tumours, in the "Veterinary Archives," Vol. XXII., 1901, page 700: "Endothelioma, a tumour of purely endothelial origin, is found only on serous membrane. It closely resembles cancer. Has never been seen in domesticated animals."

3.—SMUT EXPERIMENTS IN VICTORIA DURING 1908.

By D. McALPINE, Geol. Vegetable Pathologist of Victoria.

Although there are over 60 species of smuts *(Ustilagineæ)* recorded for Australia, there are only a comparative few which attack our cereal crops, and these have necessarily received the most attention on account of their economic importance.

Among these the parasitic smuts occuring on wheat have been principally attended to, and I propose dealing with two of the most important—viz.: Stinking Smut or Bunt and Flag Smut.

The experiments in connection with stinking smut are chiefly concerned with the supposed discovery of a resistant wheat, and the means whereby an immune variety is likely to be secured. In the case of flag smut, the experiments refer to its mode of germination and infection, with a view to its ultimate prevention.

Fig. 8.—Photomicrograph of Cicatrical Horn.

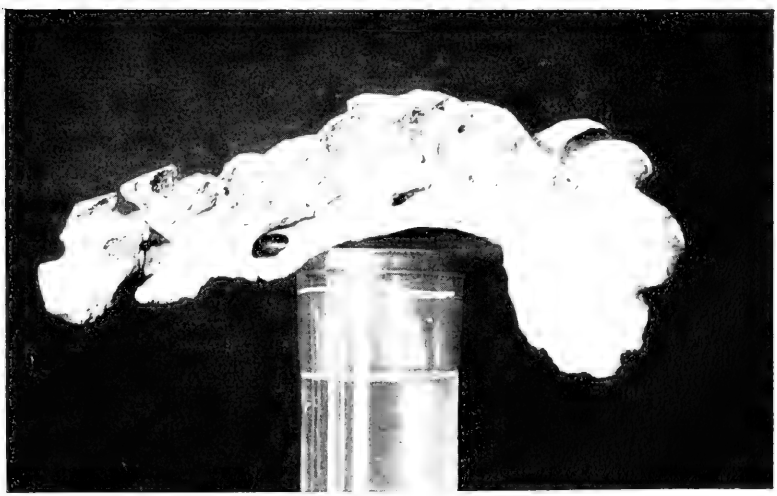


Fig. 9.—Os Sacrum.

Note involvement of this bone in connection with Figs. 7 and 8.

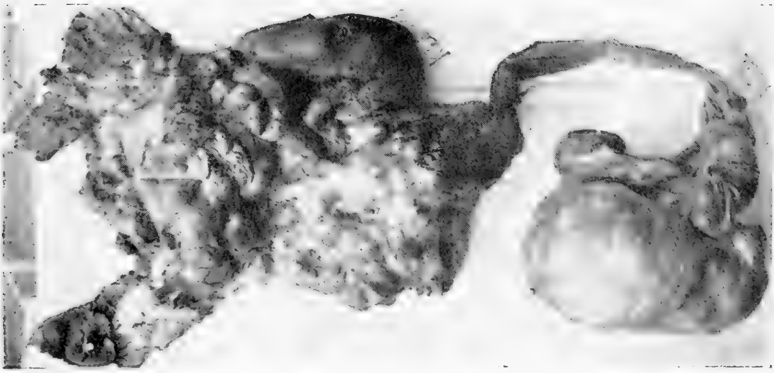


Fig. 10.—Enlarged Testicle and Pelvic Tumour.
1. Testicle. 2. Kidney. 3. Nodular Tumour.

Fig. 11.—Section of Testicle (Fig. No. 10).

I.—Stinking Smut or Bunt.

(Tilletia tritici (Bjerk) Winl.; and T. levis, Kuehn.)

This smut is known wherever wheat is cultivated, and has been recognised from the earliest times on account of the disagreeable odour emitted by it. This is due to Trimethylamin, a decomposition product of the nitrogenous constituents of the parasite. There are two species of smuts responsible for this disease, the one with smooth and the other with netted spores, but as both sometimes occur in the same ear of wheat, and generally agree in their life history, they will be treated here as practically the same.

It is well known that this disease is caused by the smut spores adhering to the grain, infecting the young seedling, and thereby enabling the mycelium of the fungus to grow inside the plant until it has reached the seed-bearing stage, and then producing its spores.

The practice of using a "steep" for the seed, such as sulphate of copper or formalin, is also a well-known preventive of the disease, since they either destroy the spores or prevent their germination. Seeing that the disease can be controlled, it is not regarded by the intelligent farmer as of serious import; but there is a growing feeling among plant pathologists that all parasitic diseases, such as smuts, should be combated, not merely by destroying the parasite, but by rendering the host plant immune or resistant. Accordingly, the late Mr. Farrer carried out the idea of producing a bunt-resistant wheat plant, and it was reserved for his successor, Mr. Sutton, of the Cowra Experiment Farm, New South Wales, to announce in the "Agricultural Gazette" for March, 1908:—"Florence and Genoa have in our trial plots shown themselves under severe trial to be practically smut-proof, and in consequence seed of them does not require to be bluestoned or treated with any other fungicide for the prevention of smut." It is not necessary here to enter into any explanation of the parentage of Florence and Genoa, which were selections from Mr. Farrer's crosses, nor of how this supposed bunt-resistance was brought about, but merely to give the results of experiments designed to test how far this immunity was hereditary and maintained under different conditions of soil and climate, heat and moisture. Mr. Sutton willingly supplied material for the purpose, and I was able to inoculate a sufficient quantity of grain to have it sown at Dookie Agricultural College, under the superintendence of the principal, Mr. Pye, at Longerenong Agricultural College, under the charge of Mr. Pridham, and at Burnley Horticultural Gardens under my own personal supervision.

Bulk samples of both varieties were dusted equally with spores of *Tilletia foetens*, derived from a common source, and it is important to note that the experiments were all on an equal footing, as far as the amount and vitality of the bunt spores are concerned.

The seed was mixed with bunt spores as follows:—Bunt-balls were taken direct from the wheat plant, and then broken up by rolling them in paper. The spores were next well dusted over the moistened grains by thoroughly rubbing them up together, so that every grain looked as if it had been dressed with soot. The grain was sent out immediately afterwards for sowing.

At Dookie the sowing took place in June, and the seed-bed was a moist one. The rainfall for April was ·23 in.; for May, 1·99 in.; and for June, 4·36 in. The bunted grain sown in a moist seed-bed was particularly liable to infection.

At Longerenong the seed was sown on 1st June, and the seed-bed was firm, moist, and in good condition. The rainfall for April was ·9 in.; for May, 3·22 in.; and for June, 2·55 in. The mean temperatures for May and June were 50 deg. Fahr. and 45 deg. Fahr. respectively.

At Burnley the plots were sown on 16th June in rather a loose seed-bed, the soil being a sandy loam. The rainfall for April was ·33 in.; for May, ·87 in.; and for June, 3·94 in. The mean temperatures for May and June were 54 deg. Fahr. and 50 deg. Fahr. respectively.

Since the weather conditions exercise an important influence on the germination of the spores, it may be noted generally for the first quarter of the year that the rainfall was scarcely 50 per cent. of the average amount, and this was followed by one of the driest April months ever known. The breaking-up of the drought occurred in May, and the rains in June were above the average, so that altogether the conditions were favourable for the germination of the spores and the seed wheat at the same time. The results of the experiments have been carefully tabulated, and while they show that Florence may have as much as 12 per cent. of stinking smut, and Genoa 22 per cent., yet on the whole they were remarkably resistant. In one plot Genoa was absolutely free, and in others both varieties had only 1 per cent.

TABLE.—RELATIVE SUSCEPTIBILITY TO STINKING SMUT OF FLORENCE AND GENOA.

Plot.	Variety.	Inoculation of Seed with.	Smutty.	Free.	Total.	Per cent. Smutty.
		I.—BURNLEY.				
5	Florence ...	*T. tritici*	2	82	84	2·38
6	Genoa ...	Ditto	7	71	78	9·
8	Florence ...	*T. levis*	10	69	79	12·65
9	Genoa ...	Ditto	5	78	83	6·02
12	Florence ...	Ditto	7	79	86	8·14
13	Genoa ...	Ditto	0	75	75	
14	Florence ...	*T. tritici*	5	79	84	5·95
15	Genoa ...	Ditto	17	58	75	22·66
16	Florence ...	*T. levis*	41	818	859	4·77
17	Genoa ...	Ditto	41	774	815	5·03
	Florence ...	General average ...	65	1,127	1,192	5·45
	Genoa ...	Ditto	70	1,056	1,126	6·21
	Florence ...	*T. levis*, general average	58	966	1,024	5·66
	Genoa ...	Ditto ...	46	927	973	4·72

TABLE.—RELATIVE SUSCEPTIBILITY TO STINKING SMUT OF FLORENCE AND GENOA—*continued.*

Plot.	Variety.	Inoculation of Seed with.	Smutty.	Free.	Total.	Per cent. Smutty.
		II.—DOOKIE.				
1	Florence ...	*T. levis*	1	85	85	1·17
9	Genoa ...	Ditto	1	74	75	1·3
2	Florence ...	Ditto Re-smutted	8	85	93	8·6
10	Genoa ...	Ditto ditto	5	76	81	6·17
3	Florence ...	Ditto	3	77	80	3·75
11	Genoa ...	Ditto	2	72	74	2·70
4	Florence ...	Ditto Re-smutted	3	83	86	3·48
12	Genoa ...	Ditto ditto	5	73	78	6·41
5	Florence ...	Ditto ditto	4	79	83	4·82
13	Genoa ...	Ditto ditto	14	72	86	16·28
	Florence ...	General average ...	19	408	427	4·45
	Genoa ...	Ditto ...	27	367	394	6·85
	Florence ...	*T. levis*, general average	4	161	165	2·42
	Genoa ...	Ditto ditto	3	146	149	2·
	Florence ...	*T. levis*, Re-smutted, general average	15	247	262	5·72
	Genoa ...	*T levis*, Re-smutted, general average	24	221	245	9·79
		III.—LONGERENONG.				
1	Florence ...	*T. levis*	45	443	488	9·22
2	Genoa ...	Ditto	95	560	655	14·50
3	Florence ...	Ditto	7	70	77	9·99
4	Genoa ...	Ditto	10	54	64	15·62
	Florence ...	General average ...	52	513	565	9·20
	Genoa ...	Ditto ...	105	614	719	14·60

I. *Burnley.*—There were seven plots of each variety sown; in two of them the ordinary seed was used as a check, while in the others the seed was thoroughly dusted with bunt spores. Both *T. tritici* and *T. foetens* were used for infection, but no conclusions as to their relative virulence could be drawn from the results of a single season's experiments.

The general average for the whole of the plots was over 5 per cent. for Florence and over 6 per cent. for Genoa. If the comparison is strictly confined to the plots on which *T. foetens* was used, as at Dookie and Longerenong, then Florence had 5·66 per cent., and Genoa 4·72 per cent., of stinking smut. In all cases the ordinary seed was sown as a check, and the plots were invariably free from bunt.

II. *Dookie.*—There were also five plots of each variety sown here to test their susceptibility to bunt, and only *T. foetens* was used. In order to make the test as severe as possible, some of the grain already dusted with spores was resmutted in the following manner:—One hundred smut balls were powdered and then made into a soft paste by the addition of water, 100 grains were placed in this paste, thus allowing one smut ball on an average for each grain, mixed thoroughly, and allowed to soak over night. By next morning the moisture had disappeared, and the seed was sown the same day. Infection in the resmutted grain was the most virulent, for, while it yielded 5·72 and 9·79 per cent. of bunt respectively in Florence and Genoa, there was only 2·42 and 2· per cent. respectively with the ordinary dusting of the grain. The general average for Florence was 4·45 per cent., and for Genoa 6·85 per cent. The higher average for Genoa was largely owing to one plot in which the percentage was over 16, while in a plot alongside it was only a little over 6. This difference was so striking that these two adjoining plots were again carefully examined, with the same result. There was no evident cause for the unequal infection.

III. *Longerenong.*—There were only two plots of each sown, a large and a small one, together with the check plots, and the dusting of the seed was entirely with the spores of *T. foetens*. The general average was much higher here than in the other two localities, being 9·20 per cent. for Florence and 14·60 per cent. for Genoa.

It is clear from these experiments that Florence and Genoa do not possess the hereditary quality of bunt-resistance, and Sutton evidently suspected this, as he wrote to me as follows in May, 1908:—"I have been referring to the results of our trials with these wheats, while they were being fixed, and I find that in 1905 they were at Lambrigg fairly bunty, and this may indicate that they are not constitutionally resistant to bunt, but that they escape bunt through some peculiar characteristic of their growth immediately after germination." I have found by experiment that they are relatively rapid in their germination, and this may account for their escaping the bunt to a large extent. But, in order to secure complete immunity and the hereditary quality of resistance, it will be necessary to breed from a variety which has shown itself to be free, such as Medeah, when exposed to the most severe infection for a series of seasons.

Experiments at Dookie Agricultural College.

Mr. Pye, Principal of Dookie Agricultural College, had been working for some years in conjunction with Mr. Farrer in endeavouring to produce bunt-resisting wheats by selection after seed-infection. He is still continuing this work, and the most promising line lies in breeding from crosses of the Durum variety that resist the bunt. He found, for instance, that Medeah is not so liable to bunt as many others, and he is using this variety as a parent. The seed of the progeny is then dusted with bunt spores, and the seed from those plants which escape infection is sown next season, and so on until a strain is secured which will be bunt-resisting.

Not only have these experiments been carried on for a number of years, but they have been conducted on a most comprehensive scale, as during the past season there were over 200 plots devoted to smuts alone. I have carefully examined them, and find that it is necessary to determine the bunted plants when the growth is completed and all the ears are more or less mature. This is owing to the fact that in many cases the secondary ears or later growths may develop disease, while the more advanced ears of the same plants are free.

Among the numerous varieties grown there were several which promised to be more or less bunt-resisting, and these were used as parents for further crosses, but the only one found to be absolutely free this season, after the most thorough infection of the seed, was Medeah. Various selections and unfixed crosses are also being tested, and, naturally, those containing Medeah blood receive special attention.

Out of numerous selections from various crosses, only two were found to be clean after infection, apart from those containing Medeah, and of those with an admixture of Medeah blood, there were also two. The crosses, together with the number of selections found to be bunt-resisting this season are as follow:—

Egyptian × Tardent's Blue / Blue Heron	— 4 Selections.
Tripoli .. .. / Tardent's Blue	— 1 ,,
Bobs × Medeah ... / Tripoli	— 7 ,,
Bobs ... . / Medeah	— 6 ,,

These will be tested in a similar fashion to Florence and Genoa during the coming season.

The difficulty and uncertainty here lies in making sure that the bunt-free plants owe their resistance to constitutional characters and not to the accident of the spores failing to germinate or the mycelium of the fungus inside the plant being unable to reach the ovary. The question as to the hereditary character of bunt-resistance can only be definitely settled by growing the seed from such bunt-resisting plants for several seasons in succession, after being thoroughly dusted with spores, and proving that immunity is or is not an inherent characteristic. Once an immune parent is obtained, then the desirable qualities to be associated with this immunity can be produced by further crossing.

There are thus at least two methods of procedure in seeking to obtain a variety of wheat immune to bunt; either to start from what is known as natural immunity, in which the plant from its very constitution inherits a certain amount of resistance, as in the case of Medeah, or by means of selection to arrive at a plant which has acquired this character, as in the supposed case of Florence.

It was the idea of the late Mr. Farrer to inoculate the seed which produced the variable generation of his new crosses with bunt spores, and then select bunt-free plants from the new generation, thereby hoping to secure an immune strain or one at least less susceptible than the parents. But in either case it has yet to be proved that immunity is absolute and complete, and that rich feeding or starvation, for instance, or the severity of the infection, may not break down the power of resistance.

II.—Flag Smut of Wheat *(Urocystis tritice, Koern).*

Flag Smut, as the name denotes, is most commonly found on the leaves and leaf-sheaths in the form of elongated streaks, but it may also occur on the stem, and even on the chaff, but very rarely in the ovary. It is sometimes called "Black Rust," but this name is so misleading, inappropriate, and confusing that it should be utterly discarded. This disease is well known in South Australia, Victoria, and New South Wales, and occurs even in Queensland. I am informed by the Vegetable Pathologist there that only a single instance of it had come under his notice, in 1906, in a wheat crop grown in the heavy soil of the Hodgson district. However, this does not imply that the disease was confined to this one spot, for he guardedly remarks "that it may have been more prevalent than is indicated by this statement, since farmers are not in the habit of calling attention to affections in their crops until these are sufficiently pronounced to cause them some concern."

In South Australia, where the disease has long been known in the wheat crops, it is regarded as being in some seasons quite as injurious as the rust itself. In Victoria, as much as half the crop may be lost through it, and in one affected paddock I found that the produce of an average square yard of crop consisted of 144 smutted straws without ears, and sixty-two clean straws with ears.

The infection experiments were carried out to determine—

1st. If the Flag Smut of rye is the same as that of wheat.

2nd. If the infection occurred in the seedling stage, or later on, since the wheat-plant is generally destroyed by this smut before the flowering stage is reached.

3rd. If spores in the soil can infect the wheat-plant.

I.—Infection of Wheat and Rye.

Although this disease has been known in Australia at least since 1868, it was only in 1873 that Wolff definitely stated that the fungus causing it was the same as that on the rye—viz., *Urocystis occulta* (Wallr.), Rab. This was the first time it had been found on wheat, although since then it has been found in India and Japan, and if the fungus was the same on both, then they ought to be mutually infective. Since this smut had never been met with on rye in Australia, I obtained material direct from the rye in Germany. In one experiment 200 grains of wheat were dusted with the spores of flag smut of wheat obtained from the crop of the previous year, and 200 grains of rye were dusted with similar spores. They were sown alongside each other on 28th June, and examined when thoroughly ripe on 29th December. Of the wheat 190 grains germinated, and of the plants produced twenty-one were affected with flag smut, or 11 per cent. Of the rye 186 grains germinated, but the plants were absolutely clean. The same variety of wheat (Federation) and rye were also sown, without the seed being infected, and the plants were entirely free from flag smut.

Another experiment was carried out in which there were six plots of twenty grains each, and wheat and rye were cross-infected. The ordinary seed of wheat and rye were sown. Then, seed wheat infested with the spores of flag smut from wheat, and another lot with those from rye grown in Germany. Finally, rye seed was infected with the spores of flag smut from rye, and another portion with those from wheat. These plots were sown on 23rd May, and on the 28th of October, three wheat plants were found out of twenty badly affected with flag smut, the infection having been brought about by the spores of wheat flag smut. The plots were finally examined at the end of the year, but there was no further development of disease. Although in this experiment there was no disease in the rye it was not owing to the spores being non-germinable; for when placed on a slide in tap-water, and kept under a bell-jar, they germinated freely in three days.

A third experiment was carried out in pots similar to the last. Only one wheat plant was diseased, and that was infected with flag smut from wheat, and one rye plant infected with flag smut from rye.

The conclusion to be drawn from these experiments is that the flag smuts of wheat and rye are not mutually infective, that the one is incapable of infecting the other, and that, therefore, the name given to this smut by Koernicke, in 1877, who received specimens from R. Schomburgh, in South Australia, should be retained—viz., *Urocystis tritici.*

II.—Infection Confined to the Seedling Stage.

For this experiment the seed wheat was planted in pots containing ordinary garden soil. There were three pots—one used as a check, in which the seed was uninfected, a second, in which the seed was thoroughly dusted with spores, and a third in which the spores were dusted over the plants when about 6 in. high. The result was that the smut developed only when the seed was dusted with spores, showing that it is the young seedling which is attacked, and that there is no infection when the plant is above ground. The experiment of dusting the seed with spores was repeated, with a similar result, and when in another experiment the young plants about 3 in. high were also dusted with spores, and kept moist by being covered with a bell-jar, there was no infection.

The experiments recorded in connection with wheat and rye, in which the seed was infected and the disease produced, also prove the same point.

III.—Infection by Spores in the Soil.

If infection was confined to the spores adhering to the seed, then the probability is that seed-treatment would be found as effectual in this disease as in the case of Stinking Smut of wheat. But I had found in my field experiments, that even after treatment of the seed with bluestone, formalin, and hot water respectively, the disease still appeared where flag-smutted crops had previously been grown, and this pointed to some other method of infection than that of the spores adhering to the grain.

By sowing clean wheat along with diseased straw it was sought to prove whether the diseased straw of one crop was able to infect the following one.

On 28th June, fifty clean grains of Federation wheat were sown, and fragments of diseased straw sown with them from the crop of

1907; fifty plants grew, and of these five were affected with Flag Smut, or 10 per cent., while those clean grains sown alongside remained free. In a previous pot experiment with diseased straw, eighteen plants out of thirty-five were diseased, or 51 per cent.; and, even when manure was added to the soil from horses which had been fed on diseased hay, there was a small percentage of plants affected.

The conclusions to be drawn from these experiments are:—

1. Plants may be infected by coating seed with spores.
2. Plants are liable to infection if seed is sown on soil containing diseased straw of the previous crop.
3. Plants may become infected if seed is sown on soil containing manure from horses fed on diseased hay.

Although this paper does not deal with treatment for disease, yet it may be stated that experiments in this direction indicate that a suitable rotation is the best method of prevention.

In conclusion, I would emphasise the necessity for experiments being conducted by those who have some knowledge of the subjects dealt with, otherwise the results are apt to be illusory and misleading. In a "Report of Experiments conducted at the Mount Templeton School, South Australia," there are some given under the heading of Black Rust or Leaf Smut *(Urocystis occulta).* This report appeared in the "Agricultural Gazette of New South Wales," and that is my only justification for quoting from it.

Some remarkable phenomena in connection with these experiments were observed, which appear to show that the insertion of Black Rust spores into the flowering head caused the variety of wheat to change.

"In one case Black Rust spores were inserted into a flowering head of White Tuscan (a bald variety), and the resulting grains produced plants of wheat, 90 per cent. of which had bearded heads.

"In another case, when spores of Black Rust had been inserted, the resulting plants were nearly all affected with Loose Smut.

"As it is known that the spores of these fungi are carried about by the wind at the time when wheat is in flower, it is probable that the infection takes place at this time through the agency of the wind."

Comment is unnecessary, but it is to be hoped that an association for the advancement of science will so leaven the community with scientific modes of thought that such a report from a scholastic institution, and its publication, would be rendered impossible in the future.

4.—SOME NEGLECTED POINTS IN FEEDING.

By HERBERT INGLE, F.R.S.S.A., B.Sc., F.I.C., F.C.S.

The feeding of domestic animals has long been recognised as an important part of the work of the farmer, and, since the application of science to agriculture, has received much attention from investigators.

Many laborious researches have been made with a view of determining the best and most economical methods of feeding animals, whether intended for labour or for slaughter.

Most of these investigations have had reference to the relative amounts of the various organic constituents of the food—*i.e.*, to the most suitable portions of protein, fat, and carbohydrates in the rations for various purposes.

Indeed, in the popular mind, these three classes of constituents comprise all that is recognised as of much importance in the ration of an animal, and though there is a general and vague belief that the food must contain a sufficiency of "bone-forming" or "ash constituents," little consideration is usually paid to the composition or amount of the mineral matter present in food stuffs.

In this paper, the writer will endeavour to point out certain facts and deductions which he trusts will show that the inorganic constituents of food are of more importance than is generally realised, and that a careful consideration of these points will frequently be of service to those interested in the feeding of animals.

It is not necessary here to dwell upon the desirability of a "well-balanced" ration, since this point has long been realised by intelligent stock-keepers.

Nevertheless, neglect of this point is only too common among farmers, cattle feeders, and poultry keepers, and a fuller and wider recognition of it is undoubtedly to be desired.

But even with a ration possessing a suitable "albuminoid ratio," the best results will not be obtained unless it also supplies all the substances essential to the formation of the body tissues and secretions, and in something like the proper proportions.

Now, in the animal body there are various secretions necessary for carrying on the processes of digestion, &c., and some of these contain as essential constituents small quantities of elements which are not very abundant in plants, or at least not in all plants.

For example, the gastric juice contains chlorine, the secretion of the thyroid gland, iodine, the blood contains iron, the saliva sulphocyanides, the bones and teeth, fluorine, &c., &c.

In the case of an animal in a state of Nature, it usually has access to a great variety of food stuffs, and thus a deficiency of any one item of food, in any one element, is probably made good by the presence of that element in some other food. But, with animals kept in captivity, the case may, and doubtless often is, different, and there can be little doubt that such animals often have perforce to do without a sufficiency of certain substances required for the formation of their secretions. In such cases, the proper growth and development of the animal must be interfered with.

I.—Lime and Phosphoric Acid.

In the case of two chief mineral constituents required for the formation of bone, the writer has shown that not only must they be present in sufficient quantities in the food, but that for proper nutrition of bone to occur, their relative proportions must be approximately right, or injury results.

In a paper on Osteoporosis*—a bone disease very prevalent in South Africa among horses, mules, and donkeys—the writer adduced

* "Journal of Comparative Pathology and Therapeutics," March, 1907.

reasons for attributing the prevalence of the disease to the usual diet of such animals in South Africa—viz., a diet composed solely of cereals.

From an examination of the bones of a large number of animals, some of which had died from the disease, while others were free from it, he found that it was quite possible to classify the bones into those of diseased and those of healthy animals.

The most striking method was to take the ratio of nitrogen (really a measure of the amount of *ossein* present) to the ash in the bones, thus eliminating the influence of the varying amount of fat left in the sample.

With the bones of healthy animals, the ratio was found to vary from 1 : 13·5 to 1 : 15·6, and to have an average value of 1 : 14·37. In the case of the diseased animals, the ratio varied from 1 : 9·8 to 1 : 11·7, the mean value being 1 : 10·8.

In tabulating the results, and considering the possible causes which might lead to such a condition, the writer eventually concluded that it was to the peculiar diet of working animals in South Africa—as already mentioned, one consisting entirely of cereals—viz., oaten hay, or oaten hay and maize—that the prevalence of the disease was due, and that the real cause was the high ratio of phosphorus pentoxide to lime in the ash of such a diet.

The most desirable ratio of phosphorus pentoxide to lime in the whole ration of animals in order to favour bone formation and renewal has not been directly determined, but some deductions may be made from a study of the composition of the whole body of animals, and of the natural food of young animals—viz., milk.

In bone itself the ratio is about 100 of phosphorus pentoxide to 150 of lime, but it must be remembered that some of the phosphorus found as phosphates in the ash of the whole bodies of animals is present in the form of organic matter—*e.g.*, in the brain and in lecithin.

In the Rothamsted experiments it was found that 1,000 lb. of the whole bodies of animals contained the following amounts of phosphorus pentoxide and lime:—

	Phosphorus Pentoxide.	Lime.	Ratio. $P_2O_5 : CaO$.
Fat calf	15·35	16·46	100 : 108
Half-fat ox	18·39	21·11	,, : 116
Fat lamb	11·26	12·81	,, : 114
Store sheep	11·88	13·21	,, : 112
Store pig	10·06	10·79	,, : 107
Fat pig	6·54	6·36	,, : 95

In all cases but the last it will be noticed that the amount of lime is greater than that of phosphorus pentoxide.

In cows' milk, on the average, there are about 0·17 per cent. of phosphorus pentoxide and 0·15% of lime; these figures being in the ratio of about 100 of phosphorus pentoxide to 89 of lime.

It would probably be safe to assume, therefore, that for proper bone nutrition the whole food of the animal should contain about equal weights of phosphorus pentoxide and lime.

Now, in the two foodstuffs so largely used for horses and mules in South Africa, the proportions are very different.

In oaten hay, according to Wolff's analyses, the ratio is 100 of phosphorus pentoxide to 77 of lime, while in maize grain it is 100 : 4.

According to the figures quoted by Warington, for the whole oat plant the ratio is 100 : 60, while in many samples of oaten hay grown in South Africa the writer finds an average of 100 : 51.

It is thus evident that the usual diet of South African horses and mules provides a large excess of phosphoric acid to lime.

Now, in Europe, oats are largely used, and highly valued as food for horses, but they are nearly always supplemented by hay—either meadow hay or clover hay, both of which, as will be shown, contain a large excess of lime over phosphorus pentoxide. Unfortunately, so far as can be ascertained, no direct experiments upon horses and mules to elucidate the effect of a prolonged use of such a diet have been made, but in 1891 Weiske experimented with rabbits on these lines, and found that animals fed on oats alone produced small, brittle bones, while exactly similar rabbits fed upon hay or upon a mixture of hay and oats developed normal skeletons.

The writer is fully persuaded that the susceptibility to the disease, if not the disease itself, is due to the use of a diet containing a relatively high proportion of phosphorus pentoxide and a low proportion of lime, and that it is not so much the deficiency of South African-grown oaten hay in lime and phosphoric acid as compared with European produce, but the fact that the diet in Africa is so restricted to oaten hay or oaten hay and maize that causes the trouble.

The view that bone diseases are due to deficiencies of the food in lime and phosphates is very wide spread, but it is not realised that it is the proportion in which these occur that is important. A striking example of error in the popular views on this point is furnished in the case of wheat bran. This material is widely regarded as particularly rich in bone-forming constituents, but from the point of view here adduced should be very ill adapted for bone nutrition, since it contains an overwhelming excess of phosphorus pentoxide as compared to lime, the actual proportions being, on the average, about 3·3 per cent. of the former to 0·3 per cent. of the latter, or in the ration of 100 to 9. This is actually confirmed by the prevalence of a peculiar bone disease resembling in some respects osteroporosis, and known as "bran rachitis," "bran disease," or "millers' horse rickets," among horses fed largely upon bran.

In this connection it may be of interest to give a list of the ratios of phosphorus pentoxide to lime in many of the common food stuffs.

Food Stuff.	Ratio Phosphorus Pentoxide.		Lime.	Authority.
Lucerne hay	100	:	478	Wolff
Crimson clover hay	...		445	,,
Red clover hay	...		361	Warington
Red clover hay	...		359	Wolff
Meadow hay	...		262	Warington
Meadow hay	...		247	Wolff
White clover hay	...		227	,,
Oaten straw	...		181	,,
Oats, whole plant, green ...	...		77	,,
Oats, whole plant, ripe... ...	...		62	Warington
Barley, whole plant	...		44	,,
Linseed cake	...		24	Wolff
Oats, grain	...		16	,,
Wheat bran	...		9	,,
Maize, grain	...		4	,,

While the following are the ratios calculated from analyses made in the Pretoria laboratories of African-grown produce:—

	Phosphorus Pentoxide.		Lime.	
Velvet bean hay (*Mucuna utilis*) ...	100	...	581	
Burnett, green (*Sanguisorba minor*) ...	100	...	485	
Lucerne hay (*Medicago sativa*)		...	431	
Sheep's parsley (*Petroselinum sativum*)...		...	312	
Veld hay (mixed grasses)...		...	320	
Tall fescue grass (*Festuca elatior*) ...		...	258	
Rhodes grass hay (*Chloris guyana*) ...		...	250	
Wheat straw		...	250	
Cow-pea hay (*Vigna catjang*)		...	248	
Oaten straw		...	209	
Teosinte hay (*Euchlœna mexicana*) ...		...	203	
Maple pea hay (*Pisum arvense*)		...	202	
Broom-corn millet (*Panicum crus-galli*) ...		...	174	
Blue grass hay (*Andropogon hirtus*) ...		...	168	
Sweet grass hay (*Chloris virgata*) ...	100	:	139	
Californian green Moha (*Setaria sp.*) ...		...	137	
Mealie stalks (*Zea mays*)...		...	136	
Teff grass hay (*Eragrostis abyssinica*) ...		...	125	
Boer Mauna hay (*Setaria italica*) ...		...	94	
Golden millet hay (*Setaria sp.*)		...	88	
Oaten hay (Malmesbury, Cape Colony)...		...	23	Mean 51
Oaten hay (Middleburg, Cape Colony) ...		...	57	
Oaten hay (Harmon, Cape Colony) ...		...	65	
Oaten hay (Magaliesberg, Transvaal) ...		...	44	
Oaten hay (Pretoria, Transvaal) ...		...	62	
Oaten hay (Potchefstrom, Transvaal) ...		...	53	
Brewers' grains		...	21	
Wheat bran		...	5·5	

There can be little doubt that animals can in course of time accustom themselves to circumstances, and it is noticed in South Africa that osteoporosis is more likely to occur among imported horses and mules than among those bred in the country.

Probably it is to the wide use of a purely cereal diet that the lightness of bone of the South African-bred horses is largely due, while another contributory cause may be the scarcity of clovers and other leguminous plants in the pasturage, for these plants, which are so abundant in certain limestone districts —*e.g.*, Ireland—are, as is seen from the above tables, particularly rich in lime as compared with phosphorus pentoxide.

It is obvious, from the above considerations, that the writer would recommend that animals should never be fed on a diet of cereals only, but that some of the plants containing a high ratio of lime to phosphorus pentoxide should replace a portion of the so-much-used oaten hay.

II.—Supply of Other Mineral Substances.

Emphasis has been laid upon the two constituents, lime and phosphorus pentoxide, because their effect upon bone formation has been studied in detail, but there can be no doubt that the same considerations apply to many other inorganic constituents of foods, of whose action little is known.

The necessity of supplying chlorine to animals is well realised in many districts, for in some cases the food stuffs used are so deficient in this constituent that it is essential that the animals be supplied with common salt, often in the form of "licks." Such licks contain common salt as their chief ingredient, but in addition, sulphur, ferrous sulphate, and other substances are sometimes added.

Doubtless, too, an adequate supply of potassium (fortunately nearly always abundant in vegetable matter), fluorine, iron, magnesium, iodine, and other elements is essential to the perfect working of the digestive mechanism of the animal and to proper growth and nutrition, but little is as yet known on these points.

To animals receiving a varied diet, composed of many food stuffs, the probability of their being supplied with all necessary substances is great, but when they are kept on one or two kinds of food only, it must often happen that they are insufficiently supplied with certain constituents, without which the proper formation of the tissues and secretions of the body cannot occur.

In such cases, the growth and health of the animals must suffer.

Methods of Making Good Deficiencies.

The most effective way of overcoming the troubles arising from lack of mineral matters in the diet, would be to substitute a varied diet for the former monotonous one, and thus increase the chances of the necessary inorganic matter being supplied.

In the case of animals fed upon oaten hay and maize, the replacement of a portion of the food by leguminous hays, or even by meadow hay, would effect this so far as the supply of lime and phosphoric acid is concerned, and, generally speaking, the more complex the rations are, the greater the chance of all necessary mineral matter being supplied.

But, in cases where it is impracticable to use a mixed diet, it is possible to artificially supply the deficiencies in mineral matter by the direct addition of saline substances.

The writer has devoted considerable time and attention to this matter, and has designed a preparation which has already proved itself, on the large scale, to be of great value in improving the health and condition of horses, cattle, and poultry kept in confinement.

Administered along with the ordinary food, it ensures that the animals receive an ample supply of all necessary mineral matter, and at the same time it corrects the unsuitable ratio between phosphorus pentoxide and lime, which, as has been shown, so generally obtains in cereal foods, and which leads to mal-nutrition of the bones. With poultry kept in confinement, the points raised are of particular importance, and the writer is convinced that the nutrition and health of such birds are frequently injured from the causes just discussed. The employment of the artificial preparation undoubtedly remedies this, as has been proved by direct experiment.

Pigs, too, are often kept and fed in such a way that they suffer from the deficiencies alluded to, and no doubt their health would be improved if the preparation were used.

The Food of Man.

The considerations discussed as to the importance of the ash constituents of food stuffs to domestic animals and poultry apply in some degree to human food, though in this case the greater diversity of the latter usually prevents the effects being so marked. But, even with human beings, cases must frequently occur, in which, through lack of sufficient variety of food stuffs in the diet, deficiencies in the supply of certain inorganic elements must be felt and the health consequently injured.*

It is quite possible that many ailments are induced by the impossibility of the body finding a sufficient supply of the substances—some of them of rare occurrence in plants—necessary to form the normal secretions which take part in digestion and other vital processes.

Given an adequate supply of the organic compounds of foods—viz., albuminoids, fats, and carbohydrates—the body itself, if its secretions be normal, can manufacture these into the various complex organic substances which form muscle, tendons, and other tissues, but unless the materials necessary to form digestive secretions are supplied in the food, this process cannot proceed perfectly.

The need for a supply of *some* of these relatively insignificant materials is already recognised, *e.g.*, the absolute necessity of a

* Sherman [Lake Placid Conf. Home Econ., Proc. 9 (1907)] states that, "In the selection of food and the planning of dietaries, at least as much attention should be paid to the amounts of calcium, phosphorus, and iron as to the amount of protein." This refers to human food, and shows that in America attention is now being directed to this important subject

supply of chlorine is evident in the craving which every human being (and many of the lower animals) exhibits for common salt, but lack of other substances, required perhaps in smaller quantity, but probably quite as essential as chlorine (*e.g.*, iodine for the secretion of the thyroid gland, fluorine in bone and teeth formation) is not rendered evident by the appetite, and is difficult to detect.

The preparation alluded to has been given to several human beings with beneficial results.

To the medical man the suggestion of a "mineral food," such as has been mentioned, may appear too materialistic, and indicative of a desire to regard the animal economy as a machine.

The writer, while admitting that it cannot be maintained that the body will be able to utilise all the elements presented to it in the simple inorganic combinations suggested as readily as if they formed part of complex organic compounds, such as exist in food stuffs, claims that it is possible that such utilisation may occur, while when the food is devoid of certain mineral constituents no assimilation of these materials is possible and the secretions consequently suffer.

In any case actual experience has clearly demonstrated the beneficial effect of the preparation with horses, cattle, poultry, and children, and at present experiments on a large scale, with control animals, are being tried.

In conclusion, it may be of interest to have the results of analyses of a considerable number of South African-grown food stuffs, as determined in the writer's laboratory.

—	Water.	Protein.	Sol. Carbohydrates.	Crude Fibre.	Ether Extract.	Total Ash.	Phosphorous Pentoxide.	Lime.
Tall Fescue (green) ...	60·69	5·90	16·75	7·94	4·64	4·08	0·12	0·31
Burnet (green)	61·56	5·64	21·56	5·56	2·09	3·59	0·13	0·63
Sheep's parsley (green)...	75·83	5·43	11·95	2·88	0·72	3·19	0·16	0·50
Prickly-pear "leaves" ...	93·79	0·42	3·89	0·65	0·12	1·13	0·02	0·29
Oaten hay..	8·00	5·65	44·03	34·22	3·87	4·23	0·34	0·18
Blue-grass hay	7·98	4·38	41·87	38·50	1·31	5·96	0·28	0·47
Teff hay	8·88	6·21	37·49	39·07	2·80	5·55	0·24	0·30
Rhodes grass hay ...	8·99	9·19	29·27	42·48	1·35	8·72	0·24	0·60
Boer mauna hay	8·25	5·00	46·24	30·85	1·83	7·78	0·32	0·30
Broom corn hay	9·65	6·83	38·84	34·76	1·16	8·76	0·19	0·33
Golden millet hay ...	7·88	11·11	29·54	41·03	0·95	9·49	0·40	0·35
Cowpea hay	8·21	13·21	39·59	30·51	2·40	6·28	0·63	1·56
Teosinte hay	11·45	7·89	38·02	31·39	1·52	9·73	0·29	0·59
Velvet bean hay	9·25	13·30	39·44	27·63	2·55	7·83	0·31	1·80
Vetches, hay	9·60	20·56	35·98	21·23	4·01	8·62	0·67	0·88
Blue lupines, hay ...	8·18	17·06	41·72	22·04	2·68	8·32	0·65	3·83
White lupines, hay ...	7·79	14·09	50·10	17·43	2·75	7·84	0·43	0·91
Lucerne hay	7·97	15·49	30·58	34·76	2·26	8 94	0·32	1·38
Maple pea hay	8·04	16·27	35·25	31·16	2·36	6·92	0·49	0·99
Veld hay	8·07	3·43	43·84	38·01	1·21	5·44	0·10	0·32
Sweet hay...	7·52	7·61	37·57	38·13	1·04	8·13	0·18	0·25
Brewers' grains	77·64	7·26	9·66	3·41	1·02	1·01	0·34	0·07
Wheat bran	11·02	19·25	54·23	6·98	2·46	6·06	2·90	0·16

5.—SOME MODERN VITICULTURAL METHODS.

By G. H. ADCOCK, F.L.S., Principal, Viticultural College, Rutherglen.

Viticulture, one of the most ancient branches of agriculture, and for which so much of the soil and climate of Australia are pre-eminently adapted, has of late years received an unfortunate "set-back," owing to the introduction of Phylloxera.

In the State of Victoria considerable progress has been made with the reconstitution of vineyards on American resistant stocks, and a brief résumé of this work may not be out of place at the present time, and before the present representative gathering from all States of the Commonwealth.

As a preliminary to the subject, it will be desirable to give, as briefly as possible, an account of the insect which has rendered reconstitution necessary.

As is probably well known, this terrible scourge, Phylloxera, is a native of America, and was first described just over half a century ago (1854) by Mr. Asa Fitch, who had been deputed by the State authorities of New York to study insects in their bearing on agriculture. During the course of his interesting investigations, he noticed "galls," on the leaves of an indigenous vine. Examination disclosed the tiny but formidable insects whose ravages are now only too well known in all the viticultural countries of the world.

In 1863 this pest had invaded the vineries of England, where it worked great havoc. About this time rumours of a serious and mysterious disease among vines in certain districts of France began to cause considerable uneasiness and alarm among vignerons. In 1864, according to Lafferiere, Phylloxera was discovered. Rooted vines had been imported from the United States, and the insects or their eggs had been unconsciously introduced with the American vines imported during 1858-1862. The importers of these plants were, of course, unaware of the presence of the deadly insect, and equally ignorant of the terrible devastation it would be likely to cause in the vineyards. Those were the days when producers had not realised the risk of importing plants without the skilled supervision now found essential, and provided for under the Vegetation Diseases Acts of almost every country.

Two infected centres were noticed in France, one near Garde, the other near Bordeaux. Like circles on the water, these infections gradually widened, taking year by year increased areas, till about 1880 the formidable invader had spread over the greater part of the south of France, and commenced its irresistible advance towards the north. Four years later, two and a half million acres had been destroyed. So rapid and thorough was the destruction that "vine stumps" became the chief supply of fuel in what had formerly been flourishing viticultural districts. All methods were tried to exterminate the insect, but all were equally unavailing. In about a dozen years from its introduction, Phylloxera had spread over the chief wine-producing countries of Europe. To-day there is hardly a viticultural country on the surface of the globe which has escaped the deadly infection. Introduced into Victoria with viticultural novelties some thirty years ago, we have to face the problem of reconstitution or see our vineyards rapidly dying out.

The life history of Phylloxera is remarkable and somewhat complicated. Owing to the great difficulties of observing so minute an insect of chiefly subterranean habits, the cycle was not so quickly discovered as would be the case with insects more readily observed, and its life history was for long unwritten. Thanks to the unwearying researches—principally of French and American investigators—we now know this story fairly well.

The eggs which tide the insects over the cold of winter are for this reason known as "winter-eggs." They are laid on the wood of the vine, particularly on the older wood. Probably they may have originally been also deposited on the younger canes, but as these are removed annually at pruning time, and destroyed, the instinct to seek the more secure positions on the vine stock became hereditary. Cold of climates much more rigorous than our own does not impair the vitality of these eggs. The warmth of spring or early summer hatches them out. If the vine be of American origin, the newly-hatched insects form galls on the leaves. If, on the other hand, the vine is what is known as European, then the insects descend to the roots, where several generations—the progeny of "laying-mothers"—carry on their work of silent destruction. About the middle, or towards the end of the summer, some of these subterranean insects begin to show signs of wing development. These are then known as "nymphs." This characteristic is especially marked when they have exhausted their food supply by destroying the feeding roots. After several moults, the wings become sufficiently developed, and the insects fly and are carried in the direction of the prevailing winds to set up new colonies of infection in the same or an adjoining vineyard. Having reached a suitable spot, these winged migrants lay eggs on the vine selected. These eggs differ in size. From the larger, females are produced, while the smaller give rise to males. This is the first appearance in the cycle of the two sexes. These insects have no organs of nutrition. They pair, and the result of the union is the fertilisation of the winter-egg already described. The tiny male insect immediately dies. His partner only survives him till the important function of egg-laying has been accomplished.

The effect of the puncture made by the insect's proboscis is to cause the rootlet to swell up and curve over in a peculiar manner, and resemble frequently a bird's beak. Not only is the plant food removed by the insects, but the puncture sets up a remarkable irritation, that causes mortification of the tissues. To a skilled observer, often the first indication of attack to the vine is an abnormal crop. As if the plant were conscious that it cannot long survive, it sets to work to make provision for the production of its seed, in order to secure the perpetuation of the species. New roots are rapidly thrown out, and the vine seems even more vigorous than ever. But it is only for a time. The unequal struggle cannot long be maintained. After vintage the leaves change colour and fall early. Next season, growth is stunted, and ere long the vine dies, and the pest spreads further afield.

When it was definitely decided that Phylloxera had been introduced to Europe on some of the native American vines, some of the keener viticultural scientists of France concluded that there must be some vines in the native home of the insect that could withstand its attacks. They argued that unless it changed its food the parasite would sooner or later destroy all the host plants, and so commit "race suicide." They set themselves the important task of investigating this problem, and discovering, if possible, a remedy. Subsidised by the French Government, a commission of the very best men was sent out to study the question in the habitat of the insect. The result was the discovery of resistant varieties of American vines, some of which, with their selected hybrids, are now being utilised in the struggle against Phylloxera. No vines are actually *proof* against Phylloxera, but they *resist* its attacks. The roots of such as possess a high resistance are hardier and protected with stouter coverings, through which the proboscides of the dreadful little parasites cannot penetrate Thus, their food supply is restricted, and a consequent limit placed on their multiplication, such as does not take place on the roots of the ordinary European vine. Then, too, in the truly resistant stocks the injured bark is excoriated, and the root itself sustains no perceptible damage. The task of the parasite, under such circumstances, resembles that of the mythic Sisyphus, who was condemned to roll up-hill an ever-returning boulder. The insect and its host plant, the American vine, have been brought up together during centuries. Plants deficient in the natural protection speedily succumbed. The more robust and better protected were the best equipped to carry on the struggle. They survived. The species were perpetuated by seed. Those seedlings that possessed sufficient resistance were allowed to remain. Those deficient in their resistant qualities were speedily weeded out by an inexorable law of Nature, aided by the insatiable Phylloxera. The test was a severe one. In this way a high standard of resistance was secured.

After the important discovery of vines that could flourish in spite of the parasitic insects, they were extensively introduced into France for reconstitution purposes. An idea that all American vines were equally resistant and suitable for all kinds of soil and varieties of scions caused heavy losses in time and capital. Seedlings were used, and, as we know, seedlings do not invariably come true. The resistance of the stock to Phylloxera must be established beyond doubt. A vigorous habit is also indispensable. Adaptation to conditions of soil and climate must be secured. In a certain soil every plant will succeed better than in others. One variety will thrive where another would assuredly fail. By actual experience it has been found that the degree of resistance of American vines largely depends on their being placed in conditions most suitable. The grafting affinity of the stock must also be definitely ascertained. Certain scions will succeed admirably on one stock. Placed on another stock they may either completely fail, or form an indifferent and short-lived union.

The "mother-stocks," as the vines are called that produce the grafting wood, are usually trained on a trellis. The canes are carefully disbudded to secure the maximum of wood suitable for bench grafting. In this work, as in all other viticultural operations, boys soon become expert. At pruning time the canes are cut into suitable lengths, tied in handy bundles, dipped in sulphate of copper solution to destroy spores of fungi, and stratified in sand till the time for grafting. The stratification not only preserves the vitality of the cutting, but also ensures a proper amount of moisture in the canes, so that they are much more easily and satisfactorily worked. Cuttings taken fresh off the vines at grafting time are often very brittle owing to the frosty weather so prevalent at that time.

Grafting is done chiefly by hand. The "whip-tongue" graft is the most expeditious and popular. The cut is made as short as possible, for the nearer the section approximates to the transverse, the better it is, as there is much less tissue to unite, and wound to heal. With this short section cleft graft tying is dispensed with, to the saving of a very considerable amount of labour.

Care is, of course, taken that suitable stocks are selected for the varied districts, as well as for the particular scions required.

Callusing is now done in seaweed and sawdust, as introduced by M. Richter in his world-famed nursery, and described by him in the viticultural journals of France. This method was brought out to Victoria by Mr. F. de Castella, who visited Europe as a viticultural commission from the Victorian Department of Agriculture last year. It is much superior to the old method of callusing in sand. Grafted cuttings are carefully packed in boxes, which are lined with several inches of seaweed. Spruce sawdust is scattered among them. To pack them the boxes stand on end. When full they are placed in proper position with the grafts vertical. They are then covered over on top to a depth of several inches with seaweed, and given a thorough watering. After draining for a sufficient time, they are transferred to the callusing house, where they are kept at a steady temperature of 72 degrees Fahr., till they have callused. They are then removed to a cooler building to "harden off" before being planted in the nursery.

The planting out is done in double rows 18 in. apart, with a space between of 4 ft. This enables the frequent cultivation that is essential to be done by horse labour. During their term in the nursery the grafts receive constant attention. Pests have to be guarded against. Watering must receive attention, and scion-roots, which readily form, must be removed, or the scion will grow on its own roots at the expense of the root-system of the stock, and the whole labour of grafting will be in vain.

The resistant stocks employed belong to several species of the genus Vitis. Not only have various species been utilised, but quite a number of hybrids, both natural and artificial, have been obtained. Some of these are between American species, and are known as *Americo × American*. A great many experiments undertaken of late years to cross the American with the European vines have resulted in many meritorious hybrids being obtained. These latter are designated *Franco × American*. As one parent is non-resistant, it was long feared that while the resultant hybrid would naturally graft more readily, yet it would probably be deficient in the most important factor of its usefulness—viz., resistance. However, many of these *Franco × American* stocks have for years stood the severest tests, and have proved that their gain in grafting affinity has not been secured at the cost of a feeble resistance. The species mostly used for reconstitution are *Vitis riparia*, *V. rupestris*, *V. Berlandieri*, with a large number of hybrids.

The Riparia, as its name indicates, is adapted for river bank and deep rich alluvial soils. In Victoria it has been discarded in all but a few special localities. Where it is planted in suitable conditions, it thrives well, and is a good graft-bearer. But for most of our viticultural areas it has been supplanted by other stocks less influenced by drought, to which, owing to its somewhat superficial root system, it is susceptible. Of the two varieties introduced into Victoria, *Riparia gloire* (de Montpellier) is very much superior to *R. grand glabre*, which is now regarded as unsatisfactory, and is in consequence very unpopular.

Of the Rupestris strain, several that came to the State with splendid reputations have now been abandoned as unreliable. These are *Rupestris Martin*, *R. Ganzin*, *R. Fortworth*, *R. metallica*, of France, and several others. A variety of the latter, grown from seed and carefully selected at the Cape, is highly esteemed as a vigorous grower, and an excellent graft-bearer. Not only is the bulk of reconstitution in South Africa carried out on this stock, but it has proved itself so far reliable and productive as a stock in the rather extensive experiments carried out in Victoria.

Rupestris du Lot, known also (in California particularly) as *R. St. George*, is a stock of considerable merit, and has proved in Victorian reconstitution to be one of the very best. It strikes easily, grafts readily, and is much more durable than many others that originally gave greater promise.

Most of the American resistant stocks are intolerant of lime, and as so much of the viticultural area of France was on limestone formation, or on soils containing a fair percentage of lime, the difficulty was rather serious. To find a stock that would be resistant and yet tolerant of lime was desired and long searched for. It has been found that the Berlandieri possesses these desirable qualities. The chief drawback is the difficulty experienced in getting it to strike roots in the ordinary way, and also the comparatively slow growth of the stock during its earlier seasons. As noted, the Berlandieri shoots strike roots indifferently. The difficulty has been overcome by utilising a *Berlandieri* × *Vinifera* hybrid, which retains the tolerance to lime and resistance to Phylloxera of the one parent, and the rooting powers and grafting affinity of the other. Owing to the fact that but few of the Victorian vine-growing districts are calcareous, the difficulty was not so great here as in the old world. In our experience, heavy clays and prolonged droughts cause more anxiety in reconstitution than the presence of excess of lime.

Reference has been made to the hybrids. The important work of breeding suitable stocks has long taken up the careful attention of a number of eminent practical and scientific men. Among others, special mention should be made of Couderc, Millardet, de Grasset, and Ravaz. A vast number of hybrids were produced, and immediately rejected as worthless. They must have a vigorous habit, suitable adaptability to soil and climate, prove to be sufficiently resistant to Phylloxera, and possess superior grafting affinity, or they are useless as stocks.

Among the *Americo* × *American* hybrids are some of the most meritorious stocks known, such as Hybrids Nos. 3306 and 3309

Couderc) and 101-14 (Millardet and de Grasset). These were obtained by the crossing of Riparia and Rupestris. No. 3306 is adapted for moister soils than No. 3309, which succeeds well in dry localities. No. 101-14 partakes more of the Riparia strain in appearance, but in actual practice is infinitely superior to it. Berlandieri hybrids include a number of estimable and promising stocks, which do not suffer from the presence of large quantities of lime or prolonged droughts. No. 420A is a hybrid between Berlandieri and Riparia, and is regarded with increasing favour. The same may be said of the hybrids 157-11 and 34E from the same parents. The former of the two gives better results when grafted in the vineyard than on the bench.

A ternary hybrid of considerable promise in our dry and heavy clays is No. 106-8. This is from Riparia and Cordifolia and Rupestris.

Of *Franco* × *American* hybrids there are quite a number. For years the writer advised the utmost caution in the use of these as stocks on account of the European strain. Recent reports from Europe, however, show that the best of them have stood the test for a number of years, and are regarded as thoroughly reliable. In *Franco* × *American* hybridisations several remarkable and inexplicable results have been secured. Thus, in Aramon × Rupestris Ganzin No. 1 we have a valuable stock, which is the progeny of a non-resistant European variety crossed with a now-discarded American vine. That it should prove so useful a stock under the circumstances is remarkable, but its value has been satisfactorily proved in both European and Victorian experience.

Hybrid No. 1202 (Couderc) is one of the best stocks for Muscat scions. It is a cross between Mourvedre (our Mataro) and a Rupestris.

Hybrid 41B is the result of crossing Chasselas with Berlandieri. Of the *Franco* × *American* it has the highest resistance to Phylloxera. In its adaptability and fertility as a graft-bearer it possesses qualities of a high order, which seem to indicate a promising future. In these cases the presence of the Vinifera strain has not enfeebled the resistance.

Of other hybrids—and their name is legion—it is not intended to treat. Only those grown at the Viticultural College Nurseries at Rutherglen and Wahgunyah, and of which we have had practical experience under Australian conditions, have been included. Others are in our collections and are being subjected to practical tests.

A number of "direct producers" have been raised, but they are not regarded with favour in Australian viticulture.

Grafting the vine brings it into earlier bearing, and also increases its productiveness. Why this is so does not appear to be fully understood. Probably the slight constriction of the sap vessels at the union of the graft acts similarly to the operation of cincturing as practised on the Zante currant.

As the yield is greater, it follows that it will be necessary to give the roots a wider range by deeply stirring the soil before planting, and also feed the vine by adding plant food. In fact, with any kind of cropping, the producer should remember that each year in his crop he sells part of the most valuable constituents of his soil. He should regard his land as a bank, and remember that unless additions are made from time to time to the food stuffs in the soil, as they are being annually drawn upon, it will not be long before his vines or other plants declare by impoverished appearance and diminished returns that there are "not sufficient funds" to carry on the business of production.

Deep and thorough cultivation is equally essential to success in establishing a vineyard on resistant stocks, more especially as, in most cases, reconstitution means replanting land that has already borne vines for many years. Various methods have been employed to secure the deep stirring of the land without bringing up the subsoil to the surface. Excellent work is being done in Victoria by means of an Oliver plough drawn across the field by stationary engines.

6.—THE AMERICAN SYSTEM OF TRANSPORTING AND MARKETING WHEAT, AND ITS ADOPTION IN N.S.W.

By S. HODDER.

7.—AUSTRALIAN DRY FARMING.

By R. W. PEACOCK, Manager, Experimental Farm, Bathurst, N.S.W.

8.—SCIENTIFIC BREEDING AND HEREDITY.

By D. F. LAURIE, Poultry Expert, Department of Agriculture, Adelaide, S.A.

Section H.

ENGINEERING AND ARCHITECTURE.

ADDRESS BY THE PRESIDENT,

PROFESSOR R. W. CHAPMAN, M.A., B.C.E.,

Adelaide University.

THE STRUCTURE OF METALS AND THEIR BEHAVIOUR UNDER STRESS.

The pleasure that I have in accepting the honour of presiding over the meetings of this section is modified by a feeling of deep regret as I remember that the gentleman who was our president at the last meeting of the association in Adelaide has been called away by the hand of death. Mr. W. Thwaites, late Engineer-in-Chief of the Melbourne and Metropolitan Board of Works, died in November, 1907, at the comparatively early age of fifty-four years, after a life of strenuous energy, spent in the furthering of engineering progress, a life that has left its indelible record in the shape of good and lasting work. After a brilliant course at the University of Melbourne, he entered the service of the Victorian Railway Department in 1874, and, with the exception of a period of three years spent in the South Australian Railway Department, he remained in the service of the Victorian Government until 1890. He assisted in the carrying out of the exploration surveys that gave Melbourne her greatly increased water supply, and was afterwards responsible for the designing and construction of extensive reclamation and other works, including the Port Melbourne Lagoon and the Dight's Falls schemes. In 1891 he was chosen Engineer-in-Chief of the Melbourne and Metropolitan Board of Works, a position that he occupied till his death, and the great sewerage works of Melbourne stand as a lasting monument to his energy, ability, and conscientiousness.

It is my purpose in this address to direct your attention to some modern views on the structure of metals and their behaviour under stress, a matter which perhaps some engineers may be inclined to scorn as being of purely theoretical interest. But I do not propose even to apologise. The very fact that this section holds its meeting under the wing of an Association for the Advancement of Science shows that we, as engineers, recognise the necessary dependence of engineering progress upon the advance of pure knowledge. And when the president of this section happens to be a man engaged in engineering teaching and experiment at a University, it is but natural that he should deal more with the scientific aspects of the subject, leaving to those actually engaged in the carrying out of works the account of practical difficulties overcome. The old fight between theory and practice lasted long: but I think we may regard it as practically over. We all recognise that the engineer must have some sort of theory to guide him in design, and if his theory is of the best it means that he best makes use of the accumulated experience and deductions from experience of the great men who have gone before. No man can become an engineer by the mere reading of books, and, on the other hand, no engineer can become a master of his profession without reading. In this way, he may build his own little mound of experience on top of the hill that has been laboriously built by his predecessors, and so by commanding a wider view than they have had he may perchance see possible avenues of progress hidden from them. Engineering progress depends upon both theory and practice marching forward together, and every engineer is bound to welcome any illuminating light thrown upon his efforts, no matter from what direction it comes.

In spite of the great numbers of investigations into the behaviour of materials under stress that have emanated of late years from the numerous well-equipped engineering laboratories all over the world, comparatively small progress has been made towards any real understanding of the nature of the phenomena observed. Immense numbers of observations have been made upon the breaking strength, the yield point, the amount of elongation under stress of various materials, upon the fatigue of metals under alternating or intermittent stresses, the flow of metals under stress, methods of hardening and softening, and the effect of changes of temperature upon strength and elasticity, but, although there must necessarily be an intimate connection between these various phenomena, it is only comparatively recently that any attempt has been possible to picture the nature of the processes taking place. I should think that most men who have done much in the way of experimenting upon the behaviour of iron and steel in the testing laboratory have been impressed with the unsatisfactory nature of the task of tabulating columns of experimental results with no real guiding principle by which they can be co-ordinated. Of course it may be said from a purely practical point of view that so long as we know the strength and elasticity of a piece of iron, that is all the engineer wants to know for structural purposes, and that the nature of the molecular processes is not his concern. But the history of engineering is full of examples of the practical advantages that may be derived by the engineer from a scientific enquiry into the phenomena with which he has to deal, and we cannot divorce the practice of engineering from its philosophy. In the case before us it is obvious that any theory which will throw light upon the nature of the molecular processes that lead up to the fracture of a metal, enabling us to form some sort of mental picture of what happens in the correlated phenomena of yield point, fatigue, and elasticity, or to elucidate the problems of annealing and tempering, may be a very important aid to progress, even if, as is most probable, the theory be only partially correct. The attempts that have been made in this direction have been largely due to the progress in the study of the metals by the aid of the microscope, an instrument that we are apt to associate rather with the study of butterflies than with engineering. But by its aid such light has been thrown upon the structure of metals that it is not at all unlikely that the microscope will in the future form just as essential a feature in the engineering laboratory as the testing machine.

The credit of being the first to apply the microscope to the difficult study of the micro-structure of metals belongs to Dr. Sorby, of Sheffield, who in 1864 published the first paper on the microscopic structure of iron and steel. Since then metallography, as it is termed, has become almost a science in itself, claiming many workers, and the literature of the subject has become extensive. The microscopic examination is done by first finely polishing a section, lightly etching with acid, and then viewing it under the microscope by means of reflected light. Most of the work has been carried out from a metallurgist's standpoint, its object being to determine the nature and proportion of the different constituents in various grades of iron, steel, and alloys, and the manner of their distribution. In this way it has proved of great practical utility. In one way it is unfortunate that so much of this work has been done upon iron and steel, because not less than five or six different constituents are commonly recognised in its microscopic structure, and the phenomena exhibited are much more complex than those shown by simpler and purer metals. It is, of course, natural that this should be the case because of the practical importance of these metals, but it seems probable that the purer metals may enable some of the fundamental processes, such as hardening under strain, to be studied more easily. One important result of these observations is to show that the structure of metals in general is always crystalline, and that an iron bar with all its properties of ductility and elasticity, is nothing but an aggregate of crystal grains. It was a common thing for engineers to speak of iron or steel, that was supposed to have become brittle through being subjected to excessive vibration extending over long periods, as having become crystalline. This work has taught us that the metal is always crystalline. The size and character of the crystals may alter; we know that they alter when subjected to heat as in the processes of annealing, and possibly their nature may change under the influence of long-continued vibration, although there is at present no proof of this, but, brittle or ductile, the bar is always built up of crystals. Iron or steel in a brittle form is usually composed of larger crystals than when it is in a ductile or malleable condition, but otherwise its general structure is the same. The polished and etched surface of a metal under the microscope exhibits a series of grains of irregular shape in close contact with one another. Evidence, which we need not detail, shows that each one of these grains is a separate crystal; in the process of crystallization each crystal has apparently grown from a nucleus until its growth has been stopped by contact with neighbouring grains. As the rate of growth is not uniform in every direction their resultant shape is irregular. Throughout each crystal the molecular arrangement is uniform, but the direction of the molecular arrangements in adjoining crystals is different. Each grain we may picture as built up of layers of molecules, the layers being all parallel throughout the grain. But the direction of these layers in one grain will not be parallel to the layers in adjacent grains. From an engineering point of view a memorable paper by Professor Ewing and Mr. W. Rosenhaim (1851 Exhibition Research Scholar of the University of Melbourne) appears in the Transactions of the Royal Society of London for 1900, in which the authors detail the results of a microscopic examination, most ably carried out, of the behaviour of metals when under stress. For this purpose polished surfaces were examined under the microscope, and gradually extended till they broke, the same group of crystalline grains being kept under observation from the first application of stress until the specimen was fractured. Under such conditions, up to the elastic limit, the microscope shows no visible effect, but, as soon as the yield point is reached and plastic deformation takes place, a remarkable change occurs in the appearance of the crystalline grains. Under a vertical illumination each grain begins to show a development of fine parallel black lines, which increase in number as the strain progresses. Throughout any one grain these lines are approximately straight and parallel, but the direction of the lines is different in the different grains. The authors showed, and the point has been more fully demonstrated by Mr. Rosenhaim in later work, that these lines are not cracks but the edges of slips along gliding or cleavage planes in the crystal, each grain apparently deforming under stress in much the same way as a pack of cards, each card sliding a little on the one below it, when pressed to one side. If strained iron be heated to boiling point or allowed an interval of rest, we know that it recovers its original elasticity, but, after such treatment, the dark lines do not disappear from the specimen. On the other hand, after repolishing the lines disappear, and cannot be brought up again by etching. This goes to show, what has been still more clearly proved by Mr. Rosenhaim by polishing cross sections at right angles to the first, that these lines are the edges of slips that have taken place along parallel surfaces in the crystal, but that the cohesion between the surfaces of slip can be re-established, and they are not at all of the nature of cracks. After severe straining a second system of bands appears on some of the grains crossing the first system at an angle, and, in some cases, showing little steps where the lines cross. These are due to slip occurring along a second set of gliding planes. Such bands are developed by compression as well as by tension, and the mechanism by which the grains deform in the two cases appears precisely the same. Thus, when a rod of steel is strained by tension or compression until it begins to give and behaves almost like a viscous fluid, what happens is that the various grains of which it is built up deform by slipping in thin layers. Each grain is like a pack of cards, but the cards in one grain are not parallel to the cards in the next grain. The analogy, however, is not a complete one, because there is more than one set of slipping surfaces in each grain. There is also another way in which the grain can deform, a method that is more common in some metals than in others, and that is by the production of twin crystals. It is possible to show this phenomena on a crystal of calcite by pressing upon it with the edge of a pocket knife. Investigations have been made to ascertain whether there is any distortion of the layers between the surfaces of slip, and, though the point is a difficult one to settle, so far the evidence is on the negative side, and the whole of the change of shape suffered by the grain appears to be due to slipping in layers in the way described. When the straining of a metal is carried sufficiently far fracture ultimately results, and this may take place in one of two ways. Either the grains themselves may suffer

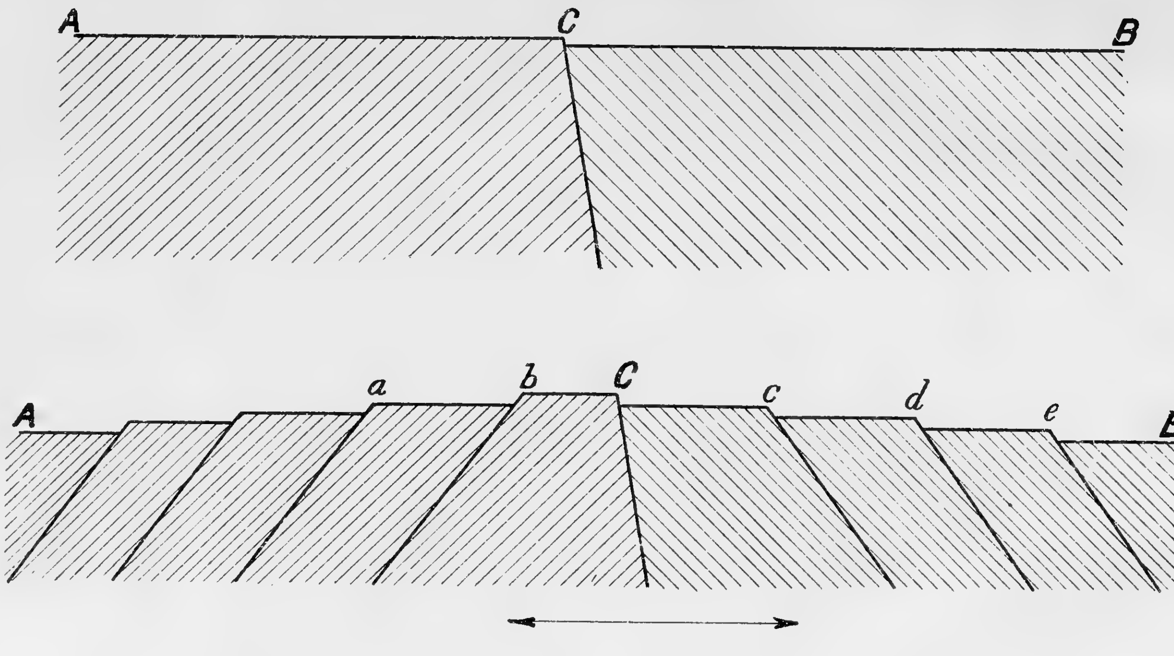


FIG. 1 Showing nature of slip bands or gliding planes

cleavage along one of these gliding surfaces or the grains may separate from one another at their boundaries. The former usually takes place in a pure and the latter in an impure metal, but, in either case, the plastic yielding that precedes fracture is effected in the same way, by the slipping on one another of the granular lamellæ.

The phenomena we have described are curiously similar to many long known to geologists on a much larger scale, by means of which the most extraordinary distortions of boulders and quartz pebbles are produced under great pressure. Indeed, it has been shown* that the deformation of marble under stress is of precisely the same character as that of iron. The movements are caused by the constituent crystals changing shape by sliding over their gliding planes or by the production of twin crystals, and the agreement between the two is so close that the term *flow* is just as correctly applied to the movement of marble in compression as to metals.

One of the most important and most puzzling phenomena with which structural engineers have to deal is that of the "fatigue" of metals. The results of the earliest enquiries into this subject appear to be contained in "The Report of the Royal Commission on the use of Iron in Railway Structures," issued in 1849. At that time cast iron was a material of much greater structural importance than it is now, and most of the experimental work referred to in the report was made upon it. The experiments showed that cast iron bars or girders which could stand any given load once before breaking could only stand half that load without fracture if the load were repeated an indefinite number of times. The cast iron itself, on the other hand, did not appear to be any the worse for these repeated loadings, for after a bar had been broken down in this way the broken halves were often retested, and never showed any signs of inferiority. At the request of the Board of Trade, Fairbairn, in 1860, carried out a series of experiments on a wrought iron girder, subjected to repeated loads. About this time also Wöhler, working from 1860 to 1870, began his laborious and now classical researches on the fatigue of iron and steel. In these experiments bars were subjected to alternations of stress at the rate of about seventy alternations per minute, and the number of reversals of stress required to break some of the bars was such that some single experiments must have taken between three and four years to complete. His work established a number of fundamentally important results. It was shown that wrought iron and steel will break with stresses considerably below the ordinary breaking stress as applied gradually in a testing machine, provided the stresses are repeated a sufficient number of times. It was shown that the number of reversals necessary to produce rupture depends on the *range* of stress and not on the maximum stress, and that, as the range of stress is diminished, so the number of repetitions necessary to produce rupture increases. Further, within a certain limiting range the stress may be reapplied an indefinite number of times without producing rupture. These results have since been amply verified and considerably extended by the researches of

* Adams and Nicholson, Experimental Investigation into the Flow of Marble—Proc. R.S., 1901.

Spangenberg, Bauschinger, Baker, and others. Osborne Reynolds and J. H. Smith have, further, shown that the rate at which the stresses are repeated has an important influence. Working with frequencies between 1,000 and 2,000 a minute, they showed that, under a given range of stress, the number of reversals necessary before rupture takes place diminishes as the frequency increases, and that the range of stress for a definite number of reversals before rupture diminishes rapidly as the rate of the reversals is increased. In a recent paper by Messrs. Stanton and Bairstow,* giving the results of an investigation made at the National Physical Laboratory, they state, however, that these conclusions do not hold good for reversals up to 800 per minute, and that there is no marked falling off in the resistance of iron and steel due to increasing the rate of reversals from sixty to 800 per minute.

One of the strange features connected with fatigue is that material which has been subjected to many reversals of stress does not show any sign of weakness when tested in the ordinary way in the testing machine. It is just as ductile and just as strong as ever it was, and yet we know that somehow there is a deterioration, because if we continue to subject it to reversals of stress it fails in the end. But an ordinary test in the testing machine will not show this weakness. In accordance with this, tests of iron and steel taken from structures where the material has been subjected to rough usage and continual repetition of strain for many years almost invariably show that the strength of the material is unimpaired. Another curious fact is that when fracture ultimately takes place in a bar which has been acted upon by a great number of reversals of stress, there is usually no trace of elongation or drawing out, although the material may be of a very ductile character when tested in the ordinary way. It looks as though the effect of repetitions of stress was to pick out weak spots in the bar, and that the deterioration that goes on is practically confined to the neighbourhood of such spots, the rest of the bar being unaltered.

Wöhler's researches showed that iron, whose tensile strength under a steady load is about 20 tons to the square inch, will break down if it is exposed to perhaps a few millions of reversals of stress of 8 or 9 tons per square inch, alternating between compression and tension. Increase the range to 10 or 12 tons per square inch, and the bar breaks with a smaller number of reversals. On the other hand, we have numbers of examples, as in the balance spring of a watch, the piston rod of a steam engine, or a railway axle, which show that provided the range of the alternating stress be kept sufficiently small many million repetitions may be made without apparent harm. A mild steel axle of a railway carriage is exposed with every revolution to continual repetition of reversed stresses which in some cases reach as high a limit as 5 tons to the square inch, seemingly without injury. Of course such axles do sometimes fail, although fortunately failure is comparatively rare, and it seems probable in such cases an explanation is to be found in the gradual spreading of a crack from an origin supplied by an air bubble or other small flaw in the material. Mr. Thos. Andrews, in a series of

* Inst. of C.E., Vol. 166.

articles in "Engineering," 1897-1898, gives the results of the microscopic examination of the fractures of a number of steel shafts and axles that had broken at ordinary work, and found that the breakage began at some spot where, owing to the presence of impurities of some kind, the crystals were not in perfect union. Now, a small flaw in an otherwise homogeneous material produces a concentration of stress in its neighbourhood, and thus under repeated stresses it tends to continually extend, the rupture in this case being primarily due to a separation of the crystals along their boundaries. Andrews propounded the view that this is the real explanation of fatigue in metals, and that the giving way under repeated loads is thus primarily due to imperfections, generally in the nature of microscopic flaws in the material, of which he says—

"Imperfections abound, without, within,
In toughest metals as metallic sin."

According to this view, if it were possible to produce a perfect metal, free from such microscopic imperfections, there should be no such thing as deterioration by fatigue. This view has been adopted by Professor Johnson, in his work on "Materials of Construction," who prefers in consequence to speak of "The gradual fracture of metals under repeated loads" as being a more truly descriptive phrase than the term *Fatigue*, which seems to imply that the metal itself has somehow deteriorated. It is, however, hard to understand how the remarkable general conformity of the numerous fatigue experiments by Wöhler, Spangenberg, Bauschinger, Baker, and the rest can be explained on the supposition of the existence of chance flaws of this nature. More recent work of Ewing and J. C. W. Humfrey (Phil. Trans., A., vol. 200, 1903) has shown that in a series of fatigue experiments undertaken by them failure took place not by the separation of the crystals from one another along their boundaries, but the line of fracture generally went through the crystals themselves, and a microscopic examination apparently showed the effect to be independent of small flaws in the material and enables something of the mechanism of fatigue for the first time to be traced out. They experimented upon rotating square bars, subjected to a bending moment after the manner of Wöhler, the sides being polished so that they could be submitted to microscopic examination at intervals. They found that after a certain number of reversals of load here and there isolated grains began to show slip bands or gliding planes similar to those that make their appearance in metal under direct tension or compression. "As the reversals proceed, the surfaces on which slipping has occurred continue to be surfaces of weakness. The parts of the crystal lying on the two sides of each such surface continue to slide back and forth over one another. The effect of this repeated sliding or grinding is seen at the polished surface of the specimen by the production of a *burr*, or rough and jagged irregular edge, broadening the slip band and suggesting the accumulation of débris. Within the crystal this repeated grinding tends to destroy the cohesion of the metal across the surface of slip, and in certain cases this develops into a crack. Once the crack is formed it quickly grows in a well-known manner, by tearing at the edge in consequence of the concentration of stress which results from lack of continuity. The experiments show how a crack may be formed without any flaw to serve as a nucleus, the first breach of continuity being set up through repeated grinding on a plane of slip in perfectly sound metal." It is obvious that in a bar built up of grains in the way we have described some of the grains will have the direction of their natural planes of slip more favourably situated for movement taking place than others; this is probably why the slip bands show themselves in only a few grains, most likely in those in which the direction of the shearing stress is most nearly parallel to the gliding planes. Besides this, it is probable in such a bar, built up of crystals irregular both in form and size, that there will be some variation in the way in which the stresses are distributed among the crystals, so that some will begin to show signs of giving before others. The microscopic examination of specimens broken under fatigue experiments at the National Physical Laboratory by Messrs. Stanton and Bairstow, as well as the work of other experimenters, have borne out these conclusions. In the case of moderately high carbon steels, it has been shown that there is a strong tendency for these cracks to develop in the grains of ferrite, as though this were the weak constituent of the steels and the cause of the ultimate failure. While much still remains to be explained in connection with fatigue, these investigations undoubtedly mark a big step forward, inasmuch as they have shown us something of the mechanism by which these remarkable effects are produced, and some of the features of fatigue that we have discussed become readily intelligible.

Testing a bar of mild steel in the ordinary way under tension we obtain the well-known type of stress-strain diagram in Fig. 2. From A to B, the proportional limit, the diagram is a straight line, showing very little extension, but its amount is always proportional to the stress. From B to C there is a slight bending of the line, showing that Hooke's law no longer holds perfectly true, and at C, the yield point, the steel begins to stretch rapidly; the material seems to become in a plastic condition and the bar stretches quite a considerable amount without any increase in the stretching force. At this stage the behaviour of the material seems to change from that of an elastic solid to that of a viscous fluid. Now, from A to B there is no time effect, that is to say the amount of stretching does not depend on the length of time the load is left on the bar. But somewhere near B a time effect begins to show itself, and at or beyond C the time effect becomes considerable, and the nature of the curve depends on the rate at which the bar is stretched. Up to the point B, or thereabouts, the elongation is practically a function of the stretching force only, but beyond B it is a function of both force and time. The fact that the time effect begins to show itself distinctly at B, and is still more marked afterwards, suggests that at this point, since it is not to be expected in a granular bar that the stress is distributed with perfect uniformity, some of the crystals have already reached their yield point, which is only reached for the bar as a whole at C, and that the deviation of BC from the straight line is due to the bar becoming plastic in spots. That even under the most careful conditions of experiment a mild steel bar does begin to yield locally long before the plastic stage is reached for the bar as a whole has been conclusively proved by Frémont*

* See "Nature," Jan. 21, 1904.

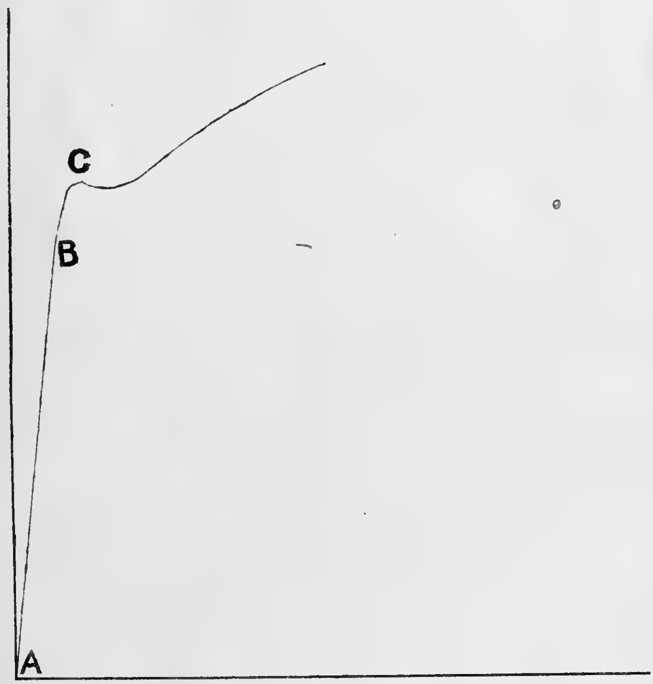


FIG. 2

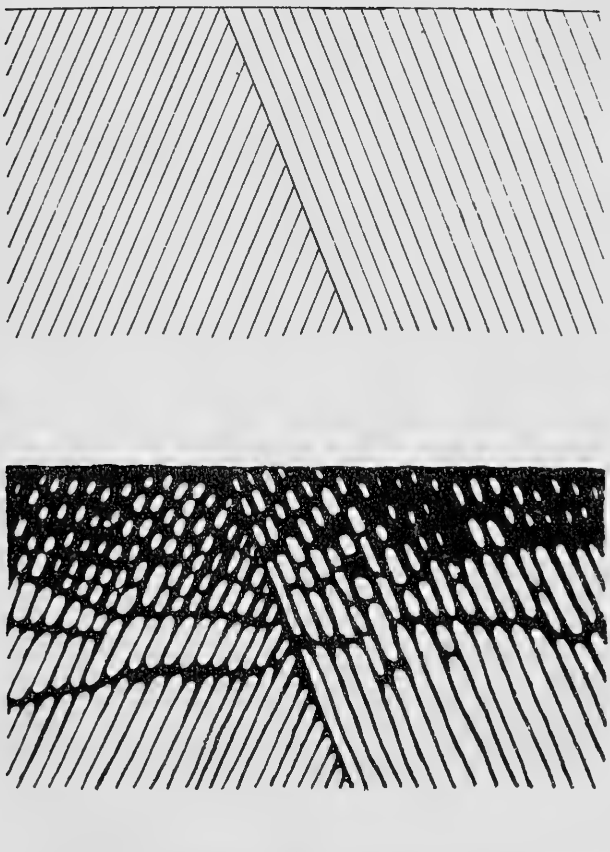


Fig. 3 Showing Breaking up of Crystal laminæ through polishing and hammering

and Osmond. They have shown that the markings known as Lüder's lines make their appearance in places on polished specimens long before even the proportional limit is reached, and these lines are due to the fact that plastic yielding has taken place at the spots where they show.

If after straining the bar to some point beyond C we entirely remove the stretching force, and then, after an interval of rest, start afresh and gradually strain the bar as before, we find that now the yield point has been raised, this increase of the yield point in tension being accompanied, as Bauschinger showed, by a lowering of the corresponding point in compression. The character of the metal is thus somehow altered by its being strained beyond its yield point; it has no longer the same qualities, but it requires a much higher stress than before to bring it to the plastic stage, and it has become, as it is usually somewhat loosely termed, harder. This particular experiment is an illustration of a very general law, apparently applicable to all the metals, that whenever a metal is strained beyond its elastic limits by any sort of stress its power of resisting that kind of stress is thereby increased. We may get an interesting demonstration by marking a small test piece with a punch, then filing off the mark and polishing the metal. If the test piece is now subjected to compression the mark will reappear soon after the plastic stage is reached. The stress-hardened parts offer a greater resistance to plastic flow, and do not in consequence lose their polish so readily as the other portions of the test piece.

We see practical applications of the principle in the processes of hammering, rolling, and wire-drawing of metals. The tensile strength of Swedish iron, for instance, may be raised from 20 tons per square inch in the bar form up to 80 tons per square inch in a thin wire by drawing it through dies. It appears to be an equally general law that whenever a metal has been "hardened" in this way its plastic quality may be restored by heating, the temperature to which the metal has to be raised in order to effect this restoration being far below that necessary to put the metal in a molten condition. This, again, seems to apply to all the metals. Thus a strip of silver foil may be made very hard and springy by hammering, but after heating to 260 degrees C. it loses all its spring, and becomes quite soft. Mr. J. Muir* made some experiments with steel that had been hardened by tensile overstrain until it could be loaded up to 50 tons per square inch without a yield point being reached. His specimens were then subjected to a series of tests after being heated to various temperatures. He found that whilst a temperature of 310 degrees C. produced no softening of the material, 360 degrees C. lowered the yield point to 47 tons; and 500 degrees, 600 degrees, and 700 degrees C. lowered the yield point to about 40, 35, and 30 tons per square inch respectively, the original yield point of the material before hardening by overstrain being 36 tons per square inch. Similarly gold, copper, and magnesium, which have been hardened by hammering, can be rendered quite soft by raising them to temperatures ranging from 250 degrees to 300 degrees C. The

* Proc. R.S., of London, vol. 67.

general principle explains why, as experiment has shown, hard copper suffers a much greater proportionate loss of strength than soft annealed copper from the effects of moderate heating.

In the light thrown upon the character of these phenomena by observations with the microscope, several hypotheses have been put forward in attempts to explain their real nature. Mr. G. T. Beilby, in the Phil. Mag. for 1904, wrote a very suggestive paper, in which he interprets the microscopic observations as showing that metals may ordinarily occur in two distinct solid states, one which he speaks of as the amorphous state, in which the molecules are arranged just anyhow, and the other in which the polarity of the molecules has caused them to become arranged in the orderly manner that produces the crystalline form. In the one case we have the molecules with no systematic arrangement whatever, like the units in an ordinary crowd of people; in the other we have them arranged like soldiers in the orderly formation of a battalion. Or, we may liken the amorphous solid to an instantaneous photograph of the molecules when in a liquid condition. All metals seem to be capable of existing in these two states, which differ not only in their mechanical properties, but their optical, electrical, and thermo-chemical properties are so distinctive as to make it appear that the metal must be in two different forms. When in the amorphous state the formation of surfaces of slip under stress is impossible, and consequently there is no plasticity; so that, contrary probably to our ordinary notions, it is the amorphous state that is the hard form and the crystalline state that is the soft or malleable form of the metal. A considerable mass of metal never appears to exist wholly in the amorphous state. It is always crystalline for the most part even after being subjected to the severest hammering. But this treatment may partly break the crystals up, and there is evidence of the existence of this amorphous structure on the surface and between fragments of the broken crystals. Mr. Beilby holds the view that a metal cannot pass from the hard phase to the crystalline or *vice versâ* without going through an intermediate mobile phase in which the molecules, if not actually in the liquid state, have at any rate something of the freedom of movement belonging to that condition. The microscopic examination of polished metals, for instance, always shows on the surface a layer of what looks like hardened viscous fluid which has to be removed by etching before the crystalline structure beneath is exposed. Mr. Beilby supposes that the same sort of thing occurs at all surfaces where slip has taken place. Thus, when a metal is strained beyond its yield point, movements take place in the various grains along the slip surfaces we have previously discussed, and between these surfaces molecules are set free that form a thin mobile layer which immediately passes over into the hardened or amorphous state. Thus exceedingly thin layers of metal in the hardened amorphous condition are formed throughout the whole mass of the strained metal. "Slipping is easy so long as fresh moving surfaces are forthcoming for the mobile phase; but when all available crystalline phase has become encased in the unyielding amorphous phase, plasticity *under these particular stresses* comes to an end." In this way he accounts for the remarkable phenomenon of the yield point, at which the metal passes through a highly plastic stage to a state of hardness and tenacity much greater than it originally possessed. According to this theory, the increased rigidity of the metal as hardened by overstrain results from the partitioning up of the whole mass by thin rigid walls of amorphous material. The theory has caused some discussion, and it appears possible that the partly amorphous form of metals that have been subjected to severe hammering or other extreme straining, owing to the grains being partly broken up into granules, may account for the change in their physical and chemical behaviour, but the evidence brought forward seems to be quite against the existence of these hardened layers between surfaces of slip.

The behaviour of iron and steel seems to show that immediately after any plastic strain the slip surfaces are left in a temporarily weak condition, so that for a time such sliding seems to take place more easily than before, but after a while these surfaces seem to heal up, and the metal recovers its elasticity. It must be remembered that the slip bands do not make their appearance until after the elastic limit is passed, so that movements along the slip surfaces imply that a plastic flow of the material is taking place similar to that which occurs at the yield point. Now, if a bar of iron that has been stressed beyond the yield point be again, very soon afterwards, subjected to a fresh test, it is found that, so far from being hardened, plastic flow takes place more easily than before, and the elastic limit is temporarily lowered. The metal slowly recovers its loss of elasticity at ordinary temperatures, but, if warmed, recovers more quickly. Thus Muir showed that at ordinary temperatures steel takes several days to recover its elasticity, but exposure to a temperature of boiling water will bring about a recovery in a few minutes, restoring it to a condition with higher elastic limit and higher yield point than before. Aluminium has been shown to behave in a similar way.* This certainly seems like a gradual healing up of the slip surfaces. If the specimen is subjected to vibration recovery is either retarded or altogether prevented. It has also been shown in the case of mild steel† that recovery is absolutely stopped if the overstrained specimen is kept at a temperature below the freezing point.

There seems a fair amount of evidence in support of Mr. Beilby's mobile layer, but will the free molecules in this layer most probably settle down into an amorphous film, or will they range themselves in harmony with the crystalline formation by which they are surrounded? Mr. Rosenhaim‡ draws the latter conclusion, and brings forward evidence from microscopic observation to show that after elastic recovery the altered layer between surfaces of slip has disappeared. He educes two reasons to account for the raising of the yield point by overstrain. Firstly, the fact that the slip bands are irregularly spaced seems to show that slip takes place only on a few out of the very large number of possible gliding surfaces, because for some reason along these slip is easier than along others. The temporary formation of a mobile layer and its subsequent rehardening probably destroys these special conditions, and such a surface

* Morley and Tomlinson. Phil. Mag., 1906.
† E. J. M'Claustland, Amer. Inst. Min. Eng., 1906.
‡ Journal Iron and Steel Institute, No. II., 1906.

will have lost its tendency to easy slip. Slip can then only take place on that surface by the application of a greater force, or it must occur on other surfaces on which slip did not at first take place so easily. The second reason advanced is that where severe strain occurs slip takes place along more than one set of parallel surfaces in each grain. The intersection of these causes the surfaces to become stepped, and thus slipping cannot take place so readily as before.

To me none of the reasons that have been put forward appear satisfactory. Bound up with this question we have the remarkable discovery of Bauschinger that whenever by tensile overstrain we raise the elastic limit in tension we always simultaneously lower the elastic limit in compression. If iron that has been stretched beyond the yield point in tension be immediately subjected to compression, before the sliding surfaces have time to heal up, the elastic limit in compression may be zero. But, even after the lapse of time, or after the iron has been moderately warmed, so that the slip surfaces are restored, the elastic limit in compression is always considerably lower than it was before the tensile overstrain. This means that once the grains have been distorted in one direction, and have been allowed to settle down into their new shapes, it is harder to distort them still more in that direction than it is to push them back again towards their original form. One would expect that any explanation of the raising of the yield point by overstrain must at the same time explain this phenomenon, but this is still wanting.

In this connection the effect of temperature is interesting. Thus, Dewar and Hadfield* have shown that ordinary soft ductile iron becomes at the temperature of liquid air quite another substance, brittle, and possessing little or no ductility, but with its tenacity more than doubled. It seems reasonable to suppose that at this temperature the molecules cannot get that freedom of motion necessary to form the mobile layer at slip surfaces, and so ordinary plastic flow cannot so readily take place. Thus, one specimen of iron tested by Hadfield carried at ordinary temperatures a maximum stress of 21 tons per square inch, with 25 per cent. elongation; at —182 degrees C. its tensile strength became 54 tons per square inch, with elongation *nil*. On the other hand, steel at high temperatures, such as 750 degrees C., has its yield point lowered, and it behaves like indiarubber or glass.† The time effects we have previously spoken of become very marked. If it is stressed for a time, and the stress then removed, it does not at once recover, but, after the immediate elastic recovery, there is a slow contraction perceptible for many minutes. Such creeping can be barely detected at ordinary temperatures, but at a red heat it attains a different order of magnitude, becoming in its total amount a substantial fraction of the whole deformation. Such time effects are ascribed by Ewing to the existence of groups of molecules in a position of feeble stability. In the region adjacent to the plane of slip it is probable that many of the molecules will be swung round by the disturbance due to strain, and may not swing right back again into their original place,

* Journal Iron and Steel Inst., I., 1905.
† Hopkinson and Rogers, Proc. R.S., Vol. 76A, 1905.

but may come to rest in some intermediate position where they are in equilibrium of perhaps a not very stable kind. We may thus have groups of molecules in a condition of very feeble stability, ready to tumble into positions of greater stability at a mere touch. The time effects proceed until all such groups have settled down into their most stable configuration.

The use of the microscope has thrown very important light upon the process and nature of crystal growth in metals, a knowledge of which is of the greatest practical importance. This process goes on not merely during the solidification of a metal from the liquid state, but commonly while the metal is still in a solid state, provided it has been heated up to a certain critical temperature. Under certain conditions crystallization goes on at very moderate temperatures. Thus after cast lead* has been severely strained by compression the large crystals of which it was originally built get broken up. They may be driven into and through one another, until at last the component grains of the overstrained lead are all quite small. Left at rest at ordinary temperatures, such lead is found to undergo a slow process of recrystallization, certain crystals growing larger at the expense of their neighbours. If the lead is exposed to higher temperatures the rate of growth of the crystals is still more rapid and pronounced. When such crystalline growth has continued for some time at a certain temperature, the structure seems to become stable at that temperature and crystalline growth ceases, but exposure to a higher temperature may cause further growth. It is curious that such crystal growth at ordinary temperatures seems to occur only in specimens that have been subjected to severe plastic strain. By casting in a chill mould specimens may be obtained having just as minute crystals as the severely-strained specimens, but the structure is stable and no growth takes place. Zinc, cadmium, and tin behave in a similar way. The process of annealing consists essentially in the raising of the temperature of the metal to one sufficiently high to allow recrystallization to take place, but this arrangement goes on while the metal is still in the solid state. Stead and Richards have made a most important application of the principles involved to the restoration of dangerously crystalline steel by heat treatment.† They have shown that iron and steel of a coarsely crystalline and brittle character may by simple heating up to a temperature of about 870 degrees C. be restored to very excellent qualities, the original coarse structure being thus destroyed and replaced by one of much greater fineness. Such coarsely crystalline steel is most commonly produced by long-continued heating at high temperatures, but with some steels it may be produced by annealing for a long period at too low a temperature in a slightly-oxidising atmosphere. If the steel has been heated until it is practically burnt, then an evolution of gas takes place in the interior which separates the crystals from each other, making the whole mass more or less discontinuous. In such a case they found that no heat treatment was successful in restoring the condition of the metal, but in all other cases the heat treatment produced a much finer structure, the

* Ewing and Rosenhaim, Proc. R.S., Vol. 67, 1901.

† Journal Iron and Steel Inst., No. II., 1903.

restored steel being far and away stronger than the original when subjected to fatigue tests, and it was quite unnecessary to forge such steel in order to restore it to good qualities. Discontinuity in the material seems, however, to be a bar to success. So it has been found* that it is impossible to restore fatigued samples of steel by mere annealing if the fatigue has been carried beyond a certain stage so that an actual crack has been started.

In thus trying to put before you some of the results of modern inquiries into the structure of metals, I hope you will not think I have attempted to turn Section H. into Section A. The matters under review lie perhaps on the border land, but they have a very important bearing upon engineering progress, and much of the investigation has been carried out by engineers. It may be classed as engineering science rather than engineering practice, but even if such knowledge does no more than give us a better understanding of the nature of practical operations it is a great advantage to have it, and there is always the possibility that the pure science of to-day may be the basis of the improved practice of to-morrow.

---

* F. Rogers, Journal Iron and Steel Inst., I., 1905.

PAPERS READ IN SECTION H.

1.—TRUSSED BEAMS AND SIMILARLY IMPERFECTLY BRACED STRUCTURES.

By GEORGE HIGGINS, M.C.E., Melbourne University, and M. Inst. C.E.

The type of structure, which it is intended to discuss in the following notes, is one that is very frequently met with. Trussed beams are more numerous than completely braced girders, and their use is likely to increase. Nevertheless, so far as the writer is aware, no publication presents the theory of the stresses occurring in trussed beams in a manner sufficiently simple to enable the dimensions of the members to be readily calculated. The subject is treated exhaustively by W. Ritter, who employs the principle of virtual work, and allows in his formulæ for such matters as possible changes of cross-section in the various members and all extensions, compressions, and deflections.

What appears to be wanted, however, is a discussion of the theory of the simple trussed beam in which all but factors really essential to the design are left out. No necessary accuracy should be sacrificed; but, seeing that the engineer does not know the strength of his material, frequently within 20 per cent. of its true value, he can well afford to ignore minor modifying factors which will affect his results to an extent not greater, perhaps, than 1 or 2 per cent. on the whole.

It will be assumed here that the beams have uniform cross-sections from end to end, likewise each tension member and each post.

It will be assumed, further, that the structure, when built and loaded with its working load, shall not undergo any deformation serious enough to influence the determination of the stresses so far as that determination depends upon the relative inclinations of adjacent members. This can be insured by making the beam stiff enough.

And, lastly, it will be assumed that the members are, severally, incompressible and inextensible—an assumption which is warranted because in most ordinary cases any deflection, or change of shape, which the structure may undergo, as a whole, owing to extensions and compressions of its members, is insignificant in comparison with the deflections that are caused to occur in the beam by transverse loading. This assumption will not appreciably affect the determination of stresses.

Let us, then, examine the effects of the foregoing assumptions upon the calculation of the stresses in trussed beams of the ordinary forms—in those, for instance, shown in Figs. 1, 2, 2a, 3, and 3a. In Fig. 1, the two ends and the middle point of the beam will remain at the same level under all loads. In Figs. 2 and 2a one post will rise as much as the other one drops. In Figs. 3 and 3a, there will be a definite geometrical relation between the rises and falls of the three posts, this relation being the same as that existing at the joints in a chain, which, being suspended as a festoon, is deformed slightly, the chain having four long links, corresponding in length and inclination to the four sections of the tension member. These results follow from our assumption as to inextensibility and incompressibility of materials. With regard to our assumption as to deformations being negligible, we have, as consequences, first, that, in Figs. 2, 2a, 3, and 3a, under all conditions of loading, the tensions in sections of the tension member symmetrically placed with respect to the centre must be equal. [In Fig. 3, where the posts bisect the angles between adjacent sections of tension member, the tension in the latter is the same throughout.] Secondly, in Figs. 2, 2a, and 3, the compressive stresses in the posts will be equal, and, in Fig. 3a, the stresses in the two side posts will be equal.

Such being our assumptions and their corollaries, it is proposed now to show how the stresses in the various members, under various loads, may be ascertained, also to ascertain the most advantageous spacing of the posts in the case of the trussed beam with two posts, under both isolated and uniformly distributed loads, and, lastly, to compare the advantages of the single and double post structures. Time has not been available for carrying the investigation fully into the case where three posts are employed.

DETERMINATION OF STRESS.

Case I.—Single Post Trussed Beam.

A.—Isolated Load.

(a) When the load is at mid-span, *i.e.*, over the post, there is no bending, and the calculations are of the simplest character. The whole of the load is transmitted through the post to the tension rods, and these impose a direct compressive stress upon the beam. The compressive stresses in beam and posts and the tension in the rods all have their maxima values as compared with the values of these stresses when the load is at other points. Referring to Fig. 4, it is seen that the stresses are $\frac{W}{2} \cot \theta$ in the beam, W in the post, and $\frac{W}{2} \operatorname{cosec} \theta$ in the tension rods.

(b) When the load is between the post and one of the abutments, the beam endures bending stresses, which have to be compounded with the direct compressive stress in it. Referring to Figs. 5 and 6, it is seen that the beam is acted upon by four transverse forces, only one of which, W, is known. We, therefore, need three equations to determine the three unknown forces, R_1, R_2, and R_3. Our first two equations are the ordinary statical ones, such as—

$$W + R_1 = R_2 + R_3 \quad \ldots \quad \ldots \quad (I.)$$

$$R_3 l + R_2 \frac{l}{2} = Wa \quad \ldots \quad \ldots \quad (II.)$$

For our third equation, the simplest appears to be that which expresses the condition that the two ends and the middle of the beam remain at the same level; in other words, that, whatever deflection at the centre W would cause, if it acted alone, and the ends of the beam were supported, would be equal and opposite to the deflection which R_2 would cause at the same point, if it acted alone and the ends of the beam were held down. Here we can make use of the formulæ for deflections of beams, as found in text books, and the text book chosen for reference is that of Lanza ("Applied Mechanics"), whose symbols will be adopted in what follows. At the bottom of p. 298 of the third edition of the volume mentioned is given the value of the deflection, v, which a load, W, acting at a distance, a, from one end of a beam, will produce at a point, distant x, from the said end, *x being less than a.* The equation is that marked "(2)", viz.—

$$v = \frac{W(l-a)}{6lEI}x^3 + \frac{Wa}{6lEI}(3al - 2l^2 - a^2)x.$$

This may be put in the simpler form—

$$v = \frac{Wx(l-a)}{6lEI}(x^2 + a^2 - 2al).$$

Owing to the convention as to signs, adopted by Lanza, v is positive when measured upwards; hence this expression is negative. We shall, for the sake of simplicity, give it its positive value and write—

$$v = \frac{Wx(l-a)}{6lEI}(2al - x^2 - a^2) \quad \ldots \quad \ldots \quad (a).$$

Fig. 7 explains the meaning of all the symbols, except E and I. E is the modulus of elasticity of the material in the beam; I is the moment of inertia of the cross-section of the beam, about the neutral axis.

We have, then, for the deflection, ^vW, which W would produce at the centre of the beam, putting $\frac{l}{2}$ for x in equation (a)—

$$^vW = \frac{W(l-a)}{12\,EI}\left(2al - \frac{l^2}{4} - a^2\right)$$

Similarly, putting $\frac{l}{2}$ for both x and a, we get, for the deflection which R_2 would produce at the centre of the beam—

$$^vR = \frac{R_2 l^3}{48\,EI}.$$

which is a well-known expression.

On the assumption of inextensibility and incompressibility, above-mentioned—

$$^vW = {}^vR$$

$$\therefore R_2 = \frac{4\,W(l-a)}{l^3}\left(2al - a^2 - \frac{l^2}{4}\right). \qquad \text{(III.)}$$

This, then, is our third equation. Combining it with equation (II.), we get R_3.

The bending moment, at the point of application of W, can then be found.

Differentiating the expression for this bending moment, with respect to a, and, equating to O, we obtain a cubic equation in a for that value of a for which the bending moment at the point of application of W is a maximum. A graphical solution of this problem is afforded by Fig. 8, where a few values of bending moments have been plotted, as ordinates, the abscissæ being values of a. From this we see that the bending moment is a maximum when W is about $0{\cdot}218l$ from the end of the beam, the said maximum value being $0{\cdot}1037\ Wl$. The bending moments at the top of the post, corresponding to different positions of the load, *i.e.*, to different values of a, are always less than the bending moments at the points of application of the load.

The force, R_1 (Fig. 6), is equal to that part of the vertical component of the tension in the inclined rod which holds the end of the beam down: the remaining portion of the said vertical component is equal to the actual pressure on the abutment, viz.—

$$\frac{W\,(l-a)}{l}. \quad \text{(Fig. 9).}$$

With reference to the force, R_3 (Fig. 6), its value is the same as though there were no tension rods, and the beam were supported at the right hand end and at the centre, and held down at the left hand end. Thus, if X be the point of contrary flexure, XC may be regarded as a beam, supported at X and C, and loaded with an isolated load, W; and R_3 is equal to the supporting force at C. It is a part of the total pressure, $\frac{Wa}{l}$ (Fig. 9), on the abutment: the remaining part of that total pressure being equal to the vertical component of the tension in the inclined rod. The tensions in the two parts of the tension member are, of course, equal.

In a completely braced truss, with an isolated load at a panel point, the whole of the load is transmitted to the abutments through the medium of the members of the truss. In the trussed beam, considered, on the other hand, when the load is not directly over the post, a part of it only; is transmitted to the abutments through the post and tension rods: the remainder is transmitted by the beam acting as a beam—*i.e.*, offering resistance to bending.

The distance, x, of the point of contrary flexure, X, from the left hand end is found from the equation—

$$R^1 x = R_2\left(x - \frac{l}{2}\right)$$

If a vertical section be taken through X, cutting the tension rod in Y (*see* Figs. 5 and 9), then the couple, whose moment is equal to the direct compressive stress in the beam, multiplied by XY, is equal to the moment, about XY, of the external forces acting on the structure, reckoned from either end. This is true of no other vertical section, because at all other sections, except XY, there are stresses in the beam, due to bending, and these help in resisting the couple due to external forces. By "moment of external forces" is meant either

$\frac{W(l-a)}{l}x$, as obtained from the left hand end in Fig. 9, or $\frac{Wa}{l}(l-x) - W(a-x)$, as obtained from the right hand end in Fig 9, these expressions being obviously identical.

NOTE.—If we transfer the origin to the right hand end, or, what is the same thing, if we imagine the load in Figs. 5, 6, 7, and 9 to be placed to the left of the post, then, writing (l − a) for a in (III.), we get $R_2 = \frac{Wa}{l^3}(3l^2 - 4a^2)$, which is a simpler expression than the other.

B.—Uniformly Distributed Load.

The load, per unit of length, may be denoted by w. So far as the beam is concerned, it is simply supported at each end and at the middle, and loaded uniformly. (*See* Fig. 11.) The results are given in many text books, *e.g.*, in Lanza's "Applied Mechanics," 3rd edition, pp. 567-8, we find, *mutatis mutandis*, that—

$$R_2 = \frac{5}{8} W l, \quad R_1 = R_3 = \frac{3}{16} W l.$$

Hence, bending moment at post $= \frac{wl^2}{32} = 0 \cdot 03125\, wl^2$. Also, the maximum bending moment between post and abutment $= \frac{9}{512} wl^2 = 0 \cdot 0176\, wl^2$, and occurs at $\frac{3}{16}\, l$ from the end of the beam.

The tensile stress in the rods $= \frac{R_2}{2}$ cosec θ and the direct compressive stress in the beam $= \frac{R_2}{2}$ cot θ. The latter has to be compounded with the stresses due to bending.

The actual pressure on each abutment is, of course, $\frac{wl}{2}$. A part of this, viz., $R_3 = R_1 = \frac{3}{16} wl$, is transmitted to each abutment by the beam, acting as a beam: the remainder, viz., $\frac{1}{2} R_2 = \frac{5}{16} wl$, is transmitted to each abutment by the tension rods, *i.e.*, the vertical component of the tension in the rod is $\frac{5}{16} wl$.

CASE II.—TRUSSED BEAM WITH TWO POSTS.

A.—Isolated Load.

(a) When the load is between the posts. (Fig. 12.)

As mentioned previously, on the supposition that the materials are inextensible and incompressible, and that practically no deformation takes place, one of the points, B and C, will be raised as much as the other is depressed; also, the compressive stresses in the posts are equal. The vertical components of the latter are denoted by R_2. We have, then, five forces acting on the beam, two of which are equal, viz., R_2. Only one force, W, is known. We, therefore, need three equations to enable us to determine the three unknown forces.

We equate the sum of the forces acting downwards to the sum of those acting upwards, thus obtaining one equation. Taking moments about some point gives us a second. For our third equation, we can express the above-mentioned condition as to the rise and fall of the points at the tops of the posts. The writer has to thank Mr. J. H. Michell, M.A., F.R.S., for this method of deflections, which is much less laborious than the method of inclinations, by means of which the writer first obtained a solution of the present problem.

Let v_W be the deflection at B, which W would cause if it acted alone, the ends of the beam being supported;

v^1_W, the deflection at C, which W would cause, under the same circumstances;

v_R, the rise at B, which R_2, acting at B, would cause if it acted alone, the ends of the beam being held down. This is also the rise at C, which R_2, acting at C, would cause if it acted alone and the ends were held down;

v^1_R, the rise of B, which R_2, acting at C, would cause. This is also the rise at C, which R_2, acting at B, would cause.

Supposing B to be the point which moves downwards, and C upwards, then—

$$\text{Deflection at B} = v_W - v_R - v^1_R;$$

$$\text{Rise at C} = v_R + v^1_R - v^1_W,$$

and these are equal, *i.e.*—

$$v_W + v^1_W = 2\,(v_R + v^1_R).$$

Putting l for x in equation (a), we get—

$$v_W = \frac{W\,(l-a)\,l_1}{6l\,EI}\,(2al - a^2 - l_1^2).$$

Coming to v^1_W, *i.e.*, the deflection at C, due to W, we notice that x is $> a$, so that in equation (a), we must put $(l-a)$ for a and $(l-x)$, which, in this case, is l_1, for x, a proceeding which is equivalent to measuring distances from the right hand end. Thus—

$$v^1_W = \frac{Wal_1}{6l\,EI}\left\{2l\,(l-a) - l_1^2 - (l-a)^2\right\}$$

$$= \frac{Wal_1}{6l\,EI}\,(l^2 - a^2 - l_1^2).$$

Then—

$$v_W + v^1_W = \frac{Wl_1}{6\,EI}\,(3al - l_1^2 - 3a^2).$$

To find v_R, we write, in (a), R_2 for W, l for x and for a, thus obtaining—

$$v_R = \frac{R_2 l_1\,(l - l_1)}{6l\,EI}\,(2ll_1 - l^2 - l_1^2)$$

$$= \frac{2\,R_2 l_1^2\,(l-l_1)^2}{6l\,EI}.$$

To find v'_R we write, in (a), R_2 for W, $(l - l_1)$ for a, and l_1 for x, thus obtaining—

$$v'_R = \frac{R_2 l_1^2}{6 l E I}\left\{2l(l - l_1) - l_1^2 - (l - l_1)^2\right\}$$
$$= \frac{R_2 l_1^2}{6 l E I}(l^2 - 2l_1).$$

Hence—

$$v_R + v'_R = \frac{R_2 l_1^2}{6 E I}(3l - 4l_1),$$

and, since—

$$v_R + v'_R = \frac{1}{2}(v_W + v_W)$$

$$\therefore\ R_2 l_1 (3l - 4l_1) = \frac{1}{2} W (3a l - l_1^2 - 3a^2)$$

$$\therefore\ R_2 = W \frac{3al - l_1^2 - 3a^2}{2l_1 (3l - 4l_1)}.$$

Then, by means of the ordinary statical equations, we can find R_1 and R_3, and, hence, the bending moments at various parts of the beam.

The forces, R_1 and R_3, are those portions of the vertical components of the tensions in the inclined rods which hold the ends of the beam down: the remaining portions of the said vertical components are equal to the supporting forces at the abutments. It is clear that, when the load is between the posts, the tension in the rods is greater than it would be if the structure were completely braced and the load had a panel point beneath it.

The force R_2 is the vertical component of the compressive stress in each of the posts. In a given case, therefore, the stress in the posts is readily found, and, from that, the stress in the tension rods.

On the diagram, Fig. 13, is plotted a curve, representing the values of the bending moments at mid-span, when the load is there: also, another curve, giving bending moments at top of post when the load occupies that position. These values of the bending moments correspond to different positions of the posts. The abscissæ in the diagram represent values of l_1—*i.e.*, of the distance between post and end of beam: the ordinates represent bending moments. This diagram will be compared, presently, with that on Fig. 16, which represents bending moments between post and abutment as the load moves from one towards the other. Confining our attention, for the present, to Fig. 13, we observe that, if the posts be placed at $0{\cdot}385l$ from the ends, the bending moment at mid-span, when the load is there, is equal to that at a post when the load is there, the common value of the bending moment being $0{\cdot}044\,Wl$. But we shall find, when examining Fig. 16, that, if the posts be placed so far from the ends as $0{\cdot}385l$, then, when the load comes between an abutment and a post, a much greater bending moment than $0{\cdot}044\,Wl$ will be endured by the beam, and thus it is seen that the condition of equal maxima bending moments, over a post and at mid-span, is far from giving the most favourable spacing of the posts.

It is seen from the diagram that of all the values l_1 may have, that which corresponds to the greatest bending moment over a post, when an isolated load is there, is the value $\frac{l}{4}$. This might be inferred from the fact that, by symmetry, the point of contrary flexure, when the load is over a post, is at mid-span. Or it may be proved thus:—Putting l_1 for a in the expression for R_2, we get—

$$R_2 = \frac{W}{2}.$$

Taking moments about left hand end—

$$R_3 l + W l_1 = \frac{W}{2} l.$$

$$\therefore R_3 = W \frac{l - 2l_1}{2l}$$

Bending moment over post $= R_3 l_1$

$$= \frac{W}{2l}(l l_1 - 2 l_1^2)$$

Differentiating this, with respect to l_1, and equating to 0, we get—

$$l - 4l_1 = 0;$$

$$i.e.\ l_1 = \frac{l}{4};$$

and the second differential coefficient is negative; therefore, this value of l_1 corresponds to a maximum value of the bending moment over a post when the load is over that post.

(*b*) When the load is between an abutment and a post (*see* Figs. 14 and 15), v_R and $v^1{}_R$ will have the same value as in the previous case.

Equation (a) cannot be directly made use of to find v_W and $v^1{}_W$ in the case shown in Fig. 14, because $x < a$; but we can deal with the case shown in Fig. 15 directly by means of equation (a), and then substitute $(l-a)$ for a, thus obtaining values of v_W and $v^1{}_W$ applicable to the case shown in Fig. 14.

Referring to Fig. 15, putting $(l-l_1)$ for x in equation (a), we obtain an expression for the deflection at C, due to W, which we may call v_W, because the deflection at C, in Fig. 15, will correspond to the deflection at B in Fig. 14—

$$v_W = \frac{W(l-l_1)(l-a)}{6l\,EI}\left\{2al - (l-l_1)^2 - a^2\right\};$$

and, putting $(l-a)$ for a, in order to transfer the origin to the right hand end, or, what is the same thing, to deduce a formula, applicable to Fig. 14—

$$v_W = \frac{W\,(l-l_1)\,a}{6l\,EI}\left\{2l\,(l-a) - (l-l_1)^2 + (l-a)^2\right\}$$

$$= \frac{W\,(l-l_1)\,a}{6l\,EI}\,(2l l_1 - l_1^2 - a^2).$$

Referring again to Fig. 15, putting l_1 for x in equation (a), we obtain an expression for the deflection at B, which we shall call $v^1{}_W$, because the deflection at B, due to W in Fig. 15, corresponds to the deflection at C, due to W in Fig. 14—

$$v^1_W = \frac{W l_1 (l - a)}{6l\,EI} (2al - l_1^2 - a^2);$$

and, putting $(l-a)$ for a, in order to transfer the origin to the right hand end, or, what is the same thing, to obtain a formula applicable to Fig. 14—

$$v^1_W = \frac{W l_1 a}{6l\,EI} \left\{ 2l(l-a) - l_1^2 - (l-a)^2 \right\}$$

$$= \frac{W l_1 a}{6l\,EI} (l^2 - l_1^2 - a^2).$$

$$v_W + v^1_W = \frac{Wa}{6l\,EI} (3l^2 l_1 - 3l l_1^2 - a^2 l)$$

and, as in previous calculation—

$$v_R + v^1_R = \frac{R_2 l_1^2}{6\,EI} (3l - 4l_1)$$

$$= \frac{1}{2} (v_W + v^1_W)$$

$$\therefore R_2 = W \frac{3(l - l_1) l_1 a - a^3}{2l_1^2 (3l - 4l_1)}$$

This equation for R_2, combined with the ordinary statical equations, enables us to calculate the bending moment at any point between an abutment and a post, as the load moves from one of these points to another.

The diagram, Fig. 16, shows portions of a few curves, each of which corresponds to a certain value of l_1, *i.e.*, to a certain spacing of the posts. The abscissæ represent different distances of the load from an abutment: ordinates represent bending moments. In this way, we ascertain, graphically, what position the load on one of the end bays corresponds to a maximum value of the bending moment at the point of application of the load.

This diagram has to be considered simultaneously with that in Fig. 13. Comparing them, with the object of finding what spacing of the posts would correspond to equality of bending moment at mid-span and in end bay, under a moving load, we find that, when $l_1 = 0{\cdot}247l$, these two bending moments are equal. This is found in Fig. 16 by interpolation between the curves for $l_1 = {\cdot}24l$ and $l_1 = {\cdot}25l$. The load is at about two-thirds of the length of the end bay, *i.e.*, $\frac{2}{3}$ of l_1, from the end of the beam, when the maximum bending moment occurs in the end bay. The common value of the bending moments, here referred to, is 0·079 Wl. Fig. 13 shows that any lesser value of l_1 than 0·247 l_1 corresponds to a greater bending moment at mid-span than 0·079 Wl, while Fig. 16 shows that any greater value of l_1 than 0·247 l corresponds to a greater bending moment in the end bay than 0·079 Wl. The diagram in Fig. 13 also shows that the bending moment at a post, when the load is there, is, for the said spacing of the posts, much less than the bending moment at mid-span or the maximum one in the end bay when the load is at these latter points. We conclude, therefore, that the best positions for the posts, so far as an isolated load is concerned, are those at 0·247 l from each end.

In Fig. 14, R_1, plus the vertical component of the tension in the rod, is equal to the actual supporting force afforded by the adjacent abutment. R_3 is that portion of the vertical component of the tension in the rod which holds the beam down: the remainder of that vertical component is the actual supporting force afforded by the abutment adjacent to R_3.

The formula for R_2 for the case where there is a single post may be deduced from that last found by putting $\frac{l}{2}$ for l_1.

$$\text{Then } R_2 = W \frac{3 \times \frac{l}{2} \times \frac{l}{2} \times a - a^3}{2 \frac{l^2}{4} \left(3l - 4 \frac{l}{2}\right)}$$

$$= \frac{Wa}{l^3} \cdot \frac{3l^2 - 4a^2}{2}$$

And, as this represents the stress in each half of the single post, formed by bringing two posts together, we have, for the whole stress in the post—

$$R_2 = \frac{Wa}{l^3} \ (3l^2 - 4a^2),$$

which is the expression previously found for the single post truss.

B.—Uniformly Distributed Load.

This case differs from that in which a beam is supported symmetrically at two points, while its ends overhang, in that the ends, in the trussed beam, are kept at a fixed level, viz., the level of the top of the posts. They must be held down to that level by the tension rods if the posts are nearer to the ends than 0·2143 l, as will be shown later on. On the other hand, if the posts are further from the ends than the said distance, the abutments keep the ends up to the said level. The latter case is that of a continuous beam, supported at the ends and at two points equidistant from the ends; but this does not appear to be one of the examples chosen by writers of text-books to illustrate the subject of continuous beams.

As in the cases previously considered, we shall make use of the work done by writers of text-books as far as that work is of service to us. In Lanza's "Applied Mechanics," 3rd edition, p. 293, equation (2) gives the deflection at a point, distant x from the end of a beam which is uniformly loaded and supported at the ends, viz.—

$$v = \frac{W}{24\,EI} \ (2lx^3 - x^4 - l^3x)\,;$$

where W is the load, per unit of length, and the other symbols have the same meanings as before.

But, by reason of the convention as to signs, which Lanza adopted, this expression for v is negative, and, as before, for convenience, we shall employ its positive value, and, hereafter, we shall make use of the formula—

$$v = \frac{W}{24\,EI} \ (x^4 - 2lx^3 + l^3x) \ . \ . \ . \ (\beta).$$

The two ordinary statical equations, formed by summing up forces acting transversely to the beam and by taking moments, are identical in this case, and of a simple character, provided we know whether R_1 and R_3, which are equal, act upwards or downwards, and this can readily be determined, as will be explained shortly. We need, however, an additional equation, for there are two unknown forces, viz., R_2 and R_1 (or R_3). This equation is to express that the beam, at the tops of the posts, is at the same level as at the abutments; *i.e.*, the downward deflection at B, which the distributed load would cause, if it alone acted on the beam, the latter being merely supported at the ends, is equal to the sum of the upward deflections that R_2, at B, and R_2, at C, would separately cause at B, if the beam were acted on by these two forces, R_2, and held down at the ends.

Let v_W be the deflection that the load wl would cause at B. Let v_R be the rise that would be due to R_2 at B, and v'_R the rise due to R_2 at C; then—

$$v_W = v_R + v'_R$$

v_W is obtained by putting l_1 for x in (B), viz.—

$$v_W = \frac{Wl^1}{24\,EI}\,(l_1^2 - 2ll_1^2 + l^3).$$

The sum, $v_R + v'_R$, will be expressed by the same symbols as when the isolated load was considered, viz.—

$$v_R + v'_R = \frac{R_2\,l_1^2}{6\,EI}\,(3l - 4l_1)$$

Equating the values of v_W and $(v_R + v'_R)$, we obtain—

$$R_2 = \frac{w\,(l_1^3 - 2ll_1^2 + l_3}{4l_1\,(3l - 4l_1)}.$$

In a given case, knowing R_2, we see, at once, whether R_1 and R_3 act upwards or downwards, because, if R_2 exceeds $\frac{wl}{2}$, then R_1 and and R_3 must act downwards, and *vice versâ.*

To find where the posts should be placed, in order that R_1 and and R_3 should vanish; in other words, to find where the supports should be placed, under a uniformly loaded beam, in order that the beam should be at the same level at the top of the posts as at the ends; or—expressing it in yet another way—to find, in a trussed beam, where the posts should be placed in order that no portion of the load should be transmitted to the abutments by the beam, acting as a beam, and, at the same time, no part of the vertical component of the tension in the rods be employed in holding the ends of the beam down, but the said vertical component be equal to the actual supporting force afforded by the abutments, we must equate—

R_2 to $\frac{wl}{2}$

$$i.e.\ \frac{l_1^3 - 2ll_1^2 + l^3}{2l_1\,(3l - 4l_1)}$$

from which we get—

$$l_1^3 + 6ll_1^2 - 6l^2l_1 + l^3 = 0$$

We can simplify this equation, for solution, graphically, by writing $l_1 = nl$, and solving the resulting equation for n, viz:—

$$n^3 + 6n^2 - 6n + 1 = 0.$$

A few values of this expression are calculated for different values of n, and the results plotted in Fig. 18. There, the abscissæ represent values of l_1 and ordinates values of $n^3 + 6n^2 - 6n \times l$. The value of l_1, for which this expression vanishes, is about $0{\cdot}2143\,l$. For any value of l_1, greater than this, R_1 and R_3 will act upwards. For any lesser value, they will act downwards.

$$\text{If, then } l_1 > 0{\cdot}2143l,\ R_1 = R_3 = \frac{wl}{2} - R_2$$

$$\text{and if } l_1 < 0{\cdot}2143l,\ R_1 = R_3' = R_2 - \frac{wl}{2}.$$

We can, next, readily find the bending moment at any point of the beam. Calculating a few values for the bending moments, corresponding to certain values of l_1, we obtain two of the curves, shown on Fig 19, where abscissæ represent values of l_1, and ordinates represent bending moments. One of the said curves shows the bending moments at mid-span; the other shows them at the posts. It will be observed that the bending moments at the posts exceed those at mid-span for all values of l_1, and that the minimum value of the bending moment at a post corresponds to the value $0{\cdot}357l$ for l_1.

We shall next investigate the bending moments in the end bays, corresponding to different values of l_1, and, with this information, added to the foregoing, we shall decide as to the most favourable positions for the posts, having regard to all the bending moments endured by the beam.

Bending Moments in End Bays.—We have seen that, when the posts are further from the ends than $0{\cdot}2143\,l$, the forces R_1 and R_3, act upwards. For any given value of l_1, then, greater than $0{\cdot}2143l$, the bending moment in the end bay will be a maximum at some particular point in that bay. The expression for the bending moment in the end bay, at a distance, x, from the end, is—

$$R_1 x - \frac{wx^2}{2} = M, \text{ say.}$$

To find for what value of x M is a maximum, we write—

$$\frac{dM}{dx} = R_1 - wx = 0$$

and notice that $\frac{d^2M}{dx^2}$ is negative; therefore M is a maximum when

$x = \frac{R_1}{w}$, and the value of M is then $\frac{R_1^2}{2w}$.

Calculating a few values of this bending moment for certain values of l_1, and plotting them, we obtain the curve marked "Max. B.Ms. in end bay" in Fig. 19. We observe that this curve crosses both of the curves previously plotted. The most important point on this diagram for our purpose is that at $0{\cdot}357l$, where the curve of maximum bending moments in end bay cuts the curve of bending moments at top of post. We see that, when the posts are placed $0{\cdot}357\,l$ from the ends of the beam, the bending moment over a post is equal to the maximum bending moment in the end bay, and the bending moment at mid-span is a very small negative quantity, *i.e.*, the beam, at mid-span, is slightly bent upwards. It is clear, from the diagram, that, moving the posts nearer the ends than 0·357 l increases the bending moment over the post, and, also, the bending moment at mid-span, while moving the posts further away from the ends increases both the bending moment over the post and that in the end bay.

We conclude, then, that the most favourable positions for the posts to occupy, when the load is uniformly distributed, is 0·357 l from each end. The bending moment is then 0·01 wl^2.

By "most favourable positions for the posts," we mean favourable so far as *bending* stresses in the beam are concerned. The *direct* stresses will be less in a single-post truss than in any double-post truss, provided the inclination of the tension rods to the horizontal is the same.

We saw, previously, that, for an isolated load, the most favourable positions for the posts, so far as bending of the beam is concerned, is at one-fourth and three-fourths of the span. If, then, a structure is to be designed to carry, sometimes, a distributed load and sometimes an isolated load, we must ascertain the magnitude of the bending moments, under both circumstances, and so space the posts as to reduce to a minimum the bending moments in the beam.

Referring, again, to Fig. 19, we observe that the bending moment over a post is again equal to the maximum bending moment in the end bay when $l_1 = 0·425\, l$; but the common value of the bending moment, in this case, is greater than when $l_1 = 0·357\, l$. Posts, at 0·425 l from the ends, would be still less suited for isolated loads than those at 0·357 l from the ends.

We observe, further, that, if the posts be placed 0·307 l from the ends, the bending moment, at mid-span, and the maximum bending moment in an end bay are equal, the corresponding value of the bending moment over a post being somewhat greater than when the posts are 0·357 l from the ends. The difference is about 0·001 wl^2. 0·307 l, from each end, would, therefore, not be an unsuitable position for each post, especially if the structure be sometimes subjected to the imposition of an isolated load.

In the case of a double-post trussed beam, as in that of a single-post one, if the moments of the external forces, acting on the structure, on one side of a vertical section through a point of contrary flexure, be taken about that section, then that moment, *i.e.*, the bending moment on the structure, as a whole, will be equal to the moment of the couple whose force is the compressive stress in the top beam (or the equal horizontal component of the stress in the tension member), multiplied by the vertical distance between the neutral axis in the beam and the centre of the tension member.

Comparison of Single and Double Post Trussed Beams.

This is best effected by summarising the principal results so far obtained. Such a summary is shown on the diagram containing Figs. 21-23, 25-26.

Comparing bridges of the same span, one with a single post and the other with two posts, the advantage lies with the double-post bridge, so far as bending stresses in the beam are concerned. This is true, no matter what the inclination of the rods at the ends may be, provided longitudinal extension and compression of the members may be neglected. The reverse is the case with regard to the longitudinal stresses in rods and beam: these are greater, under both central and distributed loads, in the case of the double-post trussed beam, if the inclination of the rods at the ends are the same in both single and double post structures.

Case III.—Trussed Beam, with Three Posts.

(*See* Figures 3 and 3a, 27, 28, and 29.)

The writer has not had time yet to fully investigate this case, but hopes to do so before long. It would be desirable to ascertain the best spacing of the posts, under an isolated load and under a uniformly distributed load; also, to compare expressions for bending moments, in this case, with those in the cases of single and double post trusssed beams, and thus determine the advantages arising from multiplying posts. In the meantime, a method of finding the stresses may be indicated.

Take the case where the posts bisect the angles between adjacent sections of tension rod, and the rods make equal angles with each other; then, by symmetry, the tensions in all sections of the rods must be equal, and the compressive stresses in the posts must be equal. Therefore, if R_2 denotes the compressive stress common to the three posts, $R_2 \cos \frac{\theta}{2}$ will be the vertical component of the compressive stresses in the two outer posts. W and θ being known, we must form three equations to determine the unknown quantities, R_1, R_2, and R_3. Summing up forces in opposite directions and taking moments will give us two equations. For the third equation, we have to express a relation among the deflections at the tops of the posts, assuming inextensibility and incompressibility.

This relation will be that existing at the joints, *b, c, d,* of an inextensible chain, whose links have the lengths and slopes that the sections of the tension rod have. (*See* Fig. 27.)

If the loading be symmetrical, if c goes downwards, or upwards, through a distance δy, then b and d will rise or fall through a distance δh, and the relation between δy and δh, under these circumstances, is found as follows, viz.—

Referring to Fig. 27—

$$\lambda_1 \cos\theta + \lambda_2 \cos\phi = \frac{l}{2}$$

$$\therefore \lambda_1 \sin\theta .\ \delta\theta + \lambda_2 \sin\phi .\ \delta\phi = 0 \quad . \ . \ (1)$$

$$h = \lambda_1 \sin\theta$$

$$y = \lambda_1 \sin\theta + \lambda_2 \sin\phi$$

$$\therefore \delta h = \lambda_1 \cos\theta .\ d\theta \quad . \ . \ . \ (2)$$

$$\delta y - \delta h = \lambda_2 \cos\phi .\ \delta\phi \quad . \ . \ . \ (3)$$

From (1), (2), and (3), we deduce

$$\delta h = \delta y \frac{\sin\phi \cos\theta}{\sin(\phi - \theta)}$$

Trussed Beams

Paper by Geo. Higgins

1909

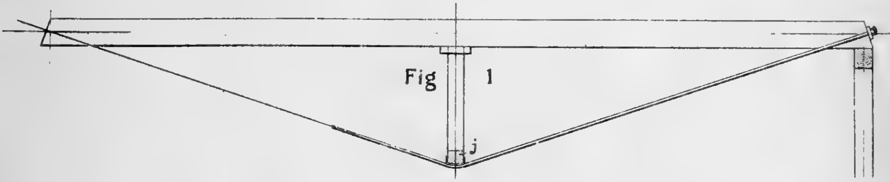


Fig 1

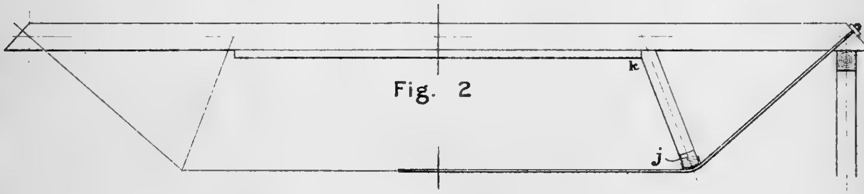


Fig. 2

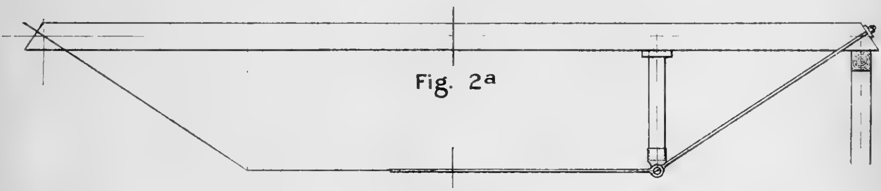


Fig. 2a

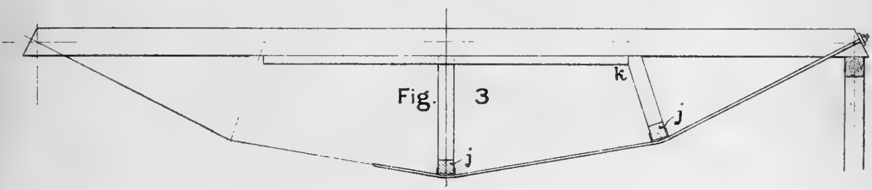


Fig. 3

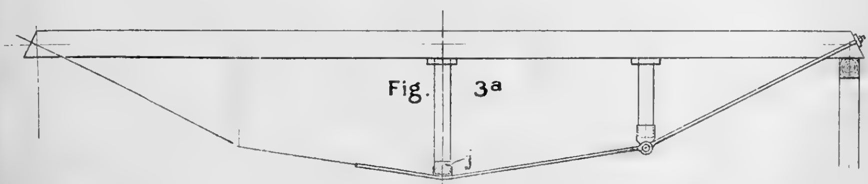
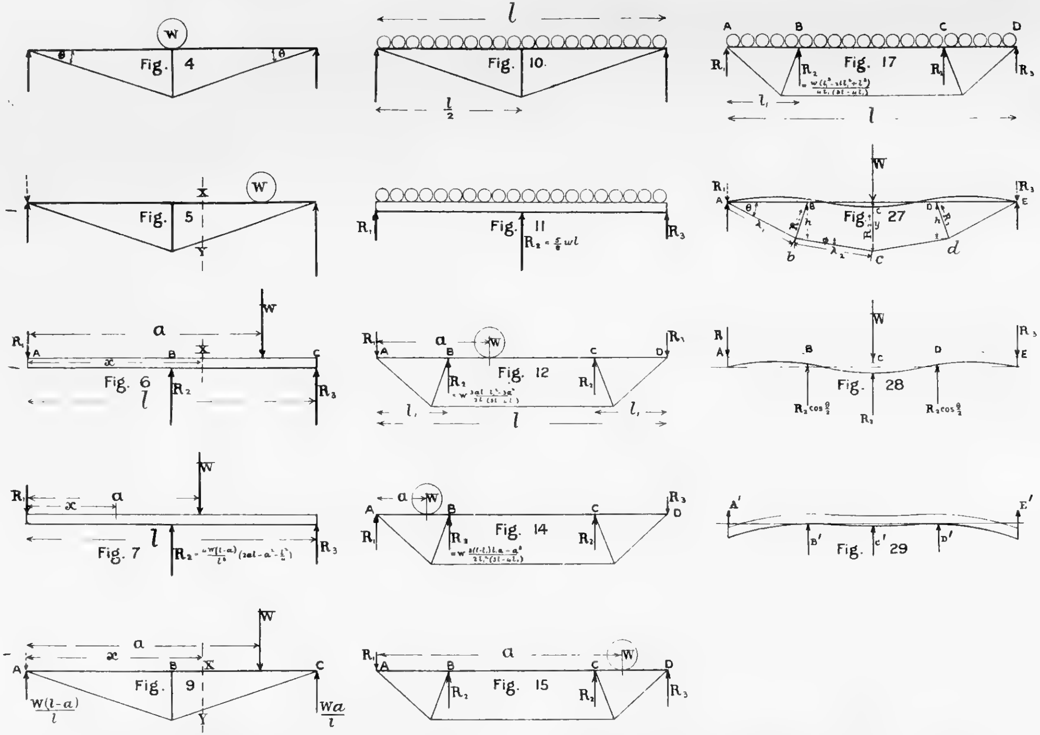


Fig. 3a

Trussed Beams

Paper by Geo. Higgins
1909



Trussed Beam with Single Post

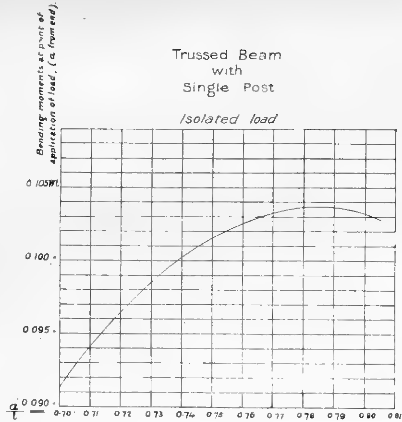


Fig. 8

Trussed Beam with two posts

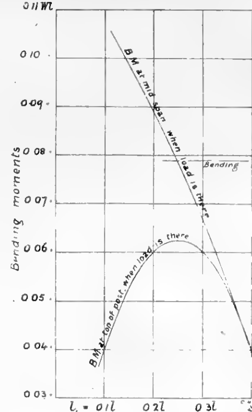


Fig. 13

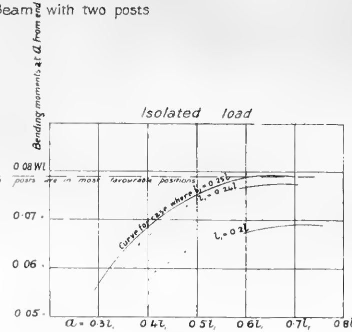


Fig. 16

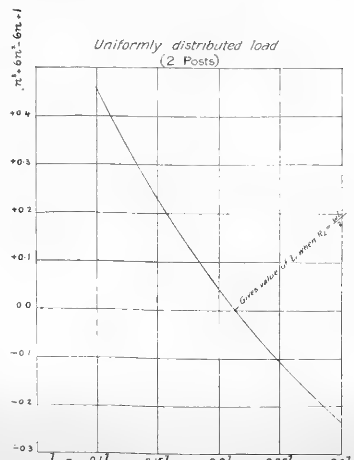


Fig. 18

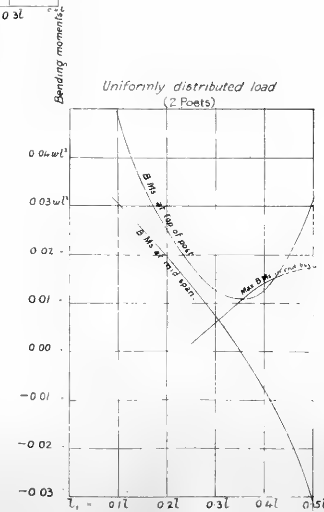
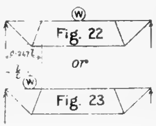
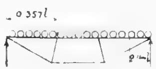


Fig. 19

Figure	Maxima bending moments		Other bending moments		Maximum Vertical Component of Compressive stress in post	Remarks
	Position	Amount	Position	Amount		
 Fig. 21	Under load shown	$0{\cdot}1037\,Wl$			W	Compressive stress in post $= \frac{Wa}{l^3}(3l^2-4a^2)$ a being less than $\frac{l}{2}$
 Fig. 22 or Fig. 23	Under loads shown	$0{\cdot}079\,Wl$			$0{\cdot}693\,W$	Posts shown in most favourable position for isolated loads so far as the beam is concerned
 Fig. 25	At top of post	$0{\cdot}03125\,wl^2$	At $\frac{3}{16}l$ from ends (max.)	$0{\cdot}0176\,wl^2$	$0{\cdot}625\,wl$	
 Fig. 26	At top of posts and at $0{\cdot}144l$ from ends	$0{\cdot}01\,wl^2$	At mid span	$0{\cdot}00033\,wl^2$	$0{\cdot}356\,wl$	Posts shown in most favourable position for distributed loads so far as beam is concerned. $0{\cdot}307l$ from ends is also a good position for the posts, but not quite so good as $0{\cdot}357l$

The writer is indebted to Professor Nanson for this simple formula expressing the relation between δh and δy, when the loading is symmetrical.

As an example of unsymmetrical loading, take the case when the load, W, is at B: then, if we neglect squares and higher powers of small quantities, it will be found that d will rise as much as b will fall, and c will remain nearly unchanged in height. Reasoning, similar to that given above, shows that this will not be far from the truth when the deflections are small. This whole matter has still, however, to be worked out. Perhaps a closer approximation may be found necessary.

It is evident that the maximum tension in the rods—in fact, the maxima longitudinal stresses throughout—occur when the isolated load is at C, because, then, no portion of the load is transmitted to the abutments by the beam, acting as a beam.

An Experimental Method of Determining Stresses in Trussed Beams, similar to that frequently employed in solving problems connected with ordinary continuous beams, gives a sufficiently close approximation to the stresses in definite cases. Possibly, when there are three, or more, posts, this method may prove more convenient than the mathematical one. As an illustration, a description may be given of the way in which the forces, R_1, R_2, and R_3, have been determined in the case of a triple-post trussed beam, loaded with a central load. For this method, one requires, in the first place, a uniform, flexible bar; secondly, a firm, level surface to work on; thirdly, a number of short columns of equal height; fourthly, a number of weights; and fifthly, several accurate spring balances.

The bar requires to be flexible, because, in most cases, the accuracy of our work depends upon our measurement of the heights of various parts of it above the level surface, and, the more flexible the bar is, the less effect upon the result will a small error in this measurement have. A steel straight-edge, about 6 ft. long, such as is used in a drawing office, answers the purpose well. The writer has also seen a long, straight-grained strip of wood used for a similar purpose.

Referring to the curved lines in Figs. 27 and 28, where the deflections of the beam are shown on an exaggerated scale, it will be seen that, under the central load, there assumed, the points A and E, only, will remain at their original level; C will fall below that level; B and D will rise above it.

We may, first, determine values of R_1, R_2, and R_3, corresponding to different values of W, without allowing for the weight of the beam, and, afterwards, modify our results in such a way as to allow for this.

We have R_1 $(=R_3)$ and W, acting downwards, and R_2 acting upwards at C, $R_2 \cos\frac{\theta}{2}$ acting upwards at B and D (Fig. 28).

We apply weights at A, C, and E, and support the points B, C, and D by means of spring balances.

The weights applied at A and E are equal in each experiment, while the weight at C is adjusted, relatively to them, until the spring balances at B, C, and D show upward forces acting there, nearly in the proportion $\cos\frac{\theta}{2} : 1 : \cos\frac{\theta}{2}$.

Different combinations of weights at A, C, and E are experimented with, and each combination is tested four times, one result being obtained with the beam in one position, a second with the beam turned upside down, a third with the beam turned end for end, and a fourth with it again turned upside down. This process eliminates the effects of any want of uniformity in the beam.

We average the results obtained in this way.

Next, *to eliminate the effect of the beam's own weight* (*see* Fig. 29). If the beam were weightless, it would be level when supported at B, C, and D, before any weights are applied. Not being weightless, it assumes a form, resembling that shown in an exaggerated way in Fig. 29. Certain forces would be required at the ends and middle to bring these points level with the tops of the posts. The beam will not even then be quite level, because there will be sagging at intermediate points; but if, by means of spring balances, forces, A^1, B^1, C^1, D^1, and E^1 be measured, and compounded with the forces R_1, $R_2 \cos\frac{\theta}{2}$, R_2, &c., previously found, we obtain a result, approximately free from the effects of the beam's own weight. This compounding is to be performed as follows, viz. :—

(1) Subtract C^1 from the reading obtained with the spring balance at mid-span, and thus obtain a corrected value for R_2.

(2) Subtract B^1 and D^1 from the readings of the spring balances at B and D, and thus get a corrected value for $R_2 \cos\frac{\theta}{2}$.

(3) Add A^1 and E^1 to the weight applied at the ends, and thus obtain corrected values for R_1 and R_3.

A^1, B^1, &c., are taken to be the averages of the values obtained with the bar in four different positions, these positions being obtained by turning the bar upside down and reversing, end for end.

Strictly, the forces $(R_2 - C^1)$, $(R_2 \cos\frac{\theta}{2} - B^1)$ and $(R_2 \cos\frac{\theta}{2} - D^1)$ should be in the proportion $\cos\frac{\theta}{2} : 1 : \cos\frac{\theta}{2}$; and, if the results vary much from this, we may have to find, by repeated trials, values for the weights and forces, measured by spring balances, which will ultimately satisfy this condition.

Concluding Remarks.

At the commencement of this paper, it was said that the use of trussed beams was likely to increase. This opinion was based upon the cheapness of structures of this type as compared with short braced composite girders, or with beam bridges whose piers are close together. A completely braced girder may contain less timber and steel than a trussed beam of the same span; but the labour in constructing the girder is very much greater than that required to construct the trussed beam, and the material cut to waste when shaping the smaller members of the braced girder might go far towards making up for the greater amount of material put into the trussed beam. Compared with a beam bridge, on pile piers, when the weight of the piles and the labour in driving them are considered, the advantage will frequently lie with the trussed beam.

In some parts of Australia the beams may be round trees, grown not far from the bridge site and rolled into position. The site may be difficult of access—one to which the conveyance of a pile engine might be a costly matter; and to cut up timber on the spot, in order to construct a pile engine, would involve nearly as much labour as building a completely braced girder. Even if it be urged that, when selecting pieces for a braced girder, heart and sap-wood may be avoided, yet, if timber is abundant, as it sometimes is, a certain excess of material may be permitted in the beam to be trussed, which will practically amount to ignoring the sap-wood in considering the strength of the beam, if any sap-wood is left on it.

Want of headroom may, of course, preclude the use of any structure in which the trussing is below the deck. If the roadway be wide, as compared with the length of span, and if an intermediate girder in the middle of the roadway is objected to, then the cross beams must be deep. It may be that the combined depth of stringers and cross-beams, in such a case, would be quite as great as the depth of suitable trussed beams, placed longitudinally, but close together. The latter may be placed so close together under the deck that nothing but the planking need be placed on top of them. Shallowness, of course, involves severer stresses and greater weight of material, both of steel and timber, and the cost of this has to be compared with the saving of labour claimed for the trussed beam.

The *details*, in the case of a trussed beam, are of an exceedingly simple character. Two tension rods to one beam would be preferable to one rod if the boring of the holes for the latter would be attended with difficulty. Little need be said about the joint at the end of the beam, which can easily be designed. The joints at the feet of the posts need pins, or other firm attachments, to prevent slipping, if the posts are vertical, as in Figs. 2a and 3a. Otherwise, if the posts are caused to bisect the angles between adjacent sections of tension rods, the rods need only pass underneath the posts, being prevented from slipping sideways. If unusual vibration is expected, then special precautions must be taken to render this joint secure. Wooden posts, with tension rods under them, would be apt to split along the grain. Some shoe would then be necessary, or, in the case of a bridge, where several trussed beams are placed side by side, a piece of timber might be introduced, as at *j* in Figs. 1, 2, 3, and 3a, transversely to the bridge, passing under the feet of the similarly placed posts. These would hold the trussed beams together, and, where wind bracing is necessary, these transverse timbers could be connected together by diagonal tie rods or timber struts.

A simple joint for connecting the posts to the beams is shown at R on Figs. 2 and 3, where a small straining piece is introduced. This is preferable to notching the main beam, which would weaken it. Moreover, if the structure is to be a temporary one, it is desirable to avoid cutting the beam. Seeing that the posts always endure equal stresses, the bolts, which attach the straining piece to the main beam, are not called upon to take any part of the thrust in the posts.

It is clear that, if diagonals be introduced at the centre panel in Figs. 2 and 2a, the joints become very much more difficult to make, especially that at the top of the post, and the beam becomes considerably cut into and weakened.

In trussed beams, then, so far as the *timber work* is concerned, the bridge carpenters' work is of a very simple kind. The *steel* or *iron work* would offer little difficulty to a blacksmith. If the rods would be unwieldy for transporting one length, pin-joints could be introduced at one or more points, but these add to the first cost.

Other Imperfectly-braced Structures.

The reversed trussed beam becomes an unbraced Queen-post truss, the stresses in which can be calculated in a way quite similar to that explained in the foregoing pages. The tension member is here horizontal, and it is relied on to resist the bending action of the loads.

In the first place, it may be laid down that no tension member should ever be made of timber, because no reliance can be placed upon its resistance to shearing along the grain, in consequence of the tendency of timber to open in longitudinal cracks. No ordinary factor of safety will allow for this. But, on the other hand, if we make the tension member of steel or iron, its section will not be a suitable one for a beam to resist bending.

Stringers, placed on cross-beams, may be made strong enough to act as beams; but, in order that they may be most effective, they must be anchored down at the ends. In fact, to make the stringers behave, in relation to the Queen-post truss, in the same way as the beam in the structure called the "trussed beam," we should introduce a stout cross-beam under the feet of the batter braces at each end of the bridge, and we should securely bolt the stringers down to these.

Or we may make the bottom member of the Queen-post truss composite in character, the tension being taken by metal and the bending by the beam, the two members lying side by side, or the steel on top of the beam.

In all that has been written, it has been taken for granted that no initial stress has been introduced, such, for instance, as that which would be caused by tightening up the nuts on the tension rods, or such as would be caused by leaving the nuts on the rods slack, thus producing initial bending stresses in the beam. These initial stresses would, of course, modify the results, just as in the case of a braced girder, having pin-joints, if the members are not perfectly made, some may be too long, requiring to be compressed into their places, and others may be too short, so requiring to be stretched, thus modifying the values of the stresses calculated in the ordinary way.

Should there be initial stress, it must be ascertained, or estimated as accurately as possible, and its amount added to, or subtracted from, those calculated, as may be necessary.

The writer has to apologise for bringing a partially completed paper before the meeting. It was with difficulty that time was found for carrying the investigation so far even as it has been carried. He felt the need of some simple treatment of this subject, and he hopes that the little he has done may help to advance this branch of engineering science. He would especially invite criticism as to the assumption of inextensibility and incompressibility, *i.e.*, as to whether or not the stresses calculated upon this assumption are sufficiently accurate for the determination of the dimensions of the members. In very shallow structures, an estimate may be made of the deflection of the whole by reason of extensions and compressions throughout, using, for this purpose, average values of the moduli of elasticity. Then, in the case, say, of the double-post trussed beam, instead of equating the drop at one post to the rise at the other, we would introduce a term for the drop due to the said extensions and compressions.

2.—REINFORCED CONCRETE—THE STRENGTH OF BEAMS.

By W. J. DOAK, B.E., Assoc. M. Inst. C.E.

I propose to consider the ordinary elastic theory of beams as modified for reinforced concrete.

The well-established formula $M = f\frac{I}{y}$ for beams of all sections, or $M = \frac{1}{6}bd^2f$ for beams of rectangular section, depends upon two principal assumptions—

1. Navier's hypothesis that a section of a beam normal to the neutral axis plane before bending remains plane after bending.
2. Hooke's Law—that stress is proportional to strain within the elastic limit.

From the first it follows that strains are proportional to distance from neutral axis, and from the second that stresses are also proportional to distance from the neutral axis.

Experiments made by Talbot, Schule, and others show that Navier's hypothesis does not hold absolutely for concrete beams, and Professor Warren's tests at the Sydney University in 1906 also show that plane sections become slightly curved.

It is generally conceded, however, that for purposes of calculation Navier's hypothesis may be accepted.

As regards Hooke's Law, it may safely be said that it is not perfectly true for any known material. Even with steel, an experiment in bending, say, a piece of rail, with careful observation of deflections, will show that the stress strain line has a small curvature well within the elastic limit on the first application of the load: on gradually unloading and reloading several times it will be found that the stress strain diagram ultimately becomes straight.

Concrete exhibits something of the same phenomenon, but in a much more marked degree. Tests made to determine the elasticity of concrete show that the elastic limit as ordinarily understood is either non-existent or else very small; that is to say, the stress strain diagram is curved from the beginning.

Now there is no obvious reason why the only elastic law should be Hooke's Straight Line Law.

A material would deserve to be classed as elastic if it always within limits followed a law that stress was proportional to square of strain, to square root of strain, or to any function of strain. The experiment then to make is to subject it to repetitions of stress to ascertain whether there is any such law. The result will certainly be disappointing, for it has always been found that permanent deformations take place after each of the first few applications of load. Fortunately, however, if enough applications are made, the stress strain diagram settles down to practically a straight line, so that Hooke's Law expresses the facts very closely up to the stresses to which the concrete has been loaded. Were this not so, concrete could not be called an elastic material, and engineers would hardly be justified in using it in structures intended to be permanent. It may be argued that timber is an imperfectly elastic material, and is nevertheless used without hesitation in first-class structures. Concrete, however, resembles in its crystalline structure metal much more than a fibrous organic material like timber. Possibly, too, experiment would prove that repeated applications of loading develop a true elasticity in timber; at all events, timber girders in railway bridges carry heavy loads for many years without visible increase in the permanent set brought about by the first few loadings.

In the November, 1908, number of "Concrete" I noticed a description of tests of an important wharf at Brocklebank, Liverpool.

The following is a quotation from it:—"The wharf was designed for a working superload of $6\frac{2}{3}$ cwt. per square foot, the test load being specified at 10 cwt. per square foot. The resulting deflection in the main transverse beam was $\frac{1}{4}$ in., and the set immediately after removal of load $\frac{1}{8}$ in. only. In the four secondary beams the deflections were $\frac{1}{4}$, $\frac{3}{16}$, $\frac{1}{4}$, and $\frac{1}{8}$ in. respectively, and the corresponding amounts of set on removal of the load $\frac{3}{32}$, $\frac{1}{16}$, nil, and $\frac{1}{16}$ in. At the middle of the two deck panels the deflections were $\frac{3}{16}$ in. and $\frac{1}{4}$ in., the corresponding set on removal of load being $\frac{1}{16}$ and $\frac{3}{32}$ in. respectively."

These tests show that a considerable permanent set, larger proportionately than we would care for in a steel or even in a timber structure, may be expected in reinforced concrete beams when loaded for the first time, but our knowledge of the elastic properties then acquired by the concrete justifies the belief that no further set will take place unless a heavier load is imposed.

It is interesting to compare this with the behaviour of steel when stressed beyond its static elastic limit; it is well known that by doing so the elastic limit may be raised almost up to breaking point, and that so long as the stress never goes below a certain limit, it may be applied innumerable times up to the new elastic limit without fear of failure.

It seems then that in concrete we do every day what no engineer would ordinarily think of doing in steel, and that is use it beyond its static elastic limit.

As regards the value of the coefficient of elasticity either in tension or in compression, it depends upon the amount to which the concrete has been stressed becoming less as the stress increases.

Many authorities claim that if a curve be plotted having stresses as abscissæ and moduli of elasticity as ordinates, it will take the form of a parabola of the second degree.

On this are based the formulæ of Talbot and Hatt for beams which necessarily are ultimate strength formulæ; that is to say, the load under which a beam will fail is calculated by these formulæ and divided by some factor of safety to obtain a working load.

A more rational method is to adopt a safe working stress, and to consider the modulus as constant, as it practically is up to that intensity of stress in the extreme fibres, and in fact to adopt Hooke's Law. To recognise the very small change in the modulus in beams which are not called upon to sustain a compressive stress of more than 600 or 700 lb. per square inch would be an unnecessary refinement. The important thing is that concrete can be regarded as an elastic material up to certain limits, inasmuch as repetitions of stress do not cause increasing deformations after the first few applications.

Reinforced concrete beams, having the reinforcement placed so as to take the tensile stresses, are readily calculated from diagrams and tables published in many text books. The best of these neglect the tensile strength of the concrete, adopt Hooke's Law, and use various ratios for the moduli of elasticity of steel and of concrete. Upon these ratios depend the amount of stress carried by the reinforcements, as it is clear that if concrete and steel are so combined as to undergo the same strain, the stresses in each by Hooke's Law will be proportional to its modulus of elasticity. Figure 1 will show the effect of this. To calculate the moment of resistance of any section, we proceed as follows:—

Total stress C in concrete $= \frac{1}{2} f_c \times kd \times b$

" " T in steel $= a \times f_s$

whence $f_s \times a = \frac{1}{2} f_c \times kd \times b$ since total tension must be equal to total compression.

$$\text{But } \frac{f_s}{f_c} = n\frac{d(l-k)}{kd} = n\frac{l-k}{k} \text{ by Hooke's Law}$$

$$n \times \frac{l-k}{k} \times a = \frac{1}{2} kd \times b.$$

If a, d, n, and b are known, we can now calculate k.

The amount of resistance may now be calculated in one of three ways—

1. By computing the moment of the compressive stress about the centroid of the tensile stress.
2. By computing in the same manner the moment of the tensile stresses.
3. By adding the moments of the compressive and tensile stresses about the neutral axis.

The third method is of but little use, since we must know both tensile and compressive stresses. The better plan is to first determine whether f_s or f_c first reaches its maximum value, and calculate resistance for that value.

If the compression side is the weaker—

$$M_c = \tfrac{1}{2} f_c \ (kd)\ b \left(d - \frac{1}{3}\ kd\right) = \tfrac{1}{2} f_c \ kd^2\ b \left(i - \frac{k}{3}\right).$$

Now, for any given beam of known reinforcement k is constant, and $\frac{1}{2} f_c$ is also constant, so that we may write—

$$M_c = R_c bd^2$$

where R_c depends upon $\frac{bd}{a}$ and f_c.

If the tension side is the weaker—

$$M_s = a \times f_s \left(d - \frac{1}{3} kd\right) = a f_s \ d \left(1 \ \frac{k}{3}\right).$$

Now if p represents the ratio, $\frac{a}{bd}$ $M_s = p\ bd^2 f_s \left(1 - \frac{k}{3}\right)$.

and we may write—

$$M = R_s bd^2.$$

In Figure 2 the values of R_c and R_s are plotted as curves for variable percentages of steel.

The data assumed are—

$f_s = 17{,}000$ lbs. per square inch.

$f_e = 600$ „ „ „ „

and $n = 15$.

At the present time engineers have a wide choice of values for these three constants, and the result is that different designers will arrive at different results for beams to carry the same load.

It would be very convenient if the engineers in Australia would meet in conference and decide upon standard data of calculation. In the meantime I should advise any one engineer to make up his mind to adopt always the same data, and keep all his designs consistent.

The working stress (17,000 lb.) gives a factor of 4 on an ultimate strength of about 30 tons per square inch denoting a mild steel procurable under the British Standard Specification for Structural Steel; 600 lb. per square inch is suitable for 1.2.4. concrete. The ratio

$$\frac{E_s}{E_c}$$

could, of course, be determined by careful experiments on the actual concrete to be used, but 15 is the value adopted by the R.I.B.A., the Prussian Government Regulations, and the Austrian Government.

It will be seen that the curves for R_c and R_t intersect at a common value of 91·5, which is obtained with 0·61 per cent. of steel. This signifies that the working stresses are reached simultaneously in the concrete and the steel. It does not obviously follow that this is the most economical reinforcement. To test this it will be necessary to assume costs of steel and concrete respectively. Taking steel laid

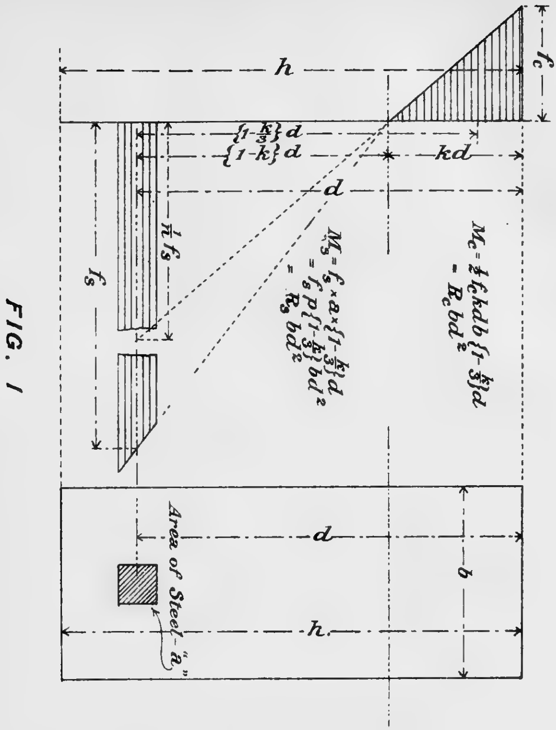

h
f_c
kd
d
$\{1-k\}d$
$\{1-\frac{k}{3}\}d$
$\frac{1}{n}f_s$
f_s
$M_c = \frac{1}{2}f_c kdb\{1-\frac{k}{3}\}d = R_c bd^2$
$M_s = f_s \times a \times \{1-\frac{k}{3}\}d = f_s p\{1-\frac{k}{3}\}bd^2 = R_s bd^2$
Area of Steel "a"
b

FIG. 1

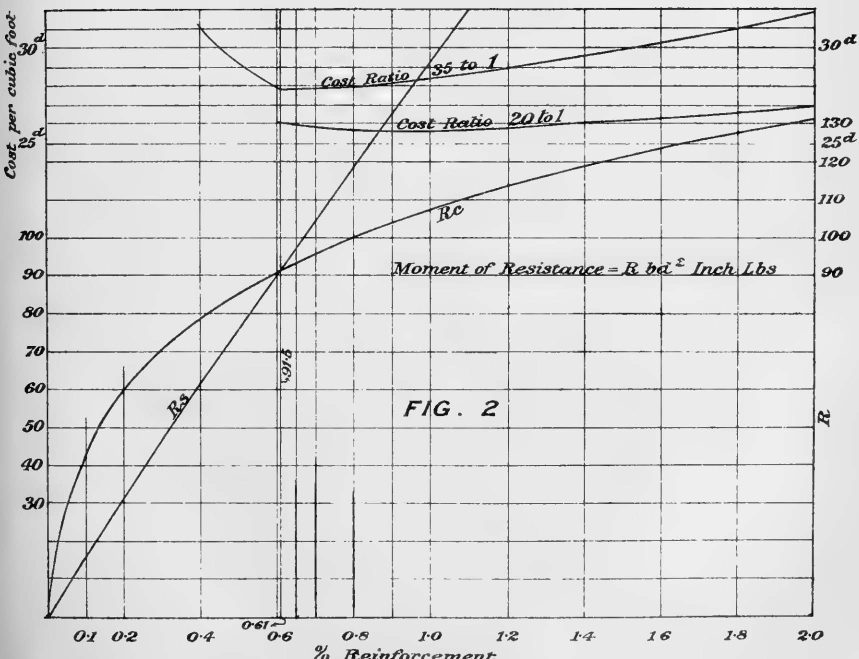

Cost per cubic foot
Cost Ratio 35 to 1
Cost Ratio 20 to 1
Rc
Rs
Moment of Resistance = R bd² Inch Lbs
R
0·61
% Reinforcement

FIG. 2

in place at £16 per ton, the cost of a cubic foot is 70s. Concrete may be estimated at 2s. per cubic foot, including labour and forms, so that the ratio of cost is 35 to 1.

A curve may be drawn showing relative cost for various reinforcements. The table below is calculated for a beam of constant width (12 in.) to carry 700 lb. per lineal foot over a span of 10 ft., and the curve in Fig. 2 drawn from it. Two inches of concrete is allowed below the reinforcement.

Proportion of Reinforcement. p	R.	Moment Inch Lbs.	Depth to Reinforced. d	Total Depth. h	Area of Concrete. h x 12″	Area of Reinforcement. a	Cost per c. ft. in Pence.
0·004	61	105,000	12	14	168	0·58	31·3
0·005	76	,,	10·73	12·73	152·76	0·64	29·2
0·006	90·2	,,	9·86	11·86	142·32	0·71	27·9
0·0061	91·5	,,	9·78	11·78	141·36	0·722	27·8
0·0065	94	,,	9·687	11·687	140·24	0·756	27·8
0·007	96	,,	9·547	11·547	138·56	0·802	27·9
0·008	100	,,	9·35	11·35	136·20	0·89	27·9
0·009	105	,,	9·13	11·13	133·56	0·98	28·0
0·010	108	,,	9·00	11·00	132·00	1·08	28·3
0·016	124	,,	8·40	10·40	124·80	1·61	30·2
0·020	131	,,	8·17	10·17	122·0	1·96	31·8

From this it will be seen that from ·006 to ·008 is the most economical proportion of reinforcement for these particular costs of steel and concrete. The curve also shows that if for any reason it is desirable to reduce the thickness of concrete it may be done without much extra cost by increasing the reinforcement up to, say, 1·2 per cent.

On the other hand, it is clearly an extravagance to reduce the steel much below 0·6 per cent.

To show that it is not obvious what percentage of reinforcement is the most economical, I have plotted a curve where ratio of steel cost to concrete cost is 20 : 1, from which it appears that 0·9 per cent. reinforcement is then the most economical.

In any case if the percentage at intersection of curves for R_c and R_s is adopted, it will be usually the most economical, or very nearly so.

Having determined the necessary dimensions at centre of span, the shearing stresses should, in case the beam may fail under them before developing the strength at the centre of span, be examined. There is considerable difficulty in this owing to the uncertainty as to the actual distribution of stress in the beam, and especially in the neighbourhood of the reinforcement. Although it is a safe thing to neglect the tensile strength of the concrete in calculating the moment of resistance at the centre of span, we must recognise the tensile resistances if we wish to know something of the real stresses in the beam.

I have endeavoured to investigate the stresses in a beam 10 ft. long, 10 in. wide, and 12 in. deep, with horizontal reinforcement of 1 sq. in. at 10 in. from upper surface. The load to be 700 lb. per lineal foot.

The central bending moment is—

$$\frac{7,000 \times 120}{8}$$

or 105,000 in. pounds.

Allowing a working stress of 600 lb. per square inch in compression and an ultimate stress of 200 lb. per square inch in tension, we have a diagram of stress as in Fig. 3. The diagram on the left applies as long as the tension at the extreme fibre is less than 200; the other diagram applies to the middle portion of the beam.

The tensile stresses would no doubt be more accurately represented by a parabola instead of a straight line, but the difficulty of calculation is greater than the possible gain in accuracy would warrant.

The total Compressive Resistance $= C = \frac{1}{2} f_c \times kd \times b = \frac{1}{2} 600 \times 10 \times 10k = 30,000k$.

The tensile resistance of concrete $T = \frac{1}{2} f_t \times x\,d \times b = \frac{1}{2}\, 200 \times x \times 10 \times 10 = 10,000\, x$

But $x = k \times \dfrac{200}{600} = \dfrac{k}{3}$

$T = 10,000 \dfrac{k}{3}$

The resistance of the steel is $f_s \times a = f_s$

and $f_s = f_c \times n \times \dfrac{1-k}{k} = 600 \times 15 \dfrac{1-k}{k} = 9.000 \dfrac{1-k}{k}$

hence $30,000\, k = 10,000 \dfrac{k}{3} + 9,000 \dfrac{1-k}{k}$

and $K = 0{\cdot}436\ x = 0\ 1453$.

Taking moments about centre of reinforcement—

$$M = C\left(d - \frac{k\,d}{3}\right) - T\left(d - kd - \frac{2}{3}\,x\,d\right)$$

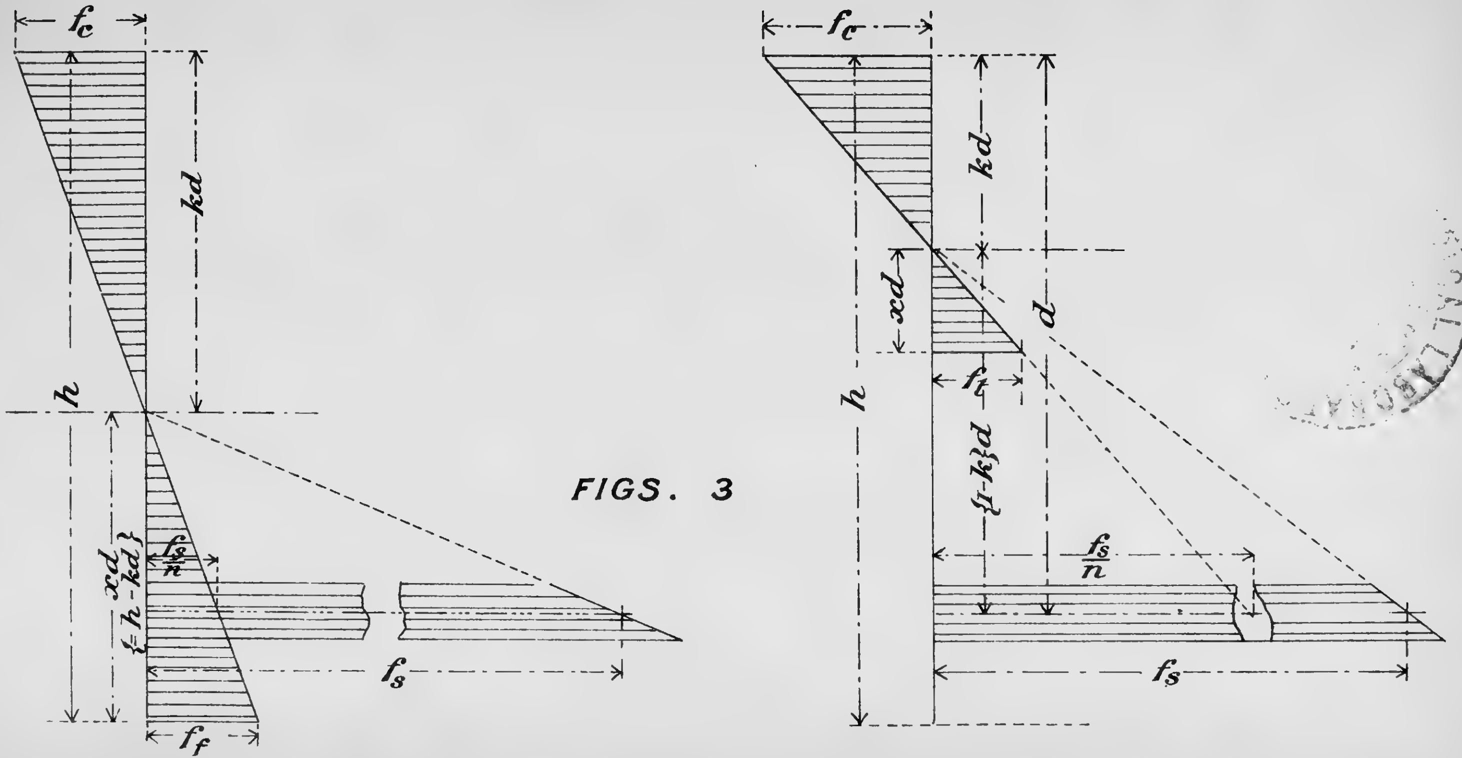
$= 13,080\ (10 - 1.453) - 1,453\ (10 - 4.36 - 0.97)$

$= 111,795 - 6,785 = 105,010$ inch lbs.

The result shows that the tensile strength of 200 lb. is reached at 1·453 in. below the neutral axis, or 5·81 in. below the upper surface. Below this depth the concrete must have previously cracked, but not necessarily in a visible crack, as Turneaure's and other experiments show that the concrete is broken up into a number of small invisible cracks by the distributing action of the reinforcement.

At any other point in the beam I have computed, the level at which the 200-lb. tension is reached by finding in the same manner as above the moment of resistance corresponding to various intensities of compressive stress at the upper surface.

The distance y from the centre where this moment is produced is calculated in the ordinary way.



FIGS. 3

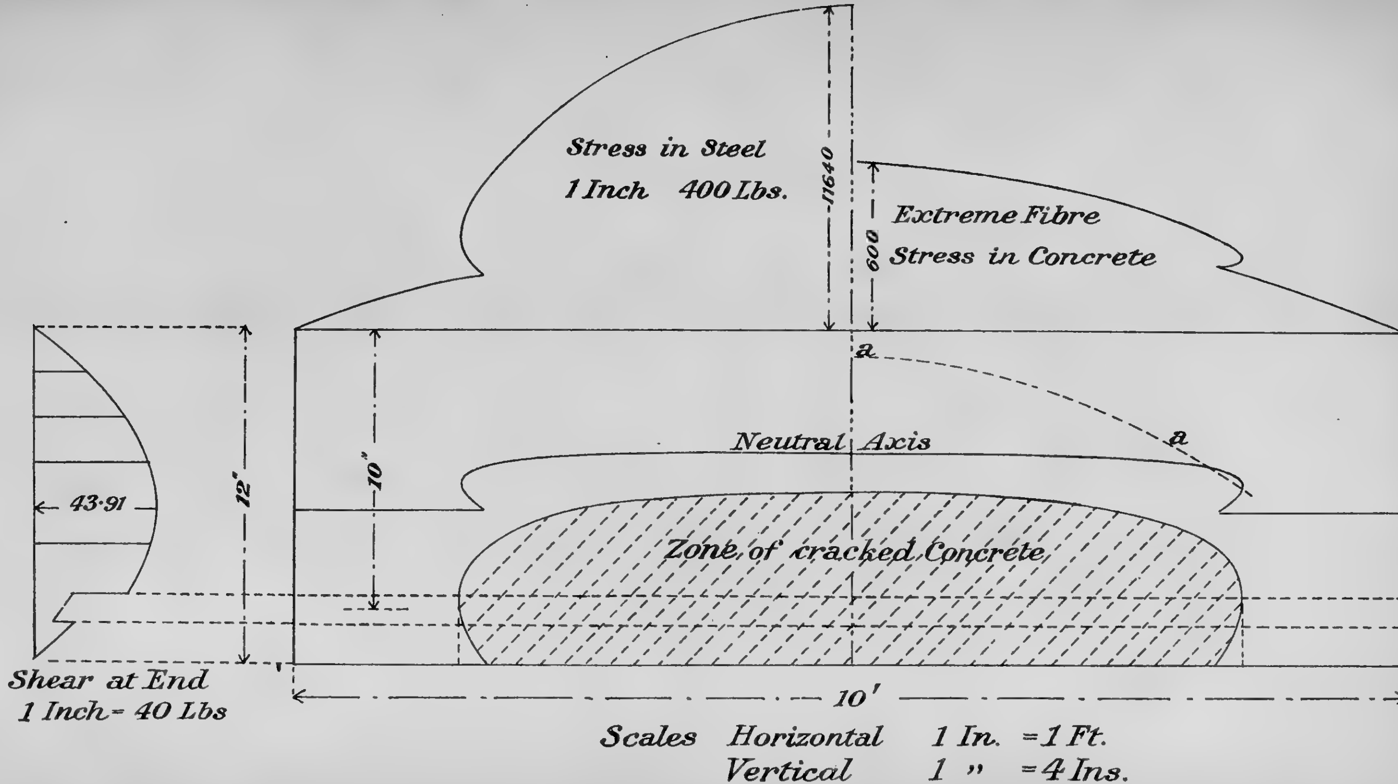

Stress in Steel
1 Inch 400 Lbs.
11640
600
Extreme Fibre
Stress in Concrete
a
a
Neutral Axis
Zone of cracked Concrete
10"
12"
43·91
Shear at End
1 Inch = 40 Lbs
10'
Scales Horizontal 1 In. = 1 Ft.
Vertical 1 " = 4 Ins.

FIG. 4

The results of these computations are given in the following table, and plotted in Fig. 4:—

F_c	kd	d	F	M	Y
600	4·36	1·45	11,640	8,750	0
560	4·39	1·58	10,734	8,154	1·30
500	4·45	1·78	9,340	7,250	2·07
400	4·63	2·31	6,945	5,800	2·904
316	5·00	3·13	4,740	4,730	3·389
300	5·14	3·43	4,283	4,580	3·450
290	5·23	3·60	3,970	4,500	3·484
280	5·33	3·81	3,675	4,450	3·506
270	5·48	4·05	3,350	4,425	3·516
260	5·66	4·35	3,000	4,450	3·506
250	5·87	4·70	2,640	4,525	3·473
243	6·04	4·96	2,395	4,625	3·434
232	6·44	5·56	1,920	4,960	3·291
200	,,	,,	1,655	4,275	3·577
100	,,	,,	827	2,137	4·346

It will be noticed that from 3·29 to 3·52 ft. from centre the neutral axis doubles back, so that we have an apparent ambiguity—that is to say, the moment of resistance at any intermediate point may be due to either one of the two diagrams or stresses in Fig. 3, one having a higher compressive stress and a higher level for the zone of fracture; the other a lower compressive stress and no zone of fracture.

A reasonable conclusion to draw would be that the latter diagram would be correct so long as the stresses represented by it were not exceeded, but if any slight extra load were added the concrete would immediately fail, and the former diagram would represent the stresses.

An examination of the diagram of stress in the steel leads one to doubt whether the stresses arrived at in the above table are possible; from the diagram we would conclude that the stress in the steel rises rapidly towards the centre from about the ambiguous region referred to above. This increase of stress can only be imparted to it by means of the shear in the concrete; now the concrete in this very region will be cracked, as shown by dotted line in figure, and consequently incapable of delivering any stress.

If the concrete in the cracked zone were stripped away, we would have less difficulty, because the remaining concrete would then be an arch of which the thrust would be supplied by the reinforcement.

In Fig. 4 I have shown at $a - a$ the pressure line which would be proper to such an assumption. It is appropriate here to remark that tests have been made at the Universities of Illinois and Wisconsin, in which the rods have been exposed for a considerable distance along the centre of the beam. Measurements of extension made in such cases show little variation from those made on the ordinary beam.

This is as much as to say that the stress in the steel is almost uniform along the greater part of its length, and is derived from the adhesion of steel to the concrete in the end portions; allowing 300 lb. per square inch ultimate strength for adhesion, an area of $\frac{11640}{300} = 388$ square inches is required. This has to be provided in a length of about 18 in., so that the total circumference of reinforcement must not be less than 2·15 in. In our beam the reinforcement of 1 square inch could be got approximately by four $\frac{9}{16}$ in. bars, of which the circumference would be more than 7 in. The factor of safety is then about 3·28. Working from the pressure line $a-a$ and admitting that the arch consists only of the concrete above the cracked zone shown in Fig. 4, there is no difficulty in finding the extreme fibre stresses in the concrete.

They are $f = \frac{H}{bs} + \frac{6He}{bs^2}$.

H = horizontal thrust = stress in reinforcement.

s = depth of sound concrete.

b = breadth of sound concrete.

e = eccentricity of thrust.

The tension at the margin of the cracked zone will now be found to be less than 200 lb. per square inch, except at the central section.

I consider that the real conditions of stress are intermediate between those due to considering the piece as a beam and as an arch.

The cracked concrete must press upon the steel, deflecting it downwards and inducing stresses in it as in a suspension cable; so that neither the diagram of stress in Fig. 4 nor a uniform stress in the middle portion truly represents the facts.

A general formula for the intensity of the shearing stress at any level in a cross section is

$$s = \frac{S \times G}{I \times b}.$$

S is the total shearing force at the section.

G is the moment of the area of the section above the level in question about the neutral axis.

I is the moment of inertia of the whole section.

b is the breadth at the given level.

In calculating I it is convenient to replace the steel by an equivalent width of concrete.

Thus 1 square inch of steel may be considered equivalent to a strip of concrete 15 in. wide by 1 in. deep at the same level as the reinforcement.

The diagram of shear at the left end of beam is shown in Fig. 4.

As the shearing strength of concrete may easily be about 1,000 lb. per square inch, it is clear that no failure is likely to take place in this beam owing to pure shear.

It is well known, however, that combination of shearing stresses with the horizontal stresses produces in the body of the beam oblique tensions and compressions similar to those which tend to buckle the webs of steel plate girders.

To determine these oblique tensions and compressions and the angles of their inclination we may use the formula—

$$p = \frac{f}{2} \pm \sqrt{\frac{f^2}{4} + s^2}.$$

Where p is tension or compression, according to the sign which is adopted—that is to say, if f is tension the $+$ sign gives us the maximum oblique tension and the $-$ sign the oblique compression at right angles to it; on the other hand, if f is compressive, the sign gives us the maximum compression.

The angle of obliquity is given by

$$\tan 2\theta = \frac{2s}{f}.$$

It is not easy to determine where p becomes a maximum; the best plan is to calculate for several points and draw a curve.

With shallow girders the shearing stresses will be small and dangerous tensions will occur at the extreme fibres where reinforcement is already provided; with deep girders it may be that heavy shearing stresses will produce tensions near the neutral axis, necessitating reinforcement.

Continuous beams often have the heaviest horizontal stresses at the supports where the shear is also large.

It is usual to specify that the shear in a beam shall not exceed 50 or 60 lb. per square inch. This seems strange when the shearing strength of concrete is about half its compressive strength, or, say, 1,200 lb. per square inch. This low stress is really intended as a safeguard against diagonal tension. A logical plan would be to determine the actual diagonal tensions as far as possible and provide reinforcement for them, if necessary.

A point which should be examined in an ordinary beam is one adjacent to the reinforcement just about the point where tension reaches 200 lb. per square inch in the concrete, and where the shear is of considerable amount. In a tee beam we should examine the web at junction with table for shear, but the principal oblique stress will be there a compressive one, except in the special case of a tee beam continuous over supports.

It is a very common practice to subject reinforced concrete constructions to tests of one and a half or more times the working load.

The effect of this is probably to raise the neutral axis and enlarge the zone of fracture. The method of calculation which neglects the tensile strength is then nearer the truth and still on the safe side.

In conclusion, I would like to point out what is perhaps not realised by most Australian engineers, and that is the weakness of reinforced concrete as compared with our own hardwoods.

For example, to carry 1 ton per lineal foot over a span of 20 ft. requires a concrete beam 12 in. wide by 3ft. deep, while an ironbark or spotted gum beam 12 in. by 18 in. (exactly half the size) is more than sufficient. The costs per lineal foot would be probably 7s. 6d. and 5s. 3d. respectively—that is, the concrete costs 27 per cent. more than the timber to do the same work. Possibly the concrete is often worth the extra money on account of its superior durability and freedom from troubles due to shrinkage and warping. In very many cases, however, timber will be preferable; it requires less headroom, imposes less weight on foundations, and has a second-hand value if taken out of a structure.

With the exception of arches, there is scarcely any engineering purpose to which reinforced concrete is put which cannot more cheaply and strongly be served by timber. The considerations which make concrete appropriate are principally its permanency, freedom from maintenance, and its fireproof qualities. In Australian waters the failure of Muntz metal to protect timber from teredo has left an opening for the reinforced concrete pile, and time will tell whether it will come up to expectations. It remains to be seen whether the cracks which, visible or not, must often exist in the piles due to handling and in driving will not some day allow sea-water to reach and destroy the reinforcement. If any one will calculate the transverse strength of a concrete pile I think he will be prepared to concede that it is exceedingly likely to be cracked in handling, and perhaps also to be cracked below the level of the bracings in a wharf which is subjected to severe treatment by the cables of vessels attached to it.

In my opinion concrete, plain or reinforced, is superior to all other materials in one thing, and that is in arches of large span.

3.—WATER AND THE ENGINEER.

By GEORGE PHILLIPS, C.E., Brisbane.

Water always has been and always will be the friend, the servant, and the most powerful enemy of the engineer.

From time immemorial it has provided him with employment—it has borne up his boats; groaned under the weight of his argosies; turned his mills, and run through his pipes and channels. At his bidding it has come from distant hills to water and fertilise the valleys, to give drink to forgotten cities, and to be led hither and thither in the service of man. By his controlling hand it has been made to defend beleaguered cities, and it has drowned or defeated attacking armies.

In later times it has toiled and sweated in his service—has moved immense weights and raced at speed over land and sea. It has fought and defeated fires, has purged away dirt and disease, and has cleansed augean stables.

Now and again it has turned in its wrath; wrecked his ships, destroyed his lighthouses, burst his iron bands, cut great gaps in his embankments, carried away his bridges, burst his reservoirs, silted up his docks and harbours, carried pestilence and death into houses and cities, mocked his sway, broken his heart and wrecked his reputation.

Volumes have been and many more might be written on the dealings of the engineer with water—and of water with the engineer—but in this necessarily short paper I must confine my remarks to a few detached aspects of the question that have come more prominently under my personal observation, whilst the formulæ that are given are such as I have found useful or have personally evolved in my practice.

Water and the Railway Engineer.

One of the first problems that confronts an engineer engaged in the survey and design of railways is the question of waterways.

Except in the very exceptional case where a railway is located along the summit of a watershed or divide, the railway engineer is continually confronted with the question of how to deal with, or how best to dispose of, the water that he knows, after each heavy rain storm, must cross the line of route here and there. What shall be the height and length and best location of this bridge? What shall be the sectional area of that culvert or drain? Shall this minor stream be diverted to a larger watercourse, or shall the water of the former be passed directly under the rails? Shall he allow, and to what extent may he safely allow, flood water to cross the line above the rails? What shall be the character as well as the dimensions of the opening? Shall it be constructed of wood, stone, brick, concrete, or iron? Are the foundations satisfactory, and what steps should be taken to discover their nature? Unless these questions are dealt with in the light of technical knowledge and trained experience the railway engineer is sure to make one of two possible mistakes—either he will underestimate the works, and, therefore, make insufficient provision for the safe disposal of storm water to the imminent risk of life and property, or, on the other hand, he may overestimate the provision required in the way of waterways, and thus load the works with unnecessary and useless expenditure.

I could quote instances that have come under my personal observation where the grossest ignorance, if not the most culpable negligence, was shown in dealing with these important questions, and I could name at least one case where loss of life and great destruction of property was the result.

I know a case where on the same section of railway and only a few miles apart, under identical climatic conditions, 10 ft. diameter circular brick culverts were provided at two places, one of which drained an area of 200 acres and the other 4,000 acres, whilst in the case of the lesser area the culvert was so situated that under any circumstances it could never run more than half full, as, at any greater height, the water would escape elsewhere down the line. The engineer responsible for such work would be hard put to it to justify his practice on any reasonable or technical grounds.

When, more than thirty years ago, I was placed in charge of the railway surveys of the Southern Divison of this State, there were only 240 miles of railway in the division, and less than 360 miles in the whole of Queensland. One of the principal duties assigned to me was the determination of waterways on all lines to be constructed in the Southern Division. At that time, although I had had considerable experience as a surveyor, both in the Northern and in the Southern Divisions of the colony, I had had no previous experience of the determination of waterways on railways. The essential problems governing the correct determination of waterways had not previously been adequately dealt with by the engineers of Queensland Railways, so that I felt the responsibility very keenly.

I quickly saw, however, that the principal determining factors of the problem were (a) area to be drained in each particular case, and (b) maximum rainfall to be expected. There are, of course, other factors to be taken into account, such as porosity of the soil and slope of the ground, but the principal factors are the two I have especially named.

I knew sufficient of the climatic conditions of Queensland to know that as a rule, and more especially in the coastal districts, provision for less than 1 in. of rain per hour would be inadequate, whilst it was apparent that to provide for unforeseen contingencies and exceptionally heavy falls of rain it would be wise to allow somewhat larger sectional areas than either the assumed maximum rainfall or the areas to be drained would indicate.

On this basis I prepared a table showing the sectional area and other dimensions of openings of various classes required to discharge 1 in. of rain per hour from areas of from one to one thousand acres, with estimated velocities at the point of exit of from one to six miles an hour when the openings were running not more than two-thirds full, thus affording a margin of one-third for contingencies. In order that the information contained in the table might be correctly applied, I instituted the practice of having all the minor watersheds traversed with prismatic compass and chain, this being near enough to ascertain the areas with sufficiently close approximation to truth. With the help of the table I prepared in 1878, I have determined the waterways on something like one thousand miles of railway now in operation in Queensland, whilst the table is still used by the engineers of the Railway Department of this State.

Whether the practice of traversing watersheds is in vogue in any other part of the world I cannot say, but I am in a position to state positively that it was not the practice of the Railway Department of New South Wales for several years after I instituted it in Queensland.

In practice I have generally assumed the velocity of discharge through the openings, when running two-thirds full, at three miles an hour. This is a safe velocity to take in the great majority of instances that are met with in the coastal districts of Queensland. It will be found that for an assumed velocity of three miles an hour the sectional area of opening required is one square foot for each three acres of area to be drained. For example, an area of thirty acres would, as a rule, require an opening having a sectional area of 10 sq. ft.; this sectional area might be obtained under a deep embankment by means of a brick, stone, or concrete circular culvert of, say, 3 ft. 6 in. internal diameter, or in the case of a comparatively shallow embankment by means of a 5 ft. by 2 ft. timber culvert. Although the table is confined to minor areas, it is often advisable to traverse much larger basins, and I know several cases in my own practice where areas of from 5,000 to 10,000 acres have been traversed with distinct advantage and economy as regards the determination of the necessary waterways.

The maximum flood levels of watercourses cannot alway be found, more especially in the case of large areas of flat country so often met with in Western Queensland, as the light débris left after each flood is soon destroyed by fire, leaving no permanent mark behind. I have observed, however, that the large red, meat-eating ants seldom, if ever, build below flood level, so that their beds may generally be regarded as above the influence of floods.

Where heavy timber is brought down the evidence of very high floods often remains for many years in the burnt stems of trees where piles of heavy timber and débris have been left on the upper sides of trees growing on the banks or on adjacent flats covered by high floods.

In the case of large streams where floods may rise 40 to 100 ft. it is always advisable to closely examine the upper sides of the large white gums that generally grow in such channels. It will often be found that the upstream sides of such trees exhibit marks or roughnesses which, to the experienced eye, indicate bruises caused by large floating logs or trees coming down on the top of high water, and striking the growing trees with sufficient force to knock off or to badly bruise the bark. These marks remain visible for many years, mute evidence of former floods. I could cite cases in my own practice where the only reliable information regarding the height of floods was obtained in this way.

When determining the height and sectional area of a large high-level bridge over a stream that has not previously been bridged at high level in the vicinity of the proposed structure, it is always advisable, in addition to such natural evidence as I have referred to, or that may be ascertained by inquiries from local residents of long standing, to investigate the discharge capacity of the proposed structure in relation to rainfall on the whole basin of the stream. Generally the area of the basin can be pretty accurately ascertained by reference to the official maps of the district, near enough, at all events, to enable a very close approximation to be made of the discharge capacity of a bridge of known sectional area.

The data required are as follow:—

Let "a" = the available sectional area of the proposed bridge in square feet, as measured at right angles to the direction of the current.

Let "b" = the estimated or computed mean velocity of the stream when in high flood in miles per hour.

Let "c" = the area of the basin above site of proposed bridge in square miles.

Let "d" = the maximum rainfall that could be discharged by the bridge off the basin in inches per twenty-four hours at the estimated or computed velocity. In this no account is taken of absorption or evaporation, because if a heavy rain storm were to occur when the ground is thoroughly soaked by previous rains practically the whole of the water of the last storm may come down to the bridge.

To obtain "d" by the ordinary rules of arithmetic would prove a long and tedious calculation, but "d" can readily be obtained by my formula—

$$\frac{3ab}{55c} = d.$$

Having obtained "d," the engineer should consider whether the result is such as to afford a reasonable margin of safety.

It should be borne in mind that in the case of very extensive basins, such as those of the Fitzroy and Burdekin Rivers in Central and Northern Queensland, "d" might give satisfactory results if it only amounted to 1 in. or less of rain per twenty-four hours, whilst in the case of comparatively small areas comprised within the same general basin, anything less than 15 or 20 in. might not be sufficient to ensure good results.

The following examples will illustrate my argument:—

The quantity of water that passed down the Brisbane River during the maximum height of the great flood of 1893 was equivalent to a discharge of about 3 in. of rain off the entire basin per twenty-four hours. It would not do, however, to assume, in the case of a small tributary of the Brisbane River, draining, say, fifty square miles, that a bridge having a sectional area equal to a discharge of 3 in. per twenty-four hours would give satisfactory results.

With a mean velocity of five miles an hour, such a bridge would have a sectional area of only 550 square feet, whereas experience has taught me that the sectional area should be fully five times as great in the case of a high-level structure.

Many formulas have been given to approximately compute the maximum discharge that may be expected from rivers of known area.

One of the best known of these and the one most commonly used in Indian engineering practice is that of Colonel Ryves, namely, $D=C\ (M^{\frac{2}{3}})$, where "D" equals the maximum probable discharge in cubic feet per second, "M" equals the area of the basin in square miles, and "C" is a co-efficient according to experience. It has been usual to limit "C" to 800, but from the experience gained in connection with the great floods in the Brisbane River of February, 1893, and from other records, I am of opinion that for the coastal rivers of Southern Queensland the value of "C" may be taken as follows:—

Area of basin.	Value of "C."
1,000 square miles	3,000
2,000 " "	2,750
3,000 " "	2,500
4,000 " "	2,250
5,000 " "	2,000
6,000 " "	1,750

In the flat country of Western Queensland, where the fall often does not exceed one foot per mile, the value of "C" is very much less than on the coast, and may be taken at about 600 for a basin of 1,000 square miles situated in the rolling downs formation of Central Queensland. I would like to give more information on this subject, but I am writing this paper in the country away from the data available in my office.

The formulæ usually given in works on engineering to compute the mean velocity of water running in natural channels, are, so far as my experience goes, not well adapted to the conditions that obtain in Queensland, and I venture to give the following formula as better adapted and simpler than those I refer to:—

$$V = (\sqrt{RS})\ (90 + \sqrt{R})$$

where "V" equals the mean velocity of the stream in feet per second —"R" equals the hydraulic radius or mean depth of the water in feet, and "S" equals the natural line of the slope, or $\frac{\text{fall}}{\text{length}}$.

In the design of railways intended to carry traffic at high speed in undulating or hilly country, too much care cannot be taken in the matter of waterways, so that the responsible engineer should be in the possession of the fullest and most reliable information to enable him to determine the height at which watercourses, both large and small, should be crossed, and the sectional area of the various openings.

There are cases, however, in even country so frequently met with in Queensland, where it is quite safe, for the small traffic at present available, to dispense with all except absolutely necessary waterways, such as at the crossings of well-defined creeks, rivers, or other watercourses where the drainage of considerable basins is concentrated within definite banks or limits. Such places, of course, must be bridged, although not necessarily at high level.

I constructed the railway from Normanton to Croydon (94 miles) on this principle, 1888-91, and, although the line has been open to traffic for nearly twenty years, no accident or derailment has resulted in consequence of the departure from usual engineering practice.

At the present time I am surveying and designing a similar railway in Central Queensland, where for 30 out of 40 miles I propose to allow storm-water to cross the rails without artificial conduits of any description, but the remaining 10 miles being in undulating country, culverts, proportioned to the areas drained, will be necessary.

Phenomenal Rainstorms.

Rainstorms of great intensity and duration are not uncommon in Queensland, and are not confined to any particular district or locality.

On the 21st January, 1887, 18·305 in. were recorded in Brisbane. This storm wrecked the railway bridge over the Logan River on the South Coast Railway, as well as several bridges on the Killarney Branch Railway. It also severely tried the capacity of the by-wash at the Enoggera Reservoir, the water rising almost to the crest of the dam. The sectional area of the by-wash was largely increased in consequence.

At Cardwell on two occasions in January, 1873, I measured with the official rain gauge more than 14 in. in twelve hours, the total record for the month being 63 in.

The most remarkable storm of which I have any personal knowledge fell in the month of February, some eleven or twelve years ago, on the resumed part of Bando station, on the western side of the

Warrego River, between Charleville and Cunnamulla. As I saw the evidences of this cloud burst in the following November I can only guess at the quantity of rain that fell, but from the close proximity of the watershed, the gentle slope of the ground, and the height to which the storm water rose as evidenced by débris in the Mulga forest, I would not be surprised if 10 or 12 in. fell in quite a short time. I am sure that if any party had been camped on the ground at the time they would have had great difficulty in saving their lives, and they must have lost their horses and effects.

Although the watershed was only some two or three miles away, and the whole of the ground quite even and unbroken, with no indication of a watercourse, the storm water rose 7 or 8 ft. deep over a considerable area. On the other side of the flat divide very little if any rain fell. It is not improbable that Leichhardt and his party may have perished as the result of a similar storm.

Mr. Charles B. Steele, at present mining surveyor at Gympie, when, some twenty-two years ago, he was engaged upon the survey of the then proposed railway to Gayndah, lost nearly all his camp equipment, instruments, and some of his horses at Wetheron, as the result of a similar storm.

Experienced bushmen are sometimes very careless where they camp for a night or two, and, although such storms as those I have referred to are uncommon, it would be wise to select the highest available ground even in the case of temporary camps. I must confess I have been rather careless myself in this respect, and have occasionally suffered inconvenience and loss in consequence, but the temptation to get as near the water as possible, for convenience sake, often proves too great.

The Protection of Foreshores.

The successful protection of foreshores from wave action depends chiefly upon the means being adapted to the end, and no hard and fast rules can be laid down.

I am of opinion that rigid structures such as concrete or timber walls, unless founded upon rock, are not suitable for the purpose, as they present much too steep or vertical faces, and generally fail by being undermined, (a) by the screw-like action of the waves as they run along the vertical face, stripping away the sand, &c., and (b) by the large quantities of water projected over the wall scouring out the backing.

Where sand can be gathered and gradually built up by wave action into banks, timber groynes answer well in most cases, but they should not be built either too long or too high. I know instances where long groynes have done much more harm than good. I do not think the angle at which they are placed has much to do with their efficiency, and on the whole I would favour their being placed at right angles to the line of beach to be protected.

Rubble stone walls of suitable height and cross section generally give good results. The material is durable, the construction simple, and the cost, where stone is procurable, not prohibitive. The weight of the stones should be proportioned to the force to be withstood, and may vary from 50 lb. upwards, according to circumstances.

As a rule rubble stone may be deposited on the natural bed, but where the ground is too soft or treacherous it may be laid on mattresses of mangrove well laced together with wire and pinned down at frequent intervals with piles of small diameter, say, 4 to 6 in.

The best material for filling immediately behind rubble exposed to wave action is small stones such as quarry chips, or where these are not obtainable good stiff clay or gravelly soil well pinned in layers.

Tea-tree bark laid between ordinary earth filling and the rubble wall will give the former time to settle down hard and firm, before the bark decays.

The Conservation of Water by Means of Tanks and Dams.

I have seen many dams constructed by squatters and others that have failed in consequence of defects in location or construction, owing to the employment of the "practical man" in preference to engineers. Even where entire failure has not resulted I have frequently observed that the success achieved has not been commensurate with the outlay.

The embanking of large streams should never be undertaken except under professional advice and supervision. As a rule, areas exceeding 1,000 acres should be avoided, and, where it is necessary to provide tanks or dams in larger areas, care should be taken to locate the works to one side of the main watercourse where a sufficient supply of water can safely be led from the principal stream into the tank, so that when it is full the surplus water may safely escape down the main channel.

Where a dam is so located that a by-wash is required, a sectional area of about 1 square foot to each 3 or 4 acres of catchment area should be provided.

A very safe method, for those who have no technical knowledge, is to make a simple hole in level ground in such a position that surface water can be led into the excavation by means of shallow trenches with but slight fall, so as not to cause much scour.

Preferably, such excavations should have a depth of at least 12 ft., so that the inevitable loss by evaporation may not bear too great a proportion to the quantity of water impounded. The loss by evaporation may amount to as much as 4 ft. or 5 ft. per annum in vertical depth.

The entrance for stock should be ramped down about 2 to 1, and roughly pitched with stone, the other sides being protected by fences. The excavated material may be run to spoil in any required direction, provided it is not laid so as to form a continuous embankment across the line of drainage.

Where, as so often occurs in even country, railway embankments are formed from side cuttings, very useful waterholes might be constructed at but little additional cost, by taking the material from such holes as I have indicated above.

Curves and Widths of Navigable Channels in Rivers and Canals.

Recently I had occasion to pay some attention to the question of curves and widths of navigable channels, in connection with a paper on the Port of Brisbane, which I read before the Queensland Institute of Engineers on the 25th June last.

As the subject is one of more than local importance, the following extracts from the paper may be of interest:—

"From an independent investigation I have made, I am satisfied that the law of curvature of rivers and canals that would permit of vessels of any given dimensions passing each other safely in opposite directions on such curves, and in cuttings of ordinary width—270 ft. to 500 ft.—may be stated as follows:—

Let the length of the vessel, regarded as a chord of the required inner curve, be called A, then the versed sine at centre of chord should equal the cube root of A.

From these simple elements the required curve can be readily determined as follows—

Let B equal half the chord, that is, half the length of the vessel.

Let C equal the versed sine, equal to the cube root of A.

Let R equal the radius of the required curve.

Then $\frac{B^2}{C} + C = 2R =$ diameter of required curve.

The width of deep water channels suitable for vessels of any given length is governed by the clearance that may be considered necessary between two vessels of the same dimensions that are required to pass each other in opposite directions on curved portions of the river or canal. By the term "clearance" I mean the distance from centre to centre of the ships, as measured along the tangent of ship A's course at the moment when ship B is crossing that tangent. (*Vide* Diagrams Nos. 1, 2, and 3.) The clearance should never be less than twice the length of the ship, and preferably should, I think, be somewhat longer, extending to a maximum of, say, two and one-half ($2\frac{1}{2}$) times the length of the ship. The table of widths of channel suitable for vessels of from 200 ft. to 1,000 ft. in length, given below, is based upon a tangential clearance of two and a-half times the length of the ship.

Where the cost of a channel corresponding in width with the tangential clearance of 2·5 times the length of the ship would be excessive, I am of opinion that a clearance of 2·1 times the maximum length of vessels using, or likely to use, the waterway would give economical and fairly satisfactory results.

Assuming that the maximum length of steamships will be 1,000 ft., then the width of channel corresponding with my formula for curvature and with the tangential clearance of 2,100 ft., (2·1 times 1,000) would be 350 ft., or 22 ft. wider than the width (100 metres) now being provided at the Suez Canal. The width of channels may be computed by the following formula:—

Let A equal the length of the vessel.

Let B equal the number of times that A is contained in the clearance allowed.

Let R equal the radius of the inner curve by my formula.

Let X equal the half-width of the required channel.

Then $\frac{(BA)^2}{2R+X} = X.$

The above is a quadratic equation, and the formula may be more simply stated as follows:—

$X = \sqrt{(BA)^2 + R^2)} - R$, which contains no unknown quantities in the second part of the equation. The width of the channel is twice X.

For ships of 200 ft. in length passing each other in opposite directions on the tabulated inner curve of 858 ft. radius, the width of channel would be as follows:—

Tangential Clearance = B.		Width of Channel = 2X.
Ship's length $\times 2 = 400$ ft.	...	178 ft.
„ „ $\times 2 \cdot 1 = 420$ ft.	...	194 ft.
„ „ $\times 2\frac{1}{4} = 450$ ft.	...	222 ft.
„ „ $\times 2\frac{1}{2} = 500$ ft.	...	270 ft.

Length of Vessel.	Radius of Inner Curve (Rad. of Outer Curve = Rad. of Inner Curve, plus Half Width of Channel).	Tangential Clearance $2\frac{1}{2}$ Times Ship's Length.	Width of Channel.
Feet.	Feet.	Feet.	Feet.
200	858	500	270
250	1,243	...	...
300	1,684	750	320
350	2,177	...	...
400	2,718	1,000	350
500	3,941	1,250	388
535	4,411	...	...
600	5,340	1,500	414
700	6,903	1,750	436
750	7,744	...	...
775	8,178	1,937·5	452
800	8,622	2,000	458
850	9,539	...	...
865	9,821	2,162·5	470
900	10,492	2,250	476
1,000	12,505	2,500	495

There are, of course, many other aspects of the question that I have not even referred to, such as the development and use of steam —water supply and hydraulic power for cities, &c.; and, to come nearer home, the vast natural reservoirs of excellent water stored in the great sandy islands that fringe the Southern coast of Queensland, but I have already exhausted the time at my disposal.

4.—SOME NOTES ON TESTING WIRE ROPES.

By ROBERT HUNTER.

In the middle of the year 1907 there was published at Pretoria the report of a commission appointed by His Excellency the Lieutenant-Governor of the Transvaal to inquire into and report upon the use of winding ropes, safety catches, and appliances in mine shafts. This report has, since its publication, been widely circulated and discussed among mining men, as it contains much valuable information. The majority of the witnesses examined by the commission with reference to winding ropes appear to have been interested in their manufacture and sale, the published evidence with regard to deterioration in ropes in actual use being extremely limited. This, perhaps, is not astonishing, when it is remembered that most of those competent to furnish information on this point are very busy men, who could ill spare the time necessary to enable them to place their knowledge before the commission in an acceptable form. The writer annually tests from 160 to 200 ropes, and it has occurred to him that others may be interested in the results obtained when testing ropes in use.

Most of the ropes used in Queensland mines are of simple construction, that is to say, of six strands, each containing seven wires, of Lang's lay, having an ultimate stress of from 17 to 35 tons. Frequently one wire in each strand is merely a core wire, being made of low grade steel or of iron. Unless the core wire is equal to the other wires in the strand, it is not considered in calculating the ultimate stress of the rope. A few compound ropes are in use having an ultimate stress of from 45 to 60 tons. Manufacturers have adopted a classification of ropes presumably based on the composition of the steel, but this classification, judging by the results of tests, does not always present the uniformity that is desirable. In its report, the Transvaal Commission states "that the deterioration of a winding rope should be capable of being assessed by a competent person while making the customary examination is a most essential point."

In Queensland sets of rope-testing machines have been placed in centres most convenient to the inspectors of mines. With these machines wires are subjected to bending, torsion, and tension tests. The two first-named tests, of course, have reference to the temper of the steel. It may not, perhaps, be out of place to here describe the system of rope-testing adopted by the Department of Mines in this State. When a new rope is purchased, a piece is cut off by the purchaser, and sent by him to the inspector of mines, together with a copy of the manufacturer's certificate. That officer then tests it, and enters the results in a register kept for the purpose, and also furnishes the purchaser with a copy of the entry in the register. Afterwards, whenever the rope is reshod, a similar test is made, the wires at the same time being carefully examined for signs of deterioration. The wires are tested singly, and in calculating the ultimate strength of the rope a deduction of 10 per cent. is generally made from the aggregate of the wires, experience having shown that when the result obtained by this method of testing is compared with the result obtained by testing a whole piece of rope this is a fair average deduction. In comparing tests of new ropes with the manufacturers' certificates of the ultimate stress, it is found that a variation of 8 per cent. below the guarantee is permissible, as it is impossible to make steel wire perfectly uniform in temper, strength, and composition. Exception has sometimes been taken to laboratory tests of wire ropes on the ground that there is no guarantee that the piece so dealt with will reveal the defects in the whole rope. This at the first glance may appear to be a very strong objection, and there are those who argue that the only way to test a wire rope is to attach to it a weight equal to about one and a half times its usual working load. Then, if it does not break, it is said to be safe. To this argument it may be replied that a dead-weight test is, if unintelligently applied, a source of considerable danger. The writer has known a new piece of rope 500 ft. long, when subjected to this test, to stretch 11 ft., and take three weeks to shrink to its former length. During this time it will be readily understood that the engine-driver was subjected to considerable annoyance. When applied to a rope that has seen service, the dead-weight test may be a death trap, since having stretched very much while working it will require very close observation to determine the amount of elongation, if any, under test. The rope's limit of elasticity may be exceeded, and what may be called "a permanent set" put in it which may cause it to break in the near future. The customary examination of winding ropes at mines is generally made once a week, when the ropes are run through some cotton waste held in a man's hands, and unless broken wires are found the rope is said to be in good order. As a rule, little notice is taken of the flattening of the wires, and no effort is made to ascertain the amount of corrosion. The chief causes of deterioration in winding ropes are wear, corrosion, and crystallisation. In a vertical shaft wear is caused by the rope coiling on the drum, and passing over the pulley wheel; this causes frequently a flattening of the wires, more especially when the drum is narrow and the rope coils several times on it. Sometimes also a new rope is damaged by being put over an old pulley wheel which has been grooved by a smaller rope. In an underlay shaft there is, in addition to these causes, wear due to the rope passing over rollers in the shaft, wear caused by changes of grade causing the rope to bang up and down between the hanging and foot walls of the shaft, and in a flat and underlay shaft wear is caused by the rope being dragged along the footwall. In many vertical shafts in metalliferous mines the shaft traffic is so small that after three or four years' work the wires show hardly any flattening. Corrosion may be either internal or external. If the former, it is probably caused by water getting into the heart of the rope. This kind of corrosion is extremely difficult to find out, and frequently it is not suspected until the rope breaks. Water often finds its way into the centre of a rope owing to neglect to properly clean and oil it, and owing to the use of a stiff lubricant which does not penetrate beyond the outside of the rope. Some lubricants that act very well in a cold climate become gummy in Australia. Outside corrosion may be caused by bad lubricants failing to protect the wires, or by water in the shaft. When selecting a lubricant for a rope, the greatest care is necessary, as acids in a lubricant may do great damage. Formerly a favourite lubricant consisted of Stockholm tar and castor oil. Since it was discovered that Stockholm tar generally contains acetic acid, its use in lubricants has been largely dispensed with in Queensland. A graphite preparation has been largely used, which seems to be fairly satisfactory. Water is, of course, generally met with in sinking shafts, and in some cases acids are associated with it. In wet sinking shafts, and in other shafts in which much water is hoisted, the ropes are often quickly rendered unsafe owing to corrosion. After ropes have been in use for some time they begin to show signs of crystallisation, probably to a considerable extent due to vibration, and as a rule it is found that the lower end of the rope becomes brittle first. It frequently happens that a rope has to be subjected to the torsion test several times until it is cut at a point behind the pulley when the cage is at the top of the shaft. A case recently came under my notice at a mine where the engines were kept bailing water continuously. Some 300 ft. or 400 ft. were kept coiled on the drums, as the bailing was not carried on from the bottom of the shaft. The engine-driver one day found a great many wires broken in that part of each rope that travelled in the shaft. A few days afterwards he found that the wires in the ropes coiled on the drums were also badly broken. Not having been much used these wires showed very little flattening or corrosion. These ropes were of simple construction, with a rather high ultimate stress, and the wires were of a large diameter, becoming brittle quickly, as is often the case in this class of rope. In the accompanying schedule are some particulars of actual rope tests. In order to save space, and not make the list too tedious, the torsions have been averaged, and I am afraid this averaging may convey a wrong impression. It will, I think, be readily conceded that if 27 wires give only 3 to 5 torsions each, and the remaining 9 wires give each 25 torsions, then the system of averaging does not convey a correct idea of the condition of the rope. It is occasionally found that when a wire rope has been in use some time its breaking stress is, especially in ropes of simple construction, slightly higher than when tested before being used. Two such instances were met with in compound ropes at the No. 1 South Oriental and Glanmire Gold Mine, tested on the 20th November, 1905, and 11th January, 1907.

This increase in the tensile strength is often accompanied by a decrease in the torsion test. Again, sometimes, but not often, it has been noticed that ropes of simple construction seem to increase their ultimate stress as they are worked, while the torsion tests give worse results. A case in point is the north rope at the Columbia and Smithfield Gold Mine, included in the schedule. As a rule, however, there is a steady decline in both the ultimate stress and the results of the torsion test, as instanced by the record of tests of the ropes at the South Glanmire and Monkland Gold Mine. When a rope begins to give bad results in either test, it is not condemned until several tests have been made, and frequently, when the bottom 50 ft. or 60 ft. have been cut off, better results are obtained, especially in the torsion test. But if, after cutting off 100 ft. or 150 ft., satisfactory results are not obtained, the rope is condemned. Frequently a rope either brittle or corroded gives fair results under the tensile test, and ropes are more frequently condemned for these defects than for any other deficiencies when subjected to the tensile test.

SCHEDULE.

Name of Mine.	Date.	Ultimate Stress of North Rope.	Average Torsions of North Rope.	Ultimate Stress of South Rope.	Average Torsions of South Rope.	Remarks.
		Tons cwt.		Tons cwt.		
1 S. Oriental and Glanmire	11-7-02	28 2·5	18	27 18·2	22·5	The south rope on the 30th June, 1905, broke at 1,100 ft. above the shoe, where the rope was riding badly on the drum
	3-8-03	28 15	17	28 11·5	12·2	
	14-3-04	27 17·5	16·3	28 12·8	11·3	
	30-5-05	27 18·9	17	28 5·6	13·5	
	20-11-05	42 7·8	24&49	45 18	26&51	
	11-1-07	43 16	20&59	46 10	26&41	Two new compound ropes. Each strand consists of 8 large and 7 small wires. Makers guarantee ultimate stress of north rope to be 42 tons 7 cwt., and South rope 45 tons 12 cwt.
	3-2-08	42 14	26&53	44 10	18&51	
N. Oriental and Glanmire	5-1-03	25 4	21	27 15	8·1	In use some time. Lot of water hoisted. 60 ft. cut off since last test
	16-1-03	...	...	...	13·8	
	5-10-03	27 9	8·6	27 12	8·7	
	8-10-03	...	13·6	...	9·6	Cut behind pulley wheel since last test
	29-8-04	27 11	15	27 11	10·5	
	13-9-04	...	...	...	13·8	120 ft. cut off since last test
	2-10-05	27 4	11·3	26 17	15·5	
	15-10-06	27 9	8·6	26 5	14·1	About 150 ft. cut off. Condemned
	16-10-06	...	8·1	...	11	
	18 10-06	...	10·5	...	8·5	End on drum
	23-1-08	...	...	27 1·35	17·5	Condemned
	25-11-08	27 1	6·3	...	...	
E. Oriental and Glanmire	10-12-02	28 4	22·3	...	...	
	12-12-03	27 15	17	...	...	
	18-1-05	28 3	2·8	...	...	New ropes
	30-1-05	30 4	25·6	25 17·5	26·3	
	25-7-06	29 16	19	26 15	13·8	
	9-1-08	28 0·7	17	25 7·6	16·6	
Columbia Extended	29-3-05	28 17·4	24·5	27 19·13	23	Two new ropes. Manufacturers guarantee ultimate stress of 28 tons
	21-3-07	...	11·6	...	13	
	3-4-07	...	20	...	19·8	
	10-1-08	..	14	...	14	
	29-7-08	26 18·6	8	29 2·75	13	30 feet cut off each rope
	10-8-08	25 10·3	14·3	28 19·6	8	Cut behind pulley wheel. Wires do not seem perceptibly flattened, but are brittle
No. 2 North Columbia and Smithfield	15-10-00	19 16·4	24	19 16	24	A great deal of water is hoisted in this shaft
	6-12-01	19 14·2	18·6	19 9·8	24	
	16-7-03	19 0·7	19	20 0·5	20	
	19-1-04	18 6	21	18 14	19	
	11-1-05	17 14·7	13·8	19 13·6	24	Wires badly pitted
	31-7-05	27 5·5	30·6	...	...	New north rope. Maker guarantees ultimate stress of 31 tons
	15-1-06	...	...	18 15·3	12	Shows much corrosion
	10-2-06	...	...	25 13	28	New south rope. Maker guarantees ultimate stress of $33\frac{1}{4}$ tons
	6-10-06	27 11·5	23	...	...	
	24 4-07	25 18	19	26 6·5	18	

SCHEDULE—*continued.*

Name of Mine.	Date.	Ultimate Stress of North Rope.	Average Tortions of North Rope.	Ultimate Stress of South Rope.	Average Torsions of South Rope.	Remarks.
		Tons cwt.		Tons cwt.		
No. 2 North Columbia and Smithfield — *continued.*	13-1-08	27 14·4	10·3	24 17·7	10	Both ropes showed corrosion and were replaced by new ones in September, 1908
No. 1 North Columbia and Smithfield	3-9-02	17 16	21·5	22 4	29	Two new ropes
	30-9-03	18 12	22	21 6·75	20	South rope corroded
	6-6-04	17 7	19	18 18	5·1	South rope condemned
	7-7-05	18 0·45	14	17 15	3	North rope condemned
	25-1-06	17 19	18	...	...	
	14-2-07	16 8	8	...	...	
South Glanmire and Monkland	3-3 02	31 1·22	23	30 18·3	27	South rope reversed on drum
	2-12-02	29 6·8	26	30 8	27	
	13-7-05	27 2·7	19	27 2·7	25	
	26-9-04	26 3·8	19	25 13	23	
	22-2-05	25 18·4	16	26 7·8	29	
	30-8-05	24 14	23	26 3·91	33	
	16-5-06	25 10	18	25 8·75	28	
	24-4-07	Too short	...	24 19·6	18	
Columbia and Smithfield	5-8-04	19 3	26	19 6	12	In use some time
	2-10-05	19 1	21·5	18 16	16	
	23-12 07	20 0	9·3	17 8	9·1	

5.—SOME NOTES ON SAFE RAILWAY WORKING.

By T. W. FOWLER, M. Inst. C.E., M. Am. Soc. C.E., M.I. Mech. E., &c.

In connection with railways, many problems of an engineering character have to be dealt with; others belong more to the commercial branch, and others again to the transportation or traffic branch. The determination of whether rail communication should be established between certain points may be considered a commercial problem, if it has not to be decided upon political grounds. The selection of the most suitable route, the construction, the equipment with rolling stock, and with interlocking apparatus, signalling gear, &c., are engineering problems; whilst the determination of the number and character of the trains and the times at which they should run are problems for the traffic branch, subject, of course, to consultation with the engineering branch as to desirable and permissible speeds and weights of trains. The engineer, and the engineer alone, has the skill required to determine the loads which the engines can haul, the speeds at which engines and rolling stock can be safely run (considering their design and condition, and also the design and condition of the permanent way and bridges, &c.), and also the distances within which they can be safely stopped under various conditions on various gradients and various speeds. He again understands the design and construction of the various safety appliances, interlocking gear, block instruments, &c., and the conditions of the working for which they are intended. Hence, the writer submits that regulating the system of train working, including details as to staff and block working, is a problem belonging to the engineering branch of a railway, including under that term the locomotive, permanent way, and telegraphic branches.

The subsequent discussion is divided into Sections in the following order:—

(*a*) Block telegraph and train staff working.

(*b*) Arrangement of junction stations.

(*a*) BLOCK TELEGRAPH AND TRAIN STAFF WORKING.—If trains could be run with unerring regularity as regards time, and were always under perfect control, if signals were never obscured by fogs or from other causes, if signal men and others never made mistakes, and if the permanent way and rolling stock were always in perfect order, accidents would become impossible. But such conditions cannot be realised; for instance, even with the most careful supervision, latent flaws in materials may exist undetected, and may develop at a critical moment. The possibility of mistakes in signalling can be reduced by the use of a modern interlocking apparatus and other safety appliances, whilst continuous brakes provide for better control on the train itself. On the other hand, atmospheric conditions may at any moment enormously increase the risk owing to "greasy rails" and signals becoming obscured by fog. The possibility of men making mistakes has to be borne in mind, and hence it is generally recognised that a system to be safe should be such that two men must each make a mistake, or one man must make two separate mistakes, before an accident can become possible. For a driver to overrun a stopping signal is a most serious offence, deserving the severest punishment, but there is always the possibility that from some unforeseen cause, such as greasiness of rails or failure of brakes on a descending grade, or in cases of fog the signal not being seen, a driver may overrun a stopping signal. Hence a system of working to be safe should be such that before a driver can cause an accident he must overrun two stopping signals at a reasonable distance apart, and both indicating danger. With the block telegraph system (hereafter referred to) carried out in its entirety, such provision is made, and any attempt to reduce it should be most vigorously resisted.

It may not be out of place to remind members that at the inception of the railway system attempts were made to secure safe railway working by preserving a time interval between following trains. This, however, was not a satisfactory safeguard, as, for instance, where for any reason the leading train was delayed between stations, or if it broke down. The development of the electric telegraph made it possible for the officials at each station to advise those at the station in the rear of the arrival of each train, and to obtain from those in advance permission to send it on, such permission being granted only after the preceding train had arrived. Hence an interval of space was substituted for an interval of time to secure immunity from collisions between following trains, and in this is the germ of the block telegraph system of railway working. The lines were divided into sections, and under the absolute blocking system only one train was allowed to be in a section at once. Hence, when a train was in a section, "line clear" (or permission to enter the section) could not be given to a following train. In view, however, of the speed at which many trains travel, even this system was found insufficient, owing to possible overrunning of signals, and hence for years past the rules have been modified so that "line clear" cannot be given unless the line is clear for a quarter of a mile ahead of the home signal in advance, and (as regards British practice) the preceding train is either shunted to one side or proceeding on its journey.

Australian railway practice in the matter of precautions for securing safe working of trains follows generally on that of British lines, as distinguished from the American train despatcher system. As regards British practice, certain requirements of the Board of Trade have to be complied with, prominent amongst which are the "block telegraph system" with double line working and the train staff and train ticket system combined with the block telegraph system, or alternately the electric staff or tablet system, on single lines, except where one engine only is allowed on a line at once, where the train staff system alone is required. Subject to the Board of Trade regulations, British railways are generally worked in accordance with the rules and regulations drawn up by the Railway Clearing House with such modifications as may be adopted on each system. The writer sought to purchase a copy of these rules and regulations from the secretary of the Clearing House, and was refused, on the ground of its being a private publication, the practice differing most markedly in this respect from that of the American railway associations, whose standard code of train rules is sold publicly. However, thanks to the courtesy of various officials, he has obtained copies of the rules and regulations and working appendix of a leading British railway, and also of the Victorian, New South Wales, and South Australian railways, and has reason to believe that those of Victoria and New South Wales are in practically exact accordance with those of the Railway Clearing House, and that those of South Australia, whilst differing considerably, mainly follow British lines.

As stated in the various rules, the object of the block telegraph system is to prevent more than one train being in the section between two block signal boxes on the same line at the same time. Whilst in general terms this may be taken as indicating the object, it will be found that where signal boxes are at stations, trains are commonly permitted to pass them to enter such stations, even if the section ahead be not clear, and, as already mentioned, the more recent codes of regulations provided that a section is not to be considered clear unless the preceding train has passed at least a quarter of a mile past the home signal in advance. Hence, for the purpose of a careful discussion, it is preferable in cases where sections are from station to station and starting signals are provided, to take boundaries of the sections as being such starting signals in lieu of either the home signal or the signal box, and to provide that such starting signals must always be a quarter of a mile in advance of the home signal. With the section thus defined, the train does not enter the section until after leaving the station in the rear, although whilst stopping at such station it would necessarily have passed the home signal and possibly the signal box, and thus have technically broken the block system were the section in advance occupied and the signal box the boundary. With this arrangement, when the section ahead is blocked, stopping trains are held up at the starting signal, and non-stopping ones at the home signal.

In South Australia the more important lines are worked on what is there termed the "absolute block system," and those on which the traffic is light on the "permissive block." "Absolute block" there means something different to what is used elsewhere, No. 81 of the South Australian Rule Book reading as follows:—"After the 'line clear' signal has been returned in answer to the question 'is line clear?' the line must not be obstructed until the train has arrived, except for shunting purposes in station yards, and only then when efficiently protected by fixed semaphores or hand signals." At first glance this would seem to imply that "line clear" in South Australia is the equivalent of "section clear, but station" or "junction blocked" of Great Britain, New South Wales, and Victoria, but this has to be read in conjunction with No. 145, the first part of which is as follows: —"Every engine man shall bring his train to a standstill at the distant signal when the arm or light indicates danger. Having done so, he must, without a moment's delay, move gently forward past such distant signal so far as he may see his road is clear, until close up to the home signal (except as provided for in Rule 148), and there wait a signal from it or verbal permission from the signalman to proceed." It will thus be seen that the South Australian distant signal is an "absolute stop" signal, and not, as elsewhere, merely an indication as to the probable position in which the driver will find a signal in advance. Hence, in South Australia, before a driver could cause an accident by running into a station in which shunting is going on, he would have to pass two stopping signals at a considerable distance apart, complying with the conditions mentioned by the writer at an earlier part of this paper. In fact, the South Australian practice may be considered the equivalent of converting each station into a section, separate and distinct from the approach section on either side. In this respect the practice is undoubtedly safe, but this may involve delay to the through traffic, which would be unadvisable on busier lines.

The block system generally adopted in Australia is that termed by Langdon, in his "Applications of Electricity to Railway Working," the "affirmative system," by which the signal man in the rear has to ask his comrade in advance for permission to let the incoming train enter the section, although he has already been advised that the train previously admitted has reached the station in advance. This is generally considered the safest system, but it involves the noting of three separate conditions of the line, viz.:—

(*a*) Section empty, but permission not granted for a train to enter;

(*b*) Section empty, and permission granted for a train to enter; and

(*c*) Train on line.

The three wire instruments in use in many parts of Great Britain and on portions of the New South Wales lines provide separate indications for these three conditions, but the single wire instrument in use in New South Wales and the Winter block instrument in use in Victoria and South Australia provide only two. Hence, as these instruments are worked, there is and can be nothing to distinguish between conditions (*b*) and (*c*) above mentioned, though, of course, the signal register-book would give the desired information. In the writer's opinion this involves an unnecessary and undesirable tax on the signal man's memory, and must at times lead to confusion.

As regards single line working, the Board of Trade requires (except in the case of lines worked by one engine) the use of the block telegraph system combined with the train-staff and train-ticket system or, as an alternative, the electric staff or tablet system. As far as the writer can gather, in Victoria and New South Wales single line working is carried out in compliance with the above systems, with the exception that in localities where the traffic is very light the train-staff and train-ticket system is used without the block telegraph system. In those localities where the staff stations are connected by telegraph or telephone, advice is given by that means as to arrival and departure of trains, but the rule provides for the departure of a train before advice has been received of the previous train reaching the station in advance, if such previous train has left at least ten minutes and the driver of the following train is given a "notice of train ahead," thus introducing the principle of the permissive system.

Whilst the general outlines of single line working by electric staff in Great Britain and Australia are identical, the following important difference is to be noted:—In Great Britain, on a single line, "line clear" means that the station in advance is clear for a quarter of a mile past the home signal, or at least up to the starting signal, and if it is desired to let a train enter a single line section whilst the station in advance is blocked, it must be on the "section clear, but station" or "junction blocked" signal, always provided that the section is one where such a signal can be given, otherwise the train would be held back until the "line clear" signal could be properly given. Neither in Victoria nor New South Wales is the "section clear, but station" or "junction blocked" signal given in single line working, but in Victoria, on single lines, "line clear" means only that the line is clear up to the home signal, whilst in New South Wales it means that if the station in advance be a crossing terminal or junction station the line is clear to the "home signal" only, whilst if it be not one of these, that the line is clear at least a quarter of a mile past such home signal.

In South Australia single lines are worked without any staff whatsoever, the Winter block instruments being used. The writer has not had the opportunity of inspecting these instruments, but, presumably, they are arranged so that "line clear" cannot be given from both ends at the one time. In any case, the instrument does not seem a desirable one, as a station-master might in error allow a train to depart without having received "line clear" for it, and, in fact, when permission has been given for a train to depart from the opposite end. With single line working a driver is entitled to a substantial guarantee that the way is clear before him to the end of the section, or at least that no train is approaching him from the opposite end, and the only satisfactory way of giving such an assurance is to put him in possession of the only sectional staff, ticket, or tablet which can at the time be away from the stations.

In South Australia, on lines with light traffic, the "permissive block" system is used, but the regulations provide that a considerable time, usually 40 minutes, must elapse before the departure of a following train.

In connection with the double line working in Australia on most of the lines a satisfactory system of interlocking between points and signals exists, and also a more or less satisfactory system of block working, as already indicated, but in the majority of cases there is no guarantee (except reliance on the signalman) that the signals agree with the block instruments. To put it another way, except where the "lock and block" system is in use, there is nothing to prevent a signalman letting a train into the section before he has "line clear." Where traffic is very heavy the "lock and block" system has been introduced at very considerable expense, and, as is well known, with that system the train itself sets the signals at danger behind it, and keeps them there until it clears the section. In many cases the expenditure necessary for the equipment would not be justified, and in such cases the writer suggests that electrical connections should be made between the block instruments and the starting levers, so that the latter cannot be pulled off unless "line clear" has been obtained from the station in advance. Such an arrangement would cost but little, and would be a guarantee of increased safety. Further, at junction stations the block instruments could be readily interlocked electrically, so that "line clear" could not be given at the same time to two or more trains which could foul each other.

(*b*) Arrangement of Junction Stations.—Whilst no rule can be laid down suitable for universal application, it will generally be found practicable (and where practicable, certainly desirable) to so arrange junction stations that the passenger platforms and the entrances to the goods yards (if any) are located past the point at which the main and branch lines separate, as under such circumstances a train stopping at its platform or shunting will block its own line only. To put this in different language, it is usually desirable that the actual junction be in the "up" direction from the passenger platforms. With this arrangement, and accepting the starting signals as the boundaries of the sections, it will be noted that the main line and branch line sections on the "down" side of the junctions are entirely separate. It may be accepted that any section is effectively protected when there is at its entrance a starting signal, with a home signal a quarter of a mile further back, and a distant signal at the usual distance in the rear, since it is most unlikely, though, of course, possible, more especially in fogs, that a driver will, by any mischance, run past two absolute stop signals when he has been previously warned by a distant signal that they are at danger. Hence, with a junction so arranged, it is reasonable to permit trains to approach the junction station in the "up" direction on the main and branch lines simultaneously, but where the actual junction is past the "down" end of the platform the circumstances are entirely different. In this case the branch and main lines past the "down" end of the platforms form one connected and continuous section, and to permit trains to approach from the branch and main lines simultaneously under any circumstances with a junction thus arranged is clearly a breach of the fundamental principle of block working. The attached diagram, No. 2, illustrative of the arrangement of the Hawthorn Junction Station, Victoria, may be taken as an excellent example of a well laid out junction between a double and a single line at a station, the single line being accommodated at an island platform, and coming in from the right when facing towards the metropolis. It will be understood that all points and signals are interlocked, and that plunger bars are provided with all facing points. The general arrangement is as follows:—When trains are passing, either up or down on the main lines, the catch points on the branch are set to divert any branch train to the siding, and when a train for the branch (*i.e.*, a down branch train) comes along it is diverted by the second facing points to the platform road of the branch line, and cannot foul anything when a train is passing from the branch to the "up" main line (*i.e.*, an "up" branch) the first facing points of the down road are set to divert any approaching down train into the No. 2 branch road. Hence the only possible collision would be caused by an "up" main line train passing through whilst an "up" branch line train was passing on the main line, and to do this the "up" main line train would have to pass distant home and starting signals all at danger.

Diagram No. 3 illustrates the corresponding arrangement where the branch comes in from the opposite side, and it will be noted that the protection cannot be made as complete, since an "up" main line train can foul a "down" branch line train as well as an "up" one. The former could, of course, be avoided by adopting a "flying junction."

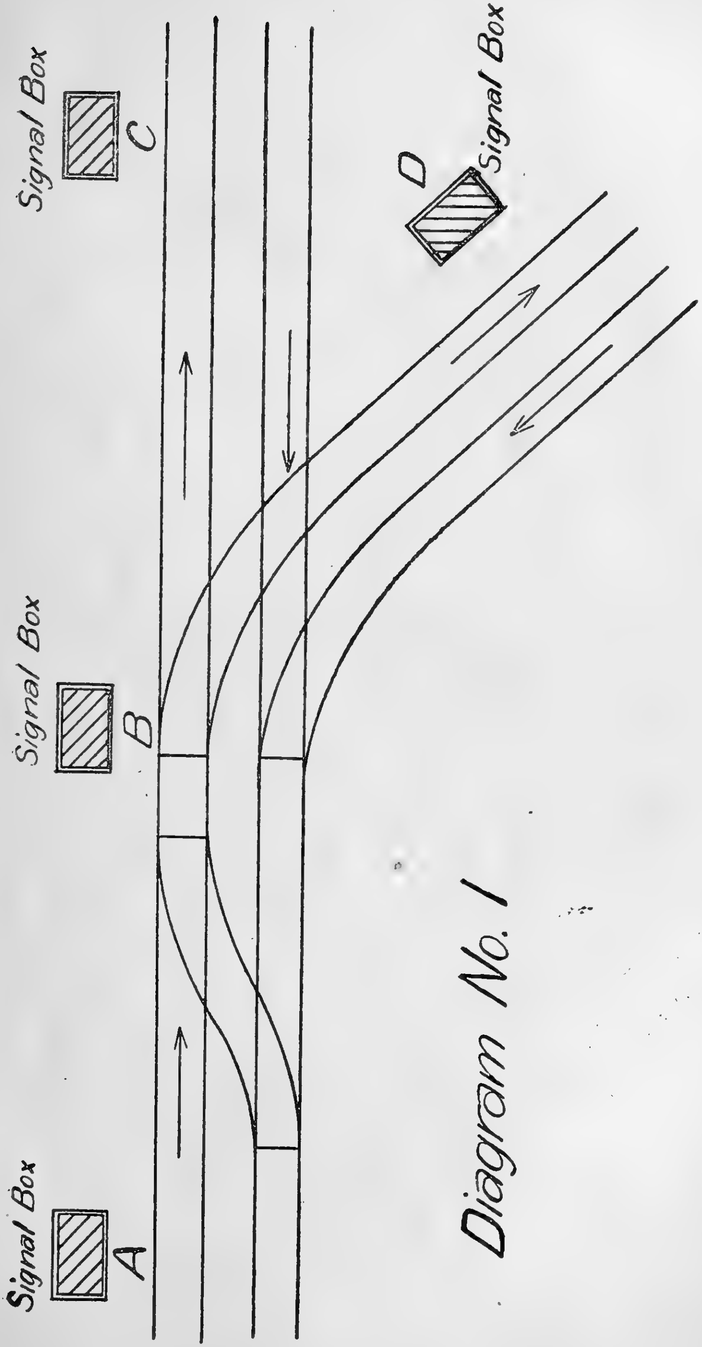


Diagram No. 1

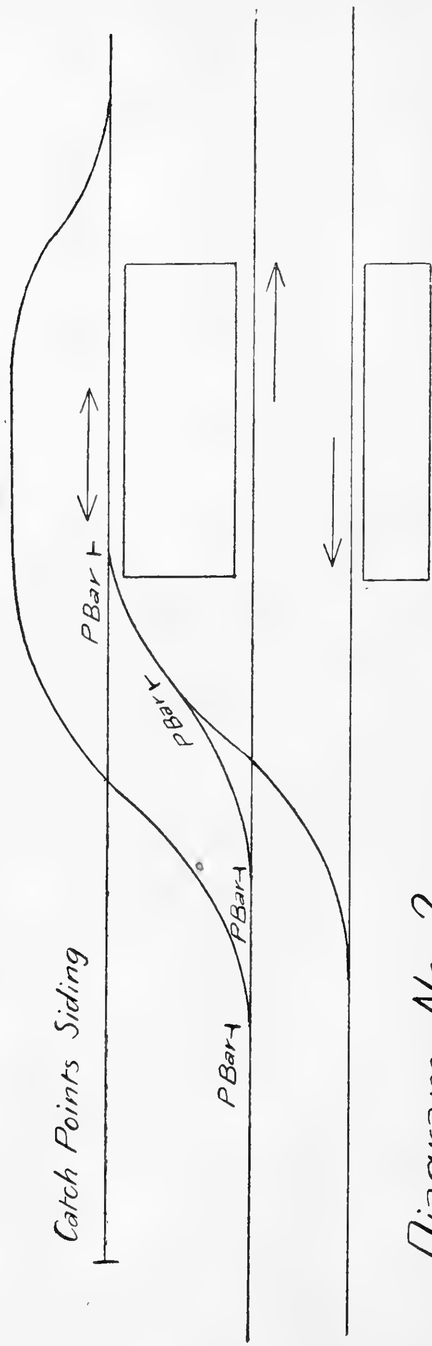


Diagram No. 2

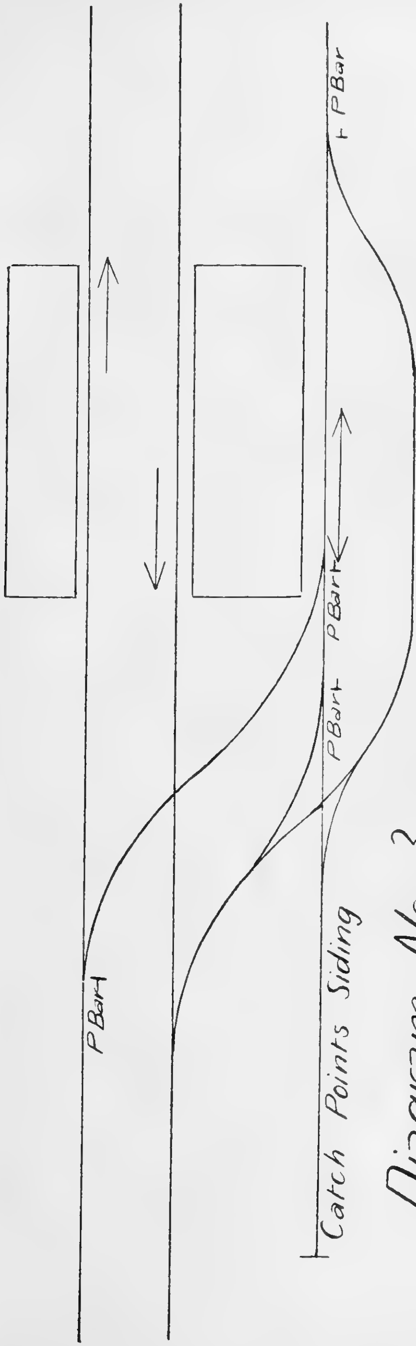


Diagram No. 3

6.—THE POSSIBILITY OF DEVELOPING AN AUSTRALIAN STYLE OF ARCHITECTURE.

By G. H. M. ADDISON.

The Athenian desire for some new thing has found an echo in all ages. There are two rocks in the stream of progress—one is the danger of an ultra-conservatism which strenuously fights against all progress on the assumption that knowledge has been perfected in the past, and that all new ideas are therefore dangerous if not impious; the other is the rock of anarchy, bred of the spirit of pessimism, which ignores all past experience and the accumulated knowledge of the ages, contending that our civilisation is rotten to its very base, and can only be regenerated by an absolutely new beginning. True progress, however, steers between these two extremes. It adopts all that is good in the past, making gradual improvements and adaptations to meet new conditions. Both the conservative and the radical schools have their exponents in architecture. The latter is often an intelligent protest against that monotony which is liable to result from too conservative a spirit. At times, however, it is a youthful protest against definite law; an abuse of the emancipation of the half-trained student who has failed to grasp the difference between liberty and license. Save during exceptional epochs when at the end of an era of civilisation the world has been thrown back into comparative barbarism, all architectural progress has been by gradual development. A new detail has been added here, a detail has been perfected there. A settlement under new climatic conditions has gradually altered the style in one direction, a difference in available material has gradually altered it in another, until from one starting point we eventually find a multiplicity of architectural styles which to the casual observer seem to have no affinity to each other.

To enable one to gauge on what lines Australian architecture will advance it is necessary to have some idea of the history of past developments. I trust, therefore, you will pardon me if I make as rapid a review as possible of those agencies which have led up to architecture as we find it to-day. Although by no means the beginning of architecture, the Egyptian buildings may be considered the starting point of that progression which has led by easy stages to the present day developments. The first principle of Egyptian architecture is what is known as "Traheated"—viz., beams supported on rows of columns, resulting in an emphasis of the horizontal lines in construction and decoration. At this early stage we find the rudimentary form of the ecclesiastical buildings as repeated to the present day. In the pylon we have the suggestion of the front of a modern cathedral with its two west towers. The great columnated hall had a suggestion of nave and side aisles, and was lighted by a clerestory, and what answers to our sanctuary was placed at the east end.

These early people living close to Nature adopted many of their architectural details direct from her. The columns were often fairly accurate reproductions of a growing palm-tree or a bundle of canes. The lotus plant was the favourite decorative inspiration. In many buildings, especially in the rock-cut temples and tombs, there is an evident copying of timber construction. In other temples the use of granite resulted in a massive severity necessitated by the material.

The Grecians, who were at an early age in close touch with the Egyptians, grafted Egyptian detail on to the cyclopean architecture of the Pelasgic. The Doric order, the first and the grandest of Grecian ideals, found its prototype in Egypt. The Grecians by slow degrees perfected its proportions until an ultra-refinement led to the development of their Ionic order, which seems to have been suggested by the lighter columns and capitals of the Persians. Later still the passion for sculpture resulted in the Corinthian, a voluptuous order, which suggests the seeds of a possible decadence in art if the decline of the nation had been more gradual. The difference of material at command and the absolute contrast in natural environment led to Grecian architecture developing on more refined lines than the Egyptian, but this refinement of necessity resulted in some loss of impressiveness.

The Romans in their national infancy were too much occupied by their material interests to find time for original art development. The Etruscan architecture of their forefathers was sufficient for their earlier needs; afterwards they grafted on to this details learned from Greece. These, however, soon got coarsened by the grosser and more materialistic character of the nation. The adoption of the arch in place of the beam as the main principle in construction led to the first big break from ancient types. The arch formation at once led to the vaulted and domed roofs, the crowning glory of Roman architecture. For years, however, the traheated treatment was kept as a false clothing to arched construction. Towards the end of Roman development the Romanesque style was evolved. This was the logical outcome of the adoption of the arch. The imitation of beam construction was abandoned, and the dominant lines were perpendicular, thus paving the way for the Gothic innovation.

The submergence of the Roman Empire by the Goths threw the architectural world back into semi-barbarism. The Romanesque forms were imitated with more or less knowledge, according to the distance of the nation from the old art centre. On these ancient details were grafted those forms of rudimentary decoration common to all half-civilised races. Side by side with the development of Western architecture, the East had advanced on different lines, reaching to highest zenith in Persia, at that era so poetically depicted in the "Arabian Nights Entertainments." The crusades, by bringing the Western nations into touch with this finer architecture of the East, introduced new ideas. Already the pointed arch had been evolved by the Gothic races. At first, however, the buildings were ponderous and clumsy. As knowledge of construction and outside influences operated they became more and more refined, and eventually more and more decorative. Finally, an exaggerated love of carving and pictorial glass, with its consequent wide expanse of window, overshadowed that true sense of proportion which was the charm of Gothic as of Grecian architecture in the days of its perfection. Time would fail us to trace the phases of Gothic architecture through the different European channels. Suffice it to say, that with each nation it varied according to national characteristics and environments. In

England a genuine playfulness was balanced by a sense of dignity. In Central Europe the dignity overshadowed the playfulness, and in France the playfulness often overshadowed the dignity. The Gothic of the Netherlands was as heavy as its people and flat as its country. The architecture of Spain felt largely the influence of its Moorish neighbour, and that of Italy the influence of either Byzantium or ancient Italy, according to geographical position. The revival of letters naturally led to a renaissance in architecture. The ancient classic forms were again revived, but with a variety and freedom which was the legacy of Gothic art.

From that time onwards the art has had many vicissitudes, according to the temperament of each succeeding generation.

In England, during the period of the Georges, architecture as an art became almost defunct. The Victorian era saw a wonderful revival of the art spirit. This commenced with tentative efforts to adapt to modern requirements one ancient style after another. The Gothic, Elizabethan, Jacobean, Queen Anne, Romanesque, Byzantine, and Renaissance followed each other in quick succession.

The battle of the styles which raged so strongly in the middle of Queen Victoria's reign is now happily ended. Artists recognise that there is a distinctive beauty in all styles, and while Gothic is in England still generally maintained as the true ecclesiastical type, a free type of Romanesque and Renaissance has been generally adopted for civil buildings, and these have been developed on lines distinctive of the era.

While the foregoing *résumé* is, I am afraid, long enough to have exhausted your patience, it is far too fragmentary for my purpose, Many of the side streams of progress have not been touched upon, and of the rest it would be impossible in a short paper to mark the stages of gradual transition. I hope, however, to have made it clear that advancement has never been by leaps and bounds, but by gradual improvements and a cumulation of almost imperceptible changes. If this is admitted, it is evident that those architects who aim at assisting in the development of an Australian style must first have a thorough academic knowledge of what has gone before.

We are the heirs of the accumulated effort and knowledge of the ancients, and it is for us to cull from the past all that is suitable to our requirements, blending them with taste into an harmonious whole.

The ecclesiastical temperament is essentially conservative, and while it is doubtful whether Gothic architecture is best suited for our conditions, it seems likely to hold its own for some time in church design. Australia has, however, a few examples of original treatment of the Romanesque which may well tempt to further effort in this direction.

It is in domestic rather than in ecclesiastical architecture that Australia may be expected to develop originality. But before much satisfactory result will be attained the nation must have formed distinctive character and habits. We are at present too near our parent stock to have formed new habits except in as far as climatic conditions have constrained us.

At present our houses are adaptations of either English or American types. The fireplace, the central feature of the English home, is modified, and the veranda is made a more emphatic if less artistic feature than in America. But in the average home we look in vain for features "racy of the soil." We have, in Brisbane, one example of the Japanese house. It was designed and constructed in Japan, and erected here by Japanese workmen. This house, while in many respects unsuitable to our mode of living, is eminently suitable to the climate. A study of such a house, together with Eastern dwellings generally, and a careful selection of those of their features fit for our requirements, may gradually give rise to an original style only indirectly traceable to its origin.

It is in this more tropical State that original character should first appear. In the past poverty has crippled Queensland efforts, but in a few instances a distinctive treatment of the veranda as an integral portion of the dwelling gives hope for originality in the future.

It is in civil architecture that Australia has, so far, made most advancement. The best of our modern architects are encouraging a feeling of simplicity of design in place of the florid decoration which in some older buildings strives to hide bad proportion. Our wealth of building materials, such as marbles, granite, and all classes of stone, should in the future enable us to progress effectually on these lines of elegant simplicity.

That the final style adopted will be one having the horizontal lines emphasised seems certain. Even if this were not suggested by the climate, the prevalence of the awning or colonnade over the footpath would make it obligatory. High-gabled roofs, suggestive of a snowy climate, will gradually give place to flats roofs and roof gardens. The point from which we shall probably make our own departure will be the buildings of Italy—either Florence or Venice. In most of our capital cities the streets are too narrow to allow of an architectural treatment of the awning as an integral portion of the building. In laying out new cities it might be advisable to allow width enough on the kerb to enable a colonnade to be erected in stone. In any case, the city authorities might justly insist that awnings erected on the public thoroughfare should be solid and artistic. This in itself would give our cities a distinctive character. In all main streets it would be advisable, before it is too late, to pass regulations fixing the maximum and minimum height of buildings, leaving enough margin between the two to avoid monotony of sky line.

The Australian style, when it comes, will not be the outcome of any conscious effort; rather will it be the reflex of a well-defined national character and the result of gradual changes of ancient types to suit our climatic and general conditions.

Section I.

SANITARY SCIENCE, AND HYGIENE.

PRESIDENTIAL ADDRESS.

BY

J. MASON, M.D.

Health Officer, New Zealand.

MUNICIPAL CONTROL OF THE MILK SUPPLY.

[*At the time of going to press, this address had not been received.*]

PAPERS READ IN SECTION I.

1.—TYPHOID FEVER MORTALITY STATISTICS FOR AUSTRALASIA, ARRANGED IN PERIODS.

By HARDOLPH WASTENEYS, T.C.S.

Compiled from Tables in "A Statistical Account of Australia and New Zealand, 1903-4," by T. A. Coghlan, and from information supplied by the Government Statists of New Zealand and the Commonwealth States.

State.	1871-75.	1876-80.	1881-85.	1886-90.	1891-95.	1896-1900.	1901-5.	1906-7.
				NUMBER OF DEATHS.				
New South Wales...	...	1,722	2,132	2,307	1,533	1,968	1,530	460
Victoria	1,799	2,174	2,364	3,209	1,571	1,722	948	251
Queensland	424	525	1,303	990	513	747	656	172
South Australia ...	372	446	632	566	369	512	291	87
Western Australia	...	...	...	59	500	1,379	627	251
Tasmania	156	184	213	401	230	251	132	†
Commonwealth ...	...	5,051	6,644	7,532	4,716	6,579	4,184	‡1,258
New Zealand ...	*632	739	626	674	561	511	327	101
Australasia	...	5,790	7,270	8,206	5,277	7,090	4,511	‡1,359
				DEATH RATE PER 100,000 LIVING.				
New South Wales...	...	52·0	50·6	44·6	25·6	30·0	21·5	15·0
Victoria	47·1	52·9	51·8	60·9	26·9	28·9	15·7	10·1
Queensland	59·1	51·4	96·7	54·8	24·8	32·0	25·5	16·0
South Australia ...	38·0	36·9	43·0	36·7	22·2	29·2	15·9	11·4
Western Australia	...	...	...	28·3	150·3	177·2	57·1	47·9
Tasmania	30·3	33·8	34·8	58·5	30·4	30·2	14·9	...
Commonwealth ...	...	48·9	53·8	51·3	28·3	36·2	21·5	‡15·6
New Zealand ...	*51·0	34·6	23·6	22·3	17·0	13·9	8·0	5·6
Australasia	...	46·4	48·4	46·4	26·4	32·4	19·1	‡13·7

* Four years, 1872-75. † Not yet available. ‡ Exclusive of Tasmania.

TYPHOID FEVER MORTALITY STATISTICS FOR AUSTRALIA AND NEW ZEALAND FROM 1903 TO 1907.

(Compiled by Hardolph Wasteneys from information supplied by the Government Statists of the States and New Zealand.)

State or City.	1903. Mean Population.	1903. Deaths.	1903. Rate per 100,000	1904. Mean Population	1904. Deaths.	1904. Rate per 100,000	1905. Mean Population.	1905. Deaths.	1905. Rate per 100,000	1906. Mean Population.	1906. Deaths.	1906. Rate per 100,000	1907. Mean Population.	1907. Deaths.	1907. Rate per 100,000.
State of Victoria	1,208,880	254	21·0	1,207,537	190	15·7	1,212,517	121	10·0	1,227,072	162	13·2	1,246,860	89	7·1
Melbourne	502,060	65	12·9	504,960	71	14·1	511,900	41	8·0	521,000	46	8·8	532,200	48	9·2
Ballarat	51,320	10	19·5	49,2[illegible]2	8	16·3	49,648	7	14·1	48,565	11	22·7	48,607	4	8·2
Bendigo	42,540	38	89·3	42,660	31	72·7	43,660	14	32·1	44,140	11	24·9	44,458	3	6·8
Geelong	25,801	3	11·6	25,957	3	11·6	26,672	2	7·5	27,416	3	11·0	28,021	1	3·6
State of New South Wales	1,419,734	475	33·5	1,446,585	249	17·2	1,478,703	239	16·2	1,514,390	271	17·9	1,551,783	189	12·2
Sydney	518,960	81	15·6	524,700	64	12·2	530,650	60	11·3	545,060	52	9·6	567,000	61	10·8
Newcastle	57,000	15	26·3	58,500	19	32·5	59,700	8	13·4	60,900	10	16·4	62,300	8	12·8
State of Queensland ...	512,690	189	26·9	519,178	91	17·5	525,728	95	18·1	532,783	88	16·5	541,204	84	15·5
Brisbane	123,639	26	21·0	125,068	26	20·8	127,704	18	14·1	131,102	16	12·2	134,062	19	14·2
State of South Australia...	361,724	57	15·8	365,586	32	8·8	370,791	41	11·1	376,335	48	12·8	384,275	39	10·1
Adelaide	...	12	30·	...	10	25·	...	9	23·	...	17	43·	...	13	32·
Port Adelaide ...	...	2	10·	..	...	...	...	...	...	...	1	5·	...	4	18·
Kensington and Norwood	...	1	8·	...	...	...	...	1	8·	...	...	...			
Port Pirie	...	8	90·	...	5	54·	...	9	93·	...	4	40·			
State of Western Australia	221,278	132	59·7	236,516	87	36·8	250,207	107	42·8	259,811	128	49·3	263,749	123	46·6
State of Tasmania	177,547	38	21·4	178,826	22	12·3	179,259	23	12·8	180,634	37	20·5			
Hobart	34,789	13	37·4	34,888	8	22·9	34,997	11	31·5	34,920	10	28·6	Statistics	not	yet
Launceston	21,336	5	23·4	21,566	2	9·3	21,592	2	9·3	21,658	5	23·1	available.		
Dominion of New Zealand	820,217	61	7·4	845,022	73	8·6	870,000	45	5·2	895,594	48	5·4	919,105	53	5·8
Auckland	55,528	8	14·4	56,951	9	15·8	58,384	7	12·0	65,381	5	7·6	70,068	6	8·6
Wellington	53,082	5	9·4	55,618	4	7·2	58,365	2	3·4	64,302	4	6·2	69,241		
Christchurch... ...	50,558	2	4·0	51,733	2	3·9	52,722	1	1·9	53,339	...	...	56,170	2	3·6
Dunedin	55,631	1	1·8	57,784	4	6·9	59,663	...	...	56,557	5	8·8	58,724	1	1·7
Commonwealth	3,901,853	1,145	29·3	3,954,178	671	17·0	4,017,205	626	15·6	4,091,025	734	17·9	*3,990,851	524	13·1
Australasia	4,722,070	1,206	25·5	4,799,200	744	15·6	4,887,205	671	13·7	4,986,619	782	15·7	*4,909,956	577	11·8

* Exclusive of Tasmania.

2.—THE COLLECTION AND TREATMENT OF SEWAGE.

By CHARLES E. BERNAYS.

As it seems probable that definite steps will shortly be taken to place Brisbane on the list of cities provided with a creditable sewage system, a few notes on the subject should not be out of place.

Here in Brisbane we are fortunately able to make a fair start, unhampered by any existing system, so there is no reason for our not adopting the most suitable and up-to-date methods or combination of methods known to modern science.

Before coming to the question of sewage collection, or treatment, it must be remembered that our present water supply is quite inadequate for any system of sewage at all, and as the cost of increasing it must be very great, any system of sewage collection that requires a minimum amount of water for working or flushing purposes should receive special consideration from that point of view.

Next to the water question comes that of outfall, and as the cost of taking any form of sewage out into the ocean would be prohibitive, whatever system of treatment is adopted it must be such that the residue therefrom is quite harmless, and can be discharged into the river or bay.

In the older countries many systems of treatment are in vogue with more or less satisfactory results; but for tropical and semi-tropical lands the septic tank, when properly designed, has proved to be quite satisfactory, and affords the cheapest and best method of dealing with sewage.

If septic tank treatment is decided upon for Brisbane, it naturally follows that the method adopted for the collection should be that which delivers the sewage in the best possible condition for such treatment, and it is doubtful whether any person can be found to argue that heavily diluted sewage is suitable for rapid and efficient treatment. This brings us to another point, and that is that our sewers should NOT be used for the conveyance of storm water. It may, of course, be contended that storm water supplies good flushing water, and that cannot be disputed, but, on the other hand, during heavy rains a great quantity of silt would be carried into the system, and the sewers and tanks would have to be made larger at very great expense, while during a flood no system could treat the sewage, plus the flood water. We already have a good scheme for dealing with our storm water, and that need not be disturbed. A very great advantage gained by keeping the sewage free from storm water is that the system would work equally well during flood time.

The system most commonly in use for the collection of sewage is that known as the "Water Carriage." In these cases the system consists of large main sewers, in brick and concrete, with earthenware pipes as feeders. When sufficient fall cannot be obtained pumping is resorted to, as in Sydney, Melbourne, and elsewhere. One great objection to this system is the large quantity of water used for flushing the sewers, which in our case would mean great expense for water and much larger treatment tanks than would otherwise be required. In nearly all places using water carriage the sewage is run into the sea.

Septic tanks in Europe are by no means new, and the writer saw one that dealt with the sewage of a town of over 30,000 inhabitants that measured only 50 ft. long and 50 ft. wide. This has been working most satisfactorily for over twelve years. The effluent after passing over an aerator went through a charcoal filter, and into the river. It was quite harmless and odourless, and said to be free from any objectionable organisms.

Having dealt with the leading features of a modern system of treatment, and shown that the less water used the better, the question of collection has next to be considered. There are two that may be called modern methods before the world; but, for various reasons that cannot be dealt with here, neither method has come largely into use. Both methods have a common point that will appeal to most people, and that is that, instead of large brick or concrete sewers made at great cost deep down in the roads, comparatively small cast-iron pipes can be laid at a greatly reduced cost under the footpaths and near the building alignment, so that the cost to property owners for connecting their buildings becomes very trifling, as compared with making connection with the big sewers deep down in the earth.

As these methods are not well known, a brief description of them may be desirable. One is a combined gravitation and pneumatic pressure system by which the sewage flows from the houses into mains in the streets, and on into a metal district receiver placed at the lowest convenient point. This district receiver is connected to a system of compressed air supply, and operates automatically, so that when it becomes full of sewage, air, under pressure, is admitted, and the sewage is ejected from the receiver, and is forced along the mains to another receiver, and so on as often as is necessary until it reaches the point of treatment or discharge. This system is in satisfactory operation in Singapore and a few other places, but the author is not aware of it being in use anywhere in conjunction with septic tank treatment; and it is doubtful whether the aeration of the sewage that occurs in this system would not be detrimental to the microbic action in the septic tank. This system would work well in a hilly place like Brisbane, and while it has many points in its favour, it is open to the serious objection that the pipes are under pressure, and any leakage means escape into the atmosphere. The appliances for use with this method are made by several well-known firms.

The second method is just the opposite. The sewage is drawn from the houses by means of a vacuum into a district receiver, and from there it is drawn into the main receiver for final treatment. In this system each house is provided with a receptacle which collects the sewage, and this is emptied once or twice a day by a vacuum which causes all the sewage in the section to immediately leave the receptacles and fly along the small cast-iron pipes to the district receiver.

This vacuum system has many advantages, among which are—(1) that all smells are drawn *into* the system, (2) a minimum amount of water can be used, (3) the sewage is delivered in the most suitable condition for septic tank treatment, (4) and the pipes are kept clean, any leakage means drawing smells into the system instead of forcing them out.

The author took advantage while in Europe to visit Trouville, in France, where the vacuum (properly known as the "Liernur") system has been in constant use for thirteen years, and, thanks to the courtesy of the municipal authorities, he was enabled to thoroughly investigate the whole system.

The main works are situated on the outskirts of the city, which has a population varying from 12,000 in the off season to 38,000 when the season is at its height.

The whole staff at the works consists of three men—one engineer, one fireman, and one turncock. In the engine-house are two vacuum pumps that exhaust the air from the district and main receivers, and discharge this foul air, which would be most offensive, into the furnaces, and so supplies the necessary draft for the fires, and is rendered free from smell.

The turncock goes round the district receivers and opens in turn the mains leading from the different streets, and as he opens the various valves the sewage is sucked from the houses into the receivers at the rate of 12 ft. per second. No extra water is used for flushing the pipes, which are found to keep perfectly clean after years of use. No foul gases can find their way into the houses, in fact, air is drawn from the houses into the system, and this is regulated by a most ingenious and simple contrivance.

The amount of sewage dealt with varies considerably, but in European cities may be taken at 10 to 18 gallons per head per diem.

The installation at Amsterdam was put in in 1870, and serves a population of 230,000.

The Trouville system was installed in 1896, and serves, as already stated, from 12,000 to 38,000 people.

A number of small installations exist on the continent of Europe, and in South Africa, and one in Great Britain in the small town of Stanstead, Essex.

The cost of installing the vacuum system at Stanstead was £3 per head for 750 persons; at Trouville (originally) £1 per head for 12,000 persons.

An estimated cost prepared some years ago for Maitland, New South Wales, was about £3 per head, the difference in cost being due, no doubt, to the extra cost of labour and material in Australia.

The cost of a water carriage installation, without pumping (as in Sydney), ranges from £8 to £10 per head, but the main objection to this system is the tremendous cost to property-holders, who have not only to fit up their buildings but to connect them with the sewers, which are often many feet down in the ground. In Melbourne some property-owners found the cost of connection almost ruinous, although quite a number of years were given to pay it in.

With regard to the cost of operating the vacuum system at Stanstead the recorded cost is 1s. per head. At Trouville the proved cost is 3½d. per head on 12,000 population, and naturally less for 38,000.

As regards the health aspect of this system, Amsterdam supplies some interesting figures. Taking the thirty years during which this system has been installed, from 1871 to 1901, the mortality has decreased more than 50 per cent. Now, while it may not be fair to credit any one system with all the decrease in the death rate, yet the following figures point to a large amount of credit being due to the system:—In 1871 the population was 300,000 and in 1901 531,000, and the number of inhabitants served by the vacuum or Liernur system went up from 0 to 200,000.

In 1871 the death rate was 33·21 per 1,000.
„ 1901 „ „ „ 15·15 „

Each of the systems here referred to has another enormous advantage over the old system of water carriage, and that is, that the work can be done in sections and proved as it progresses, whereas when large underground sewers have to be built the system cannot be tried until the whole work is completed, when, as was the case in two large cities, it may be found a huge failure.

To localise the point, Clayfield could be sewered on the vacuum system, and the treatment tank placed down the river, say at Myrtletown, and could form one or more of a series of tanks to be added after the system had proved a success, all suitable additions being made without disturbing the existing plant. The words "suitable additions" being used advisedly, as the adoption of septic tanks makes it absolutely unnecessary that all the sewage of a large town should be treated at one spot, and, as in the case of Toowong and South Brisbane, each could have its own treatment tanks and operate the small amount of machinery required by electricity, and so reduce the labour at each station to one man and save the cost of conveying the sewage all the way to Myrtletown for treatment.

In conclusion, it may be pointed out that, while there are many groups of houses around Brisbane that would be exceedingly costly to connect with a large system of gravitation sewers, there are no parts that could not be connected by either of the two systems referred to, at a comparatively low cost.

3.—THE PREVENTION OF INFANTILE MORTALITY.

By B. BURNETT HAM, M.D., D.P.H., Health Officer, Queensland.

The tale of infantile mortality—the modern slaughter of the innocents—is an oft-told one. It has been told and retold by sanitarians and medical men in almost every country of the world. All authorities are agreed that it is one of the gravest problems with which we in this 20th century have to deal.

References to the mortality records of Registrars-General in various countries show that the mortality of infants—that is, of children under 1 year of age—is absolutely appalling, and that it does not decrease with the progress of civilisation in the same ratio as the mortality from other preventable diseases.

Infantile mortality is perhaps the most important medical and social problem of the age. It is a standing reproach to our much-vaunted civilisation. It is not altogether unreasonable to expect that public health administration would have a marked influence in reducing infantile mortality to what may, under present circumstances, be regarded as a normal standard.

"To those engaged in the work of preventive medicine the continuance of a high rate of infantile mortality, in spite of the great improvements in public health administration of the last 30 years, is a problem of special interest."

The object of this paper, however, is not so much to discuss how far administrative measures may serve, or to discover how much infantile mortality is due to causes which may be directly attacked by legislation and administration, and those which cannot be so dealt with, but rather to say something on the measures which have been proposed in late years to deal with this great problem.

So much has been said and written during the last decade about infantile mortality that the remedies proposed and suggested are even more numerous and varied than the causes assigned to it. It is obvious, therefore, that if we are to deal successfully with the problem confronting us, there is need of more specialised measures than those hitherto adopted.

The National Conference held in London in June of 1906 closed a period of isolated and spasmodic effort, and marked the commencement of what, it is hoped, may prove an united, systematic, and organised attempt to deal with the problem of infantile mortality. At that congress, presided over by the Right Hon. John Burns, the President of the Local Government Board, Mr. Burns, said:—"There are, in the United Kingdom, over 100,000 infants under 12 months old who are ruthlessly put to death, not willingly, but through ignorance and vice."

Ignorance, therefore, would seem to sum up the causes, as Education would appear to be the keynote in the prevention of this waste of infant life.

The following statistics from various countries are of interest:—

Country.	General Mortality—Deaths to 1,000 Living; Average Annual Rate in 10 Years (1895-1904).	Infantile Mortality—Deaths of Children under 1 year to 1,000 Births—Average Annual Rate in 10 Years (1895-1904).
France	20·4	153
Spain	27·8	182 (average for 5 years)
Italy	22·7	170
Japan	20·5	151 (average for 10 years—1892-1901)
Switzerland ...	18·1	142
Austria	25·2	224
Russia (European)	33·6	268 (average for 10 years—1892-1901)
England and Wales	17·2	150
Scotland	17·8	126
Ireland	18·0	103
Victoria	13·3	105
New South Wales	11·7	108
Queensland ...	11·8	101
South Australia ...	11·5	102
West Australia ...	14·6	147
Tasmania	11·8	94
New Zealand ...	9·8	79

In Paris, the deaths at all ages from all causes (1892-1897) was 303,206. The deaths of infants under 1 year of age per 1,000 of all deaths at all ages was 145·35.

The deaths from diarrhœa and gastro-enteritis of infants under 1 year of age per 1,000 deaths under 1 year from all causes was 380·30.

In Germany, according to Behring, of every 1,000 children born alive 235 succumb during the first year of life. Only 510 out of 1,000 males born attain manhood. These sad facts Behring attributes very largely to the ulterior effects of infection derived in infancy from milk.

Dealing with vital statistics of more recent date, based upon the Registrar-General's weekly returns for the third quarter of 1908, for 76 of the largest English towns, we find that infant mortality, measured by the proportion of deaths among children under 1 year of age to registered births, was equal to 145 per 1,000.

In London the rate of infant mortality in the third quarter of 1908 was equal to 129 per 1,000, while it averaged 152 in the 75 other large towns, and ranged from 42 in Hastings to 258 in Burnley.

The proportion of deaths of infants under 1 year of age to every 1,000 births for the United Kingdom shows the following means for ten years (1898-1907):—

England and Wales	141·65
Scotland	124·66
Ireland	100·39

In Queensland, 86 out of every 1,000 male children born, and 68 of every 1,000 female children, died during the year 1907 before attaining the age of 1 year. The mortality was thus 1 in 12 of male infants and 1 in 15 of female infants.

The means of 10 years (1898-1907) was 460 deaths under 1 month and 1,318 under 12 months.

The following table is added to show the comparison of Queensland to other States of the Commonwealth and New Zealand:—

PROPORTION OF DEATHS OF INFANTS UNDER 1 YEAR OF AGE TO EVERY 1,000 BIRTHS.

Year.	Queensland.	New South Wales.	Victoria.	South Australia.	West Australia.	Tasmania.	New Zealand.
1898	110·5	122·0	134·1	140·1	166·1	115·9	79·7
1899	109·4	118·7	114·2	111·3	139·9	116·2	95·9
1900	98·4	103·3	95·3	99·8	126·1	80·0	75·2
1901	101·9	103·7	102·9	100·0	128·7	89·0	71·4
1902	100·2	109·7	108·6	94·0	142·0	79·1	82·9
1903	119·9	110·4	106·4	97·3	141·2	110·8	81·1
1904	76·1	82·4	77·9	70·5	113·0	90·7	71·0
1905	75·5	80·6	83·3	73·0	104·2	79·0	67·5
1906	74·7	74·5	92·9	75·9	110·0	90·2	62·1
1907	77·2	86·6	72·6	65·9	97·7	82·8	88·8
Means of 10 years	94·1	98·7	98·8	92·8	124·3	93·0	77·2

The Statistics given show how large a proportion of all deaths are among infants.

It is seen also that no cause is so prolific among children in the first year of life as disease of the digestive organs.

Diarrhœal diseases of infants are generally accepted to be due to improper or impure food. There is ample evidence to show that the proportion of deaths among infants is greatly reduced when they receive the food nature designed for them—namely, mother's milk.

The accumulated experience of the world confirms the conclusion that the nursing of all infants by healthy mothers would contribute immensely to the reduction of the infantile death-rate. It is a matter of history that during the siege of Paris the death-rate among infants went down enormously, because the mothers were confined to the home and had no occupation and little else to do but to look after their babies and those in their own homes. Few features are more striking than the contrasts which are noticed in the death-rate of babies over a series of years.

In Ireland the general death-rate is higher than it is in Scotland or in England, yet taking the means of ten years (1895 to 1904) the infantile death-rate in Ireland was only 103, as against 126 for Scotland, and 150 for England and Wales—Why?

Because the mothers of Ireland give their babies their birth-right, and suckle their own babies.

One hears a good deal about injustice to Ireland, but in this connection Ireland should receive its due merit, as it most certainly reaps its just reward.

The high mortality among infants and young children arises from various causes, some of which are unavoidable; others largely and distinctly avoidable or preventable.

A certain proportion of the deaths are premature; some infants are born with malformations and other congenital defects, which soon terminate their existence; others, with hereditary tendencies, or the offspring of weakly parents, start greatly handicapped in life, but making due allowance for these causes many medical and sanitary authorities are agreed that about 50 per cent. of infant deaths are preventable.

Ignorance and carelessness of parents and others cause a fearful waste of infant life.

From mortality returns of various countries of the world it will be seen that, excepting the deaths from premature births and the causes mentioned above, half of the deaths are due to diseases caused mainly through bad and improper feeding—*i.e.*, diarrhœa, convulsions, dentition, debility, &c.

Such causes of infantile mortality are common to every locality, and to every community.

Enough, then, has been said to show that a very large percentage of the deaths of infants and young children is preventable.

The question that now arises is what practical measures can be adopted which will tend to reduce this preventable mortality?

The problem is how to extend to all children who require it the individual interest now permissible only to the few.

The measures immediately practicable may be divided into three, viz.—Legislative, Administrative, and Educative.

Legislative.

The measures requiring additional or further legislation in this State of Queensland are:—

(1) Earlier notification and registration of births; the amendment of "*The Registration of Births and Deaths Act of* 1855";
(2) Amendment of "*The Infant Life Protection Act of* 1905";
(3) A Bill for the sale and control of infant foodstuffs and quack nostrums;
(4) A Midwives Act; and
(5) The increase of the powers of Local Authorities in regard to the milk supply.

Administrative.

Under this head may be considered—

(1) The establishment of infant milk depôts (Municipal or otherwise) for the supply of a pure and specially modified milk for the feeding of infants;
(2) The teaching of infant feeding and nursing in schools;
(3) The appointment of qualified women with special reference to the hygiene and feeding of infants;
(4) The bounty system; and
(5) The establishment of Crèches.

Educative.

(1) Distribution of circulars giving hints and advice as to the care and feeding of infants;
(2) The proper care of poor women during and immediately after puerperium;
(3) Infant life insurance;
(4) The inexperience and neglect of mothers;
(5) Women as sanitary reformers;
(6) Industrial conditions and social position of women; and
(7) The relation between the birth-rate and infantile mortality.

Under the present Registration of Births and Deaths Act of 1855, of Queensland, births are required to be registered within 60 days of their occurrence, while still-births are not required to be registered at all.

Sixty days is a long time, and many infants could die during that period for want of skilled attention or advice.

Probably the registrar is not unfrequently asked to register the birth and death at the one time.

For statistical purposes it is, perhaps, well enough to secure the returns within 60 days, but for preventive purposes it is quite useless, as by the time the authorities are notified the child has already passed through a critical period of its existence, even if it be not already dead.

The English authorities have had a similar experience, and the National Conference on Infantile Mortality of 1906 passed a resolution to the effect that all births and still-births should be notified within

48 hours, and further, that no burial should take place without a medical certificate.

As notification of births has a very important bearing upon the prevention of infantile mortality, we cannot do better than follow this good example and recommend to the proper authorities the advisability of all births and still-births being notified within a period of 48 hours of their occurrence.

It is important that the health authorities and the Medical Officer of Health to the Local Authorities be provided with particulars as to births within the respective areas of the latter at the earliest possible moment.

With regard to the births of illegitimate children, police investigation is provided for in the case of every illegitimate child born in this State, by the provisions of "*The Infant Life Protection Act of* 1905."

As a percentage only of illegitimate children find their way into registered homes, police inspection cannot be closely carried out in those cases where the parents or relatives take charge of the child, or in the cases of adoption.

While it is not a fact, necessarily, that illegitimate children are born less healthy than legitimate children, it is a fact that many more illegitimates die in infancy than legitimate children.

Even in some of the States of the Commonwealth the proportion is two or three times as high as among those of legitimate births.

The extremely high death-rate among the children who were thus born, has been ascribed by some authorities to the neglect of the putative father to recognise his parental responsibility, by contributing either to the expenses incidental to the birth, or to the subsequent maintenance of the child.

While the sole burden falls on the mother, the result is too often a recourse to the baby farmer.

There can be little doubt that in a certain proportion of cases the existence of the child is, in itself, a strong incentive to do away with it, especially in such cases where, in addition to her shame, the woman has also to bear poverty.

That cruelty is perpetrated on this class of child is evident by the fact that a Society for the Prevention of Cruelty to Children is existent, and that complaints more or less well founded are not uncommon.

"*The Infant Life Protection Act of* 1905" is now administered by the Police Department, and, in his Annual Report for 1907, the Commissioner of Police points out the fact that the full intention of the Legislature cannot be given effect to till periodical inspection of nursing homes by medical men is arranged for.

I can quite agree with my fellow Commissioner that the inspection, feeding, and nursing of infants received into these homes are matters more naturally pertaining to the duties of trained medical officers of health than to the police.

A Midwives Act is urgently needed in Queensland. Some administrative body entrusted with the examination and certification of obstetric nurses is essential.

At the present time the standard of knowledge is not very high among some of the unqualified, and, therefore, untrained women, who pose as the modern Sairey Gamps. Beyond a small amount of technical work, this class of women, who practice their so-called profession among the poorer classes of the community, know nothing of the feeding and care of infants. The elimination of these unsuitable and untrained women, and replacement by qualified, skilled, and experienced nurses, would do much to increase both the safety and comfort of the mother and the viability of the infant.

Midwives must be scrupulously clean in every way. Nothing is so important in successful midwifery as absolute cleanliness. Her duty is not only the care of the mother, but the care of the newly-born infant as well.

As the child that is not suckled has only half the chance of living that a breast-fed infant has, the mother must in all cases, where practicable, be encouraged to suckle the child herself. The tendency of some midwives to advise early weaning of the child is a responsibility which should not be assumed except after advice by the medical man, if any, in attendance.

A body of skilled and experienced obstetric nurses could do much in the direction of the dissemination of knowledge as to the care and feeding of infants.

Legislation for the regulation of the milk supply is enacted, or should be enacted, with the fact in mind that milk is a food. "*The Dairy Produce Act of* 1904" of this State marked a departure in milk legislation from somewhat established lines. "*The Health Act of* 1900" makes no reference to the control and inspection of dairies, the Local Authorities having had power under "*The Health Act Amendment Act of* 1886" to make by-laws for the registration, cleansing, lighting, ventilation, drainage, and water-supply of dairies, as also for prescribing the precautions to be taken for protecting milk against contamination or infection.

"*The Dairy Produce Act of* 1904," administered by the Department of Agriculture, provided that the by-laws made by the local authorities under "*The Health Act Amendment Act of* 1886" should be suspended in any district assigned to an inspector appointed under the Dairy Act.

This latter Statute thereby modified the practice of the Health Department and the Local Authorities with respect to the supervision of the milk supply and the maintenance of the dairy inspection service.

While the relation of the milk supply to the public health is important in the matter of a general food service and the spread of diseases through the agency of milk, the relation between the milk supply and infant mortality has commonly been accepted as the standard by which the efficiency of the milk-inspection service is measured. While it can be shown that many factors other than the milk supply have been at work to increase the number of infantile deaths, the intimate relation between diarrhœal diseases and digestive troubles among infants under 2 years of age and the milk supply is now almost universally conceded by the medical profession.

Stated as a general proposition, then, the control of the milk supply from the cow to the child should be in the hands of the medical and sanitary authorities, rather than under the supervision of inspectors of the Agricultural Department, who, however experienced in the methods of manufacturing milk products, are not necessarily trained in matters of sanitation.

In a recent Report by the City Inspector to the Brisbane Municipal Council, Mr. Fraser states:—

"It was anticipated by public health advocates that the enforcement of the provisions of the Dairy Act would have a markedly beneficial effect upon the conditions of the town dairies generally, and that some at least would find it necessary to remove into extra-urban localities, in order to acquire the requisite space for conducting their business in accordance with the new measure. Such anticipations have not so far been realised; some of the dairies are objectionably cramped for space, and there are many instances of bad and inadequate drainage, of unsuitable buildings, and other matters which call for amendment. It is also to be noted that the Dairy Produce Act does not comprehend all the matters covered by "*The Health Act Amendment Act of* 1886," and two of the omissions are serious. In the first place, in cases where the grazing grounds are unwholesome, there is no power to interdict the use of such lands; and some at least of the much-used cattle pasture in and around the metropolis includes within their area swamps or pools of water contaminated with sewage; and the cattle not merely drink such water, but may be seen standing in it, thereby incurring serious risk of carrying upon their flanks or udders organisms of an acutely dangerous character, which in turn are almost certain to be dropped into the milk-pails in the process of milking.

"In the second place, 'milkshops' are only registerable when 'milk is the only or principal product retailed,' and even in these cases registration is apparently not compulsory. In the Health Act Amendment Act, however, power is given to prohibit the use for the depasturage of milch cattle of any lands which are prejudicial or likely to be prejudicial to health; and, further, the power of compelling registration extends to all premises without distinction at which milk is sold or exposed for sale. For the above reasons I am strongly inclined to the opinion that from the 'pure food' standpoint the latter named measure is a better instrument to work under; and it may be noted that, so far as I am able to see, the mere elimination of the City of Brisbane from the district assigned to the Inspector under the former Act (the Dairy Produce Act) would enable the Council to assume, under its existing By-law (Chapter 21, at present dormant), a more comprehensive, and therefore more effective, control of the city dairies, and also of the persons and the premises by whom and at which milk is vended. And a similar principle might be urged in respect of the suburban dairies in all cases in which the respective Local Authorities are prepared to undertake the proper supervision of the dairies in their district."

Of infant feeding in relation to infantile mortality it may be said that the form of food and its method of administration are capable, perhaps more than any other component factor of the child's environment, of influencing the future development and determining the fate of the newborn infant. In common with adults, the infant requires proteid, carbohydrate, fat, mineral salts, and water in its food, but owing to the undeveloped state of its organs of assimilation an infant cannot avail itself of any wide dietary range. Milks, therefore, are practically the only class of foodstuffs which Nature has designed to that end. No artificial food can ever really replace the mother's milk.

If the mother's milk is the ideal food supplying the infant with proteid, fat, and carbohydrates in proportions adapted to its needs, the only logical substitute is a food which will do the same. The carbohydrates are the ingredients in the dietary of infants least likely to be represented in too small amount. There is, on the contrary, a much greater danger of supplying them in excess, or of making them a substitute for fat.

There is an immense number of patent infants' foods on the market, each of which claims to be "the best food for infants," or "a perfect substitute for mother's milk."

The majority of such foods are found to be deficient in fat and too rich in carbohydrate. Some of these foods may be of some service in supplementing the diet of infants who are unable to digest much cow's milk, but they are not to be recommended as the "perfect" or "ideal" foods the elaborate wording of the labels would have us believe.

All these patent and proprietary infant foods should contain on each packet or bottle a printed statement showing the full analysis (certified by a competent analyst) of their contents.

Legislation on this matter, as well as legal control of the many useless and often dangerous quack infant-nostrums now on the market is urgently needed, if the food factor be recognised as having an important bearing on infant mortality.

Administrative.

With regard to administrative measures in the problem of infant mortality, the methods hitherto adopted by local authorities have been chiefly educational.

Leaflets containing instructions in infant feeding and circulars on the prevention of infantile diarrhœa have been widely distributed by many health and local authorities, and, in addition, women health visitors have been appointed to give personal instruction to mothers on these subjects. These educational methods are to be commended, but it is doubtful whether they have had a distinctly appreciable effect in preventing the wastage of infant life. Mothers should certainly be taught how to feed their infants and what to avoid, but, as artificial feeding of infants is a matter of some technical difficulty demanding care and most scrupulous cleanliness, many mothers in our poorer districts with their wretched housing accommodation must often fail to successfully carry out the suggestions recommended in the usual municipal leaflet.

Something more is required than mere advice.

Milk to be used for infant feeding has to be diluted and otherwise modified, and it is best that such modification should be carried out under medical or other expert supervision.

The establishment of municipal infants' milk depôts have made this supervision possible. At such depôts the milk is modified to suit the infant's digestive capabilities, sterilised to destroy contaminating organisms, and supplied in stoppered and sterilised bottles containing sufficient food for one meal, and no more, to prevent home contamination.

As the largest part of the immense mortality of the first year of infant life is traceable directly to disorders of nutrition, the question whether a child will be strong and robust, or a weakling, is often decided by the quality of the food given to it during the first three months of its life.

It must be remembered that temporary success may mean ultimate failure.

A good illustration of this is seen in the too exclusive use of patent or proprietary foods containing much carbohydrate. The absence from the food of some of the more important elements in body building may not be evident for months, hence the common mistake of the laity that children fed on these foods are thriving. Infants so fed grow very fat and for a time appear to be properly nourished, but this outward appearance of apparent robustness is false and fleeting. The natural, and therefore the best, food for babies is the mother's milk for at least nine months of life, but as mother's milk is not always available, we have to face this problem—viz., that for a large and increasing number of infants artificial feeding is a necessary evil. The question then remains as to whether this artificial feeding is to be well or badly performed.

The object of the municipal infants' milk depôt is to reduce the heavy infantile mortality dependent upon improper artificial feeding. The depôt is not intended to weaken parental responsibility.

In France, where a very low birth-rate has compelled the question of infantile mortality to be considered as of national importance, efforts have been made to improve the defective methods of infant feeding by the establishment of organisations having for their object the encouragement of breast-feeding and the supply of a specially prepared milk for those infants for whom breast-feeding is impracticable.

At the French institution, the *Goutte de Lait*, which is the precursor of the British milk depôt, the medical supervision of the babies is a most important feature of the work. The baby is brought to the depôt once a week to be weighed and examined by the medical director of the institution.

Some of the *Gouttes de Lait* are municipal institutions, but the majority are managed by philanthropic societies.

The French institutions not only care for the child but for the mother as well. The French have realised that many a suckling mother required nourishment as well as her child, and restaurants have been established in Paris where women nursing at the breast are fed gratis twice a day.

"There is no question asked as to birth, religion, or legitimacy. The woman is hungry, and has an infant to feed, and that is sufficient for the French philanthropist."

The movement for the supply of a modified milk for the use of infants, particularly of the artisan class, has now become a considerable one both in Europe and America.

With regard to the British depôts, it may be said that there appears to be, if not divergent views, at any rate a divergence in the method and procedure adopted. On the one hand, the energies of the sanitary and municipal authorities are directed almost entirely to the feeding of the babies with a suitable but artificial milk supply, while, on the other hand, every effort is being concentrated on the nursing mothers.

Of the British depôts, the former method of procedure is that of the St. Pancras and Lambeth Borough Councils, the latter that of Battersea and Liverpool.

There is evidence to show that at Battersea, St. Pancras, Liverpool, and other places, these specialised milk supplies for infants have been of service in the reduction of infantile mortality. The infant milk depôt is not, however, of the nature of control of the general milk supply, but rather of a specialised supply to meet special needs.

The St. Pancras scheme includes both a municipal and a philanthropic branch. "The latter is centred around the Babies' Welcome and School for Mothers, where dinners are provided for suckling mothers, classes are held on simple cookery, lessons are given on food, food values and prices, on the cutting out and making of babies' clothes, the preparation for and care of babies, and on housewifery and domestic health."

The municipal part of the St. Pancras scheme is administered by the medical officer of health, assisted by a woman inspector, who, on her part, has the assistance of voluntary visitors. Inquiries are made as to the surroundings of the mother and infant, and general information is imparted to the mother, including the importance of breast-feeding and of seeking medical advice before weaning from the breast.

At the Battersea depôt, milk, which has been modified to suit infants of varying ages, is given to applicants who produce an intimation from a medical man that the case is suitable, while the attendance of the children at the depôt is made the opportunity for periodical weighings and for observing the effects of the milk upon the infants. The milk is supplied by a contractor, and the source of the milk supply is inspected and controlled by the Borough Council.

On arriving at the depôt the milk is strained, modified, bottled, and the quantity of milk in each bottle is sufficient for one meal, and no more. The milk is given to the baby from the depôt bottle through a short rubber teat supplied at the depôt, and as each meal is in a separate bottle a "feeding bottle" with its dirt and germs becomes unnecessary.

The efforts of the British local authorities, adopting one or the other of the methods above described, will be watched with much interest, and it is probable that a solution of the infantile mortality problem will be found in a combination of the principles involved in the two schemes. The object of the depôt being the saving of life and prevention of infant diseases, it is necessary that either system be individualised.

Each mother and each infant, each home, and each cow from which the milk is derived, must be separately supervised.

An Infants' Milk Depôt run on much the same lines as the one at Battersea is shortly to be established in Brisbane, and many poor mothers will have cause to bless the name of Lady Chelmsford, to whose kindly influence and interest the proposed depôt has already been placed on a solid basis.

An infants' milk depôt, however, is not, and cannot be made, a profit-earning concern, and while the grant of £300 per year from the Government will do much to meet the necessary expenses and somewhat heavy initial outlay, the depôt will still have to depend largely on funds from the charitable and more philanthropic portion of the community.

In Glasgow, Huddersfield, Dundee, and other places, the local authorities have adopted what is known as the "Bounty" System, a gift of £1 sterling to the mother of each child born between certain dates, provided the child survives the first year of life. Whether it is desirable that the bounty scheme should be applied generally is not at all certain, but this much at least may be said of it, "that the cardinal principle of taking the child life at the very commencement with a view to the prevention of disease is a sound principle."

One word as to the utility of crèches as a measure in the prevention of infant mortality.

The factory crèche is not, of course, the same thing as an ordinary crèche; the former is merely a nursery where children are cared for during the mother's absence at her employment. There is, however, a large number of women who are forced to go out to work daily, leaving their babies to the care of ignorant and dirty landladies, or to inexperienced children of an older age. Reasons sufficient to justify the existence of a crèche can be found if only on the grounds that the child brought to he crèche must be clean. The mother is therefore taught the necessity for cleanliness. The child is also properly fed and cared for during at least a portion of the day. The possibilities of the crèche as an educational factor should not be overlooked. A suggestion has been made for its use as a "School for demonstrating to elder girls the principle of Infant Hygiene, in actual practice with real babies."

Educative.

Now, if the defective feeding of infants, and the impaired nutrition resulting from it, be the most important condition giving rise to the deaths of infants, it is obvious that the women, and particularly the mothers of the community, have a special and peculiar interest in this question of infantile mortality.

Whatever the causes of artificial feeding may be—physical inability of the mothers to suckle their offspring, or inability on the woman's part by reason of engagement in some industrial pursuit, or selfish considerations—the disinclination by reason of the trouble maternal feeding involves and the divorce it necessarily entails from social pleasures and pursuits—whatever may be the cause, this one fact stands clear—viz., that from $\frac{1}{3}$ to $\frac{1}{2}$ of infant deaths would be expunged from mortality records if the mothers were able, universally, to breast-feed their infants.

The Rt. Hon. John Burns, President of the Local Government Board, in his address to the National Conference on "Infant Mortality in 1906," said: "What the mother is the children are. The stream is no better than its source."

Although it be true that fewer present-day mothers are able to perform their maternal vocation of suckling their offspring than formerly, it is also true that a large number deprive their offspring of their natural food through selfishness, laziness, and indifference.

It would appear, then, that all our efforts to improve the feeding of infants bring us to the one conclusion—viz., Education.

To educate one must teach. Who are the teachers?

The medical profession itself can do much more in the future than it has done in the past towards overcoming the ignorance which exists as to infant feeding and management.

The clergy, too, might on occasion preach with advantage "the next to godliness" and the duty the mother owes to her child and to society.

But of all reformers in the great movement now on foot to save the lives of the coming race the woman is the first and the best.

The interests of this Commonwealth are bound up in the interests of each of its separate States, and "not the Fates themselves were more the mistresses of the destinies of our race" than are the women of an educated Commonwealth conversant with the art of the prevention of disease and the premature death or decay of the young. There is not one single difficulty in the way of making the woman the active domestic health-reformer.

The only thing that requires to be put forward is the method of bringing her universally into the work. In this connection woman has a distinctive work. The woman's part in the domestic care and management of her children is all her own.

We men hold our congresses year by year, formulate our laws and administrate our Statutes; we read our papers and talk more or less learnedly on the deplorable waste of infant life, but be we ever so earnest, and ever so persistent, we shall not move a step in a profitable direction until we carry the women with us heart and soul on this question.

In saying that the problem of infantile mortality is largely one for our women to solve, I do not wish to imply that all our womenkind are behind in this work. On the contrary, every praise is due to woman as a forerunner in the race. If we take the question of organisation itself, we have to admit that the many admirable Institutions, such as the Ladies' "Health," "Sanitary," "Pure Milk," "Infant Protection," "Nursing," and other Associations and Societies have done, and are still doing, a splendid work by their practical aid to mothers, the teaching of the simple and more essential laws of health, the care and management of infants, and, where necessary, the supply of a suitable food.

The woman sanitary inspector and the lady health visitor are not unfamiliar figures to us in these days.

In Glasgow, there are 6 women inspectors; in Birmingham, there are 12: in Manchester, there are 20 women health inspectors whose work is on lines very similar to that of male sanitary inspectors.

These female inspectors receive, as a rule, but a small salary, and in certain towns their work is to some extent supervised or supplemented by unpaid educated lady visitors. Here again the woman's province is all her own. The house is her citadel. What does a man know about a house and its domestic management, even about the very house he lives in?

The woman can afford a guidance in those small matters of domestic economy and the affairs of babydom in a way no mere man can do. No, we must employ women to teach women the lost art of mothering. We must get into touch with the mothers of to-day if we are to get into touch with the mothers of the future.

But what is wanted is quiet educative work rather than official inspection.

Education on this question must be general rather than special. We must not drive, but lead; not dictate, but patiently suggest. The late Sir Benjamin Richardson, M.D., in one of his delightful lectures on "Woman as a Sanitary Reformer," said:—

"If what Pope said of man be true—

> Men should be taught as though you taught them not,
> And things unknown be told as things forgot."

In respect to the sex still more susceptible and impressionable, especially when those truly feminine duties which are connected with domestic health and happiness form the subject of advancement, it may with equal truth be said:—

> Women should ne'er be taught a thing unknown,
> It should be credited as all their own.

The influence of woman is all potent for good or for evil in her sphere of life and duty.

If all the mothers who are capable of nursing their infants could but be encouraged to do so, the artificial feeding necessary for the remainder could be so supervised that the dangers attributed to the food factor in infantile mortality would lose much of their present significance.

Section J.

RECENT DEVELOPMENTS IN EDUCATION.

PRESIDENTIAL ADDRESS

BY

MR. P. BOARD, M.A.,

Under Secretary for Public Instruction and Director of Education, New South Wales.

MENTAL SCIENCE AND EDUCATION.

INTRODUCTORY.

A presidential address is necessarily of a character introductory to the business of the session. I shall, therefore, endeavour to deal with some of the broader aspects of the educational situation of to-day, leaving it to other members of the section to treat of special features and discuss special questions.

THE 20TH CENTURY RENAISSANCE.

A survey of the great world movements of our time suggests that the historian of the future will write of the Renaissance of the twentieth century as the historian of to-day speaks of that of the sixteenth. In every department of human activity there is a deep consciousness that there is something better to be gained, and that every step onward is a step upward. Religious questions are discussed with an independence of traditional beliefs that causes no shock to even pious minds. Social conditions are under review, and reorganisation proceeds by rapid steps to a goal that it is yet impossible to determine. Political theories are being re-cast under the pressure of social rearrangements. Science "reaching down to the infinitesimally small" brings to the surface fact upon fact that reveals new world and unimagined possibilities. Industry expresses itself in methods and processes, kaleidoscopic in their changes, the old scarcely giving place to the new before the new gives place to the newer. Literature has shaken itself free of all trammels and, more prolific than ever, maintains a constant intellectual ferment. The world is in travail.

ITS CAUSE.

When the historian of the future looks for the cause of this Renaissance, he cannot fail to observe that it has followed closely upon the democratising of education that marked the latter half of the nineteenth century. "The first need of man is bread, the second is education," said a leader of the French Revolution, and the modern patriot without any thought of revolutionary methods has embodied the demand in the legislation of his country. Practically, all the great movements of to-day have become possible because the multitude has been educated—the aggregate knowledge-power of the nations has been multiplied a million fold. Literature, science, industry, social development, politics, religion, all owe their vitality, their dynamic restlessness, to the wide diffusion of intellectual power that has followed upon popular education.

ITS BEARING ON SOCIETY.

This great extension of educational opportunities must stand intimately associated with the organisation of society, and consequently in late years the sociological aspect of educational problems has gained marked prominence. A wide view of the movements that are taking place in the structure of society shows a striving after greater homogeneity. The old clearly-marked subdivisions are yielding, and there is a tendency to fusion of ranks that in older times were kept apart. The maxim that enjoins contentment with the sphere of life that follows the accidents of birth no longer holds sway. A common education is smoothing out the unevenness due to inherited disadvantages. It is becoming more and more possible for the child of more than average natural capacity to rise to the level where that capacity finds its best expression, and, as a consequence, the lines of separation between class and class are becoming blurred; and the change is welcome. It makes for stability.

EXTENSION NEEDED.

It still remains to carry this unifying and consolidating influence of education further by perfecting the methods of primary instruction and by extending to wider areas of the community the opportunities for higher instruction. The most enthusiastic admirer of modern progress must feel that there still remains much perfecting of the methods of elementary education in its bearing on social well-being, when he sees in times of turmoil that men's minds are subject to the tyranny of a happily-turned phrase and their opinions modified by the mere influence of an epigram. It is suggested to him that there may be much learning with little thinking, and that society demands from the schools that their finished products shall think more even though they may learn less. The structure of modern society calls loudly also for something more than the higher education of the few. Along with the development of industrial means of production has come the minute subdivision of labour that requires from the few the ability to direct, and from the many the power to do some small thing. But as a compensating consideration, along with the evolution of civic organisation, the individual with the very limited field of wage-earning labour finds himself charged with civic responsibilities that demand the highest intelligence, and endowed with a leisure that offers scope for the pleasures of cultivated tastes. While then educational agencies must concern themselves with the qualifications that make for the earning of bread, they must also take account of the fact that the bread-winner has high obligations that lie outside the narrow limits of his daily toil. Whereas in ancient Greece the State itself was the end of education, in medieval times the Church, at a later period the individual, educational aims and ideals must now shape themselves upon the requirements of the social unit. The complex demands now made upon the individual constitute in themselves the reason and the justification for a conception of education that is distinctly utilitarian, in the sense that it must be essentially a preparation for all the phases of complex living. The term, "bread and butter studies," was at one time used as a term of inferiority, implying the sacrifice of real education to material ends. It implied that studies that had a direct value in equipping the student for practical affairs could not be admitted as elements in what was called a liberal education. One of the most significant tendencies in modern education is the removal of the reproach of utilitarianism as applied to it, by widening out the meaning of the term "utilitarian," making that term applicable to all that equips the individual for rendering service to society, whether that service is of the material kind for which money payment is made or of the more immaterial kind by which the spiritual, or æsthetic, or intellectual wants of society are met.

EDUCATION BECOMING A SCIENCE.

The extension of the meaning of education has made the educational problem exceedingly complex; but, at the same time, it prepares the way for a science of education. The endeavour to create a science of education has been rapidly developing. Observation and experiment, analysis and synthesis, which have gone to the building of other sciences, are being employed. The facts of mental growth, of the bearing of physical constitution on mental processes, of the relation of social claims to the training of the individual, are furnishing a basis for an educational science. It has now come to be recognised that while many things are subjects of instruction, the child is the subject of education. As a result, the study of educational psychology has been far-reaching, and is rapidly establishing the relation that should be maintained between, on the one hand, the methods of instruction, and, on the other, the process of development and mode of action of the mind of the child. The acquisition of knowledge as one of the results of education is dependent, not upon the logical arrangement of the subject matter, or as something imposed upon the pupil from without, but is rather the result of the proper direction of the pupil's own natural tendencies and activities, and the utilising of motives towards healthy action. Education in this view is the systematising of the child's experiences, a variety of disjointed experiences being brought together, correlated, interlocked, organised, before resulting in acquired knowledge.

But while this subjective-psychological method of education has enjoyed a revival that has had a salutary effect on school methods, it is not an entirely adequate basis on which to build the various activities of the school. Taken by itself, it minimises the value of the subject-matter of studies. Educational work that is controlled entirely by the principles of educational psychology is individualistic, and leaves out of account the claims of the community. The individual child cannot be educated as an isolated unit, and because of this the content of his studies, and the practical purposes for which subjects are studied, must frequently determine methods. The expression is still heard that certain studies should be retained in the curriculum for the simple and only reason that they supply the student with a mental discipline, as if mental power produced in the study of one subject were equally available in dealing with other and unrelated subjects. To regard the value of a subject from this point of view is to disregard the thought-content of it, and it is this which entitles it to a place in the school course. The value lies in the subject itself; in the manner in which the subject-matter when acquired enables the possessor to react to the conditions of his environment. It is this consideration that in recent times is moulding the instructional work of schools and colleges, so that the student may be saved from a devotion of his energies to that species of fruitless study by which he can, as Bacon expressed it, "out of no great quantity of matter, the infinite agitation of wit, spin cobwebs of learning, admirable for the fineness of thread and work, but of no substance or profit." The term "mental discipline" is still vaguely used to justify the making of a classical language an indispensable subject for either matriculation or graduation in some of our Universities, ignoring the fact that, in the case of many students, the content of the study contributes in a very small degree to fit them for their future career. One of the most hopeful signs of change in educational thought is seen in determining the value of a study, not by the mental gymnastics it affords, but by the practical use to which it can be put by the student.

TRAINING OF TEACHERS.

The growth of a science of education has made teaching a profession, and the training of the teacher an absolute necessity. There is, perhaps, no change affecting educational administration more marked than the change of attitude with regard to qualifying the teacher for his work. On this question public opinion has had to be led by those who have thought most on the subject, since the question is not one that appeals to the popular imagination. The State that waits for the expression of opinion through popular agitation on this subject is sure to be left behind. It is a question in which statesmanship consists in leadership. The mass of popular opinion is not sufficiently well informed on the real needs of the case to initiate a movement of this kind. Progress here depends on leaders.

But in most civilised countries the question has now been determined, and normal schools and training colleges are rapidly increasing in number. The problem now is not whether teachers should be trained, but how they should be trained.

PRIMARY EDUCATION.

Primary education is gradually shaking itself free from the defects that have reduced its effectiveness in the past. Under ordinary conditions, eight years of a child's life are spent in this stage of his education, and the question arises, whether the results usually evident at the end of this period are commensurate with the time and labour that have been devoted to them. It has to be recognised that no absolute standard can be fixed as one to which all children should attain by their fourteenth year. The variations in individual inherited capacity, and still more, the variations in home environment make an absolute standard impossible. But, apart from these modifying circumstances, the operations of the school should, under ideal conditions, enable each child to reach the limit of his possibilities. Since the time when elementary instruction aimed at nothing more than proficiency in two or three mechanical arts, the curriculum of the primary school has received one addition after another, until it embraces a wide range of subject-matter. This has led to the comment that the primary course is overloaded with subjects. The comment, however, is made without taking account of what should be the distinguishing characteristic of the instructional course up to the age of fourteen. This is the period in which the child needs to be brought into contact with the world about him at as many points as possible. In the five or six years before he enters the school, he has gained from his practical experience a store of knowledge on a number of subjects as various as his experiences have been, and has learnt to express himself in speech on a wide range of topics. It is the function of the primary school to continue that education, and the methods by which the child gained his knowledge, and the power to use it, before he enters the school at all, should suggest the methods by which he might acquire it after he enters the school. During this formative period, variety of subject is the keynote of the school course. There has been no more valuable development in primary education than that which has enriched the course of instruction with subjects that supply the child with fresh experiences, and that give him his first insight into the multitude of activities and ideas with which, whatever may be his future career, he must be, to a greater or less extent, brought into contact. It is difficult to see on what ground, either practical or theoretical, it can be urged that the primary course of instruction in the modern school includes too large a number of subjects. But, on the other hand, there is a sense, and a very definite one, in which primary courses of instruction may become overloaded. This arises, not from the inclusion of too many subjects, but from the inclusion of too much subject-matter. It is this that has contributed to no small extent to reduce the value of the product of the primary school, and to give rise to the inaccurate comment to which reference had been made. The attempt is too often made to import into the instruction given a range of information which might become useful as part of the mental furnishing of the adult, whose experience of the world would enable him to appreciate and use it, but which to the child is so remote from his experience that it has no meaning for him. It sometimes occurs that the information given has not even the merit of being sufficiently useful to either the adult or the child to make it necessary that it should always be carried in the memory. In all the subjects of the school course this danger is imminent. In the teaching of arithmetic, grammar, geography, history, and other subjects, the temptation is constantly present to the untrained teacher to introduce into his instruction, lesson material that is either not adapted to the assimilative powers of the pupil, or is not of sufficient value in itself to be part of the mental outfit of the pupil. If this temptation be resisted, it will be seen how much of the conventional text book knowledge may be set aside as inappropriate to the primary course. No more important call is made upon the judgment of the teacher than that which arises from the necessity for the selection of the material for his lessons; and if that selection is properly made, there can be no ground for the assertion that the curriculum is overloaded.

THE SCHOOL AGE.

These considerations raise the question of the primary school-leaving age. During the early period of compulsory education the limit of age was fixed at 13 in some States and 14 in others. This determination of age limit belongs to a time when it was considered that every child should receive the minimum of education necessary for the most elementary duties of citizenship, and the most mechanical of vocations. In Australia compulsory legislation in this direction, notwithstanding serious defects in one or two States, has fairly fulfilled its purpose within this very limited range. But the demands of the evolving social organism have given a new meaning to the functions of the State in the matter of education. Not the mere minimum education for a rudimentary citizenship, but the preparation of the youth of the nation for the most efficient participation in productive industry, is now being recognised as determining the range of the State's responsibility. In several States of America and Germany this has already led to the extension of the compulsory age from 14 to 16 years, while in England the same need is rapidly gaining recognition. The boy cannot secure by the age of 14 the whole of the scholastic outfit necessary for his entrance into the skilled occupations. On the other hand, not only are there few boys who can longer defer the earning of money, but there are many occupations which should be taken up not later than the fourteenth year of age in order that the manual dexterity and technical skill necessary to the skilled workman may be acquired. The apprenticeship system only imperfectly meets these two claims. The continuation school is supplying in England and Europe the solution of the problem. Granted an organisation of day and evening continuation schools, and adequate provision for secondary education in other directions, the extension of the compulsory age of school attendance not only becomes practicable but highly desirable. When Australia is prepared for this forward step, provision will doubtless be required to so far limit the hours of boy labour as to admit of a fair division of the working day between attendance at the school classes and attendance at practical trade work. Meanwhile it remains for the elementary school to thoroughly organise its manual training courses so that, to the accompaniment of thinking in the concrete, hand and eye may be made the ready instrument of the brain.

SECONDARY EDUCATION.

Reference has already been made to some of the phases of higher education. The period of secondary education is essentially the time for what Walter Pater calls "arranging the littered work-chamber of the mind." So far the pupil has been occupied with the concrete; he has been coming into contact with the facts of sense and feeling; his use of language has been to express the individual facts and experiences. If he stops there his vision is limited; he cannot see the unseen that lies beyond the bounds of concrete experience. He fails to grasp wide generalisations. His mind is littered, and arrangement is necessary. The inductive process is now to be given a chance to turn the littered work-chamber of the mind into a well-ordered laboratory, to make, as the author already quoted expresses it, "terms exactly conterminous with thoughts, and thoughts conterminous with facts." As variety is the keynote of the primary course, exactness, precision, thoroughness, should direct the aims and methods of the secondary school. This being so, it is here rather than in the primary course that the curriculum is in danger of being overloaded with too many subjects. In the secondary school the need for thoroughness of mastery entails a limitation in the number of subjects studied. This type of school should, however, be further differentiated from the primary school by the attitude of its students. Instead of the pupil instructed by his teacher, he should be more of a student guided by his teacher. It is a noticeable fact that in our Universities a large number of first-year undergraduates fail to satisfy their examiners at the end of that year. It is well that the student who shows himself unfit for the higher portions of his University course should be "plucked" in his first year. But, after all, this is the remedy for an evil that should be prevented. The causes should be removable. One cause may possibly be found in the failure of a University entrance examination to guarantee an adequate preparation on the part of the student. The examination is not a sufficient test of an educated mind. It needs to be supplemented by applying the same principle of "graduation" to the student of the secondary school that is applied to the undergraduate of the University. An academic degree is conferred by the University upon the student who has not merely passed a final examination but who has "graduated" through his courses. If the doors of the University were open to those who had not merely prepared for a final examination, but had in a similar definite way "graduated" through the secondary school, there would be the less need for "plucking" in the first year at the higher institution. Another cause is doubtless found in the sharp transition of the student from the dependent and externally controlled attitude which the secondary school imposes on him to the self-dependence and freedom which University life allows to him. The remedy for this touches an important principle in secondary education, and one which does not yet find sufficient application in practice. The student should as he passes through this stage of his education be thrown more upon his own resources. The laboratory method that is now gaining a footing in the teaching of science should be applied to other subjects of the school course. The student, especially in the latter part of his course, should pass much of his time in personal investigation into the subject of his study. The school library may be as much a laboratory as the chemistry room. The adoption of this principle involves a much more liberal equipment than is usually found in secondary schools, but its value for practical efficiency fully justifies liberality in this direction. To the student passing on to the University the transition from such a secondary-school atmosphere would be less likely to make him a first-year derelict.

LANGUAGE TEACHING.

One of the most important innovations in method in higher education is seen in the teaching of modern languages. Instead of the older translation method based on a previously acquired knowledge of grammatical forms and syntax, the newer method begins with the immediate use of the language as the expression of thought, so that the thought and the expression of it are brought into direct association without the intermediary of the mother tongue. This immediate mental transition from idea to expression gives from the first a usable command of the idioms of the language, and combined with phonetics the pupil's speaking power is acquired at the same time that he is building up his knowledge of syntax and inflection. If it be kept in view that the learning of a foreign language is not for some purpose vaguely expressed as mental discipline, but to give the power of speaking, reading, and writing in it, there can be no doubt of the superiority of the newer method. It, however, requires a specialised class of teachers who have themselves a ready and fluent control of the language and a knowledge of phonetics, and the best teachers will be, not those to whom the foreign language is the mother tongue, but those Australian teachers who have, combined with a knowledge of the literature of the foreign language, the power to use it fluently in ordinary speech. As the need for modern language masters increase, it will doubtless be in the interests of Australian education to set apart scholarships to enable students to gain the necessary qualification by a period of study in the home of the language. With the entry of Australia into the field of international commerce, the provision for the best instruction in German and French has already become a pressing necessity. Incidentally it may be mentioned that the application of the newer methods of language study to the study of Latin and Greek is being introduced into at least one of our Australian Universities. But in this as in other directions the Universities of the Commonwealth cannot do their highest work in the most efficient way unless this is made possible by the methods and organisation of the secondary schools.

SCIENCE TEACHING.

Among the hopeful signs of the times is the increased attention being given to the teaching of science in the higher schools. But even yet, science is but timidly securing its rightful place in the sisterhood of studies. When France was writhing under her defeat in 1870, her great scientist, Pasteur, keen in his despair at his nation's abasement, appeals to his countrymen:—"I implore you, take some interest in those sacred dwellings meaningly described as laboratories. Ask that they be multiplied and completed. They are the temples of the future, of riches, and of comfort. There humanity grows greater, better, stronger; there she can learn to read the works of Nature, works of progress and universal harmony." Then he reminds his nation that "rich and large laboratories have been growing in Germany for the last thirty years, and many more are still being built." This was said nearly forty years ago, and we stand wondering to-day at the commercial and industrial progress of Germany. Australia presents numberless problems that are awaiting the work of the scientist. In agriculture, in mining, in manufacturing enterprises, in municipal sanitation, on almost every hand there is the call for scientific investigation. Why should not Australia contribute more widely to the world's scientific knowledge? The plea that we cannot undertake this work because we are a young nation is the plea of ineptitude. The qualities that make for successful scientific research are not wanting in the Australian people. The necessary enthusiasm, imagination, initiative, and resourcefulness are available. But there is a lack of the atmosphere in which these can bear fruit, the atmosphere that only our higher educational institutions can supply. It is for the schools to create a public that can appreciate scientific work. It is even now difficult to convince the so-called practical man that the student in his laboratory can improve the product of the farm or of the mine. The theorist in the inquiry room of science is met by the practical man with the cold look of scepticism. Reliance is rather placed on what is called common sense, forgetful that Nature herself rises in revolt "to teach our common sense its helplessness" (as Browning puts it). Empiricism, with its lack of progress, its imitative methods, looking to precedent for its guide, can only give place to freshness and originality in industry and business as a larger and larger proportion of the population has had its eyes opened to the methods of science, and been taught to appreciate the lessons which scientific inquiry enables the student to learn. Pasteur, in 1870, asks "why France found no superior men in her hour of peril?" And he finds the reason in "the forgetfulness, disdain even, that France had for the work of her great intellect, especially in the realm of exact science." In the absence of widespread instruction through the agency of the schools, the time may come when the verdict will apply in Australia, that no great work can be done here because of our unbelief.

THE OUTLOOK.

Some forecast may, perhaps, be ventured upon. This address commenced with a reference to the turbulence of the world's thought-currents. Education as an organised function of society cannot fill its right place if it lags behind—nay, more, if it does not keep well in the head of these currents. No education system can afford to plume itself on the finality of its methods. It cannot be static, nor should it wait to be thrust into the current of progress. From the very nature of the case it is needful that in many directions educational organisation should lead public sentiment on education, even at the risk of temporary misconception and condemnation. No very profound examination of the larger movements of civilised society is needed to show that public education is to play a larger and larger part in the fulfilment of distinctly national purposes. The question will become more insistent, not merely what is it doing for the progress of this or that individual, but in doing that, what is it doing of set purpose for the nation as a nation?

As time goes on the evolution of the industry will become more and more bound up with our educational systems. The school will become the adjunct of the workshop, and the workshop a class-room of the school. The gap between the desk of the pupil and the bench of the artisan, or the office of the business man, will be bridged, and the schoolroom will be filled with an atmosphere out of which the pupil will pass to the practical business of life without feeling that he is passing into a different world. Our educational systems will become responsive more to the spirit of the future than to that of the past. That which is traditional in practice will be brought under rigorous criticism, and be required to justify itself by something more than its antiquity. The rapid evolution of social ideals will demand an equal modification of educational aims and methods. The occupations of the primary school, aiming at greater breadth of mental outlook and greater adaptableness of manual skill, will be linked with the technical and trade school as well as with the ordinary secondary school. The secondary school and the university will fill a larger place in the educational scheme than at present, opening their doors more widely, with the same freedom of admission that now obtains in the primary school for all those who can benefit by their teaching. If this outlook is at all a correct one, the State systems of education will thus become so interwoven with the progress of the nation, and so necessary for the maintenance of its place in international competition, that the education of the people will fill an increasing place in the functions of government. The schools of all grades will be the instruments for national purposes, for the cultivation of individual productiveness and intelligent citizenship, the training grounds for national defence, and the nurseries of the nation's morality.

PAPERS READ IN SECTION J.

1.—THE TRAINING OF TEACHERS.

By A. MACKIE, M.A., Principal of The Training College for Teachers, N.S.W.

During the past few years very considerable advance has been made in the courses of training for teachers, and the growing dissatisfaction with the pupil-teacher system in particular has led to successive modifications which have resulted in raising the standard of general education as well as of technical skill.

I propose in this paper to discuss the sort of training which it is now very generally agreed should be provided for those intending to take up class teaching in public or private schools of primary or secondary character. No doubt the different types of class teaching require differentiation in the training courses. But this comes best towards the close of the training period, and in no case involves any fundamental difference in the principles which determine the arrangement of the course. Although the course of training may be longer or shorter, it should in every case be complete; that is, it should provide definitely for the development of the teacher's culture and of his technical skill. Further, it is earnestly to be hoped that the time is not far distant when no unqualified person will be allowed to practise in the schoolroom, either because his general education is too limited or too advanced. At present the arrangements for training the non-college teacher are in a very chaotic and unsatisfactory state, and require serious attention if the rural areas are to receive their educational due.

Before I outline the main features of an organised course of training for the practice of class teaching, it is necessary to refer briefly to arrangements which are rapidly being superseded. It is certainly the case that the pupil-teacher system fulfilled its purpose of securing a supply of fairly competent teachers during a difficult period, but it cannot be regarded as any longer a satisfactory means of providing teachers to meet the educational demands of the present. And, indeed, the latest modifications which it has undergone in England have taken most of the earlier virtue out of it. It is certainly true that the apprentice teacher acquired, in favourable circumstances, a very fair, or rather, limited power of instructing and handling large classes. But too often the circumstances were unsatisfactory, and pupil-teachers were allotted to schools where the head teacher had neither competence for nor interest in the work of training his apprentices.

With the abolition of apprenticeship a new task confronts the Teachers' College, and one which has somewhat slowly been realised by the older colleges. It falls to the colleges to make much more thorough arrangements than were formerly necessary for the training of their students in methods of instruction and class-room management. A failure to recognise this necessity explains the adverse criticism which is sometimes directed against the rawness of the students on entering college. They cannot, it is said, stand up to a class as the pupil-teacher could. This has to be admitted, and it is the main business of the college to lay the foundations of that teaching skill which previously was acquired too early and at too great a cost. For it cannot be doubted that the teaching character of many pupil-teachers set too early, and became incapable of modification with wider knowledge and more extended experience. This has always been a serious bar to college training whenever it has been sought to make that training effective.

The first changes in the pupil-teacher system were intended to secure better opportunity for general education, and eventually the half-time system with central classes was invented. But these changes inevitably brought about a decay of that ability to manage large classes which was claimed as the main advantage of early apprenticeship. Hence it is coming to be realised that there is neither practical nor theoretical justification for the system, and the opinion is gaining ground in England that even the half-time system had better be given up and all technical training deferred till the secondary course is completed.

I may quote here two recent expressions of opinion:—

Vide "General Report on the Instruction and Training of Pupil-Teachers, 1903-1907," published by Board of Education, London, 1907:—"The Regulations of 1907 now render possible an alternative system, which was, indeed, foreshadowed in the Prefatory Memorandum of 1903 itself, whereby the general education of future teachers may be continued uninterruptedly in secondary schools until the age of 17 or 18, and all attempt to obtain a practical experience of elementary school work may be deferred until the training college is entered, or at least until an examination making a natural break in that general education and qualifying for admission to a training college has been passed" (p. 26).

Vide also "The Training of the Primary School Teacher," by C. Birchenough, in "School" for September, 1908 (p. 75): "The root idea of pupil-teachership was to provide a supply of expert assistant teachers with considerable practical knowledge of school organisation and method; it required that the teacher should be an expert in class management and class teaching the moment he fully embarked on his profession. Immediately this ideal failed to be realised the system must become discredited, and in the nature of things it was bound to fail once teaching came to mean something more than drilling, and as the standard of general education required of the average teacher was raised. Judged from such a standpoint the

> present pupil-teacher system would have some difficulty in justifying its existence, for the salt of the old method, responsibility and guidance, has, in the vast majority of cases, been taken away, and even if this were not so, to teach according to modern ideals demands a wider knowledge and a maturer mind, as well as time for reading and preparation, that the student cannot have. The standard of academic work has increased, too, and to attempt both is to do neither."

The academic and the professional standard of teaching competence have risen to a marked degree, and it is no longer possible for the average student to meet the demands of both coincidently. A realisation of this principle—viz., the separation of general from professional education—has been the determining motive in bringing about the altered arrangements for the training of teachers. It is likely, in my opinion, to lead to even further modifications than have so far been carried into effect. The only effective argument that can now be advanced for the retention of the pupil-teacher is that of cheap staffing of schools, and this argument will not bear examination either on economic or on moral grounds.

One other matter must here be referred to. Nothing is more striking than the change that has come over educational aims and ideals during the past few years—especially in elementary education. The prefatory note to the code of the English Board of Education gives clear evidence of this change. The significance of this in its bearing on training is that much more, both in the way of knowledge and of skill, is required from the primary teacher if he is to meet the new requirements. These increased demands have brought about a new set of conditions which necessitate a more comprehensive system of training. However satisfactory the apprenticeship system was for the simpler conditions of former days it will not prove satisfactory now. And in this matter no community can afford permanently to adopt a lower standard of educational efficiency any more than of military or legal or medical efficiency. Economic considerations, if no higher, can be urged against such a short-sighted policy.

My criticism of the system that is passing away has been brief because I believe that few now regard it as satisfactory or wish to retain it. It will be more practical to pass to the consideration of the scheme which is replacing it. In setting before you this scheme I shall concern myself in the main with its underlying principles, as the working out in detail shows many minor variations to suit local circumstances. For illustration I shall refer to the arrangements in operation in New South Wales, although it has to be borne in mind that many of these are of a temporary nature, and either are being modified or will be so very shortly.

A course of training for class teaching in primary or secondary schools falls into three main stages:—(*a*) The pre-college stage, when the prospective teacher is designated junior student, probationary student, or student teacher; (*b*) The college stage; (*c*) The post-college stage or period of ex-studentship.

Under the old system too little accout was taken of this third period. The student was supposed to leave the college with his training completed, and with nothing more to acquire in the way of professional skill or knowledge. This is not so, perhaps never was so, and hence, to secure the full benefit of training, supervision and direction are needed for some time after the college course is completed. Something analogous to the hospital practice of the young medical man is needed.

In arranging the work of the first two periods of training there are two principles to be kept in view:—(*a*) The separation as complete as possible of professional and non-professional work; (*b*) A much more thorough professional study than has been customary in the past.

My own opinion is that professional study and practice should be almost, if not entirely, excluded from the first period. In this I am not borne out by current practice in England and Scotland, though educational opinion, as shown for instance in the recent Blue Book, is moving in this direction. In New South Wales the plan I suggest is already in operation.

The future teacher should pass from the primary to the secondary school along with other children without being marked in any way. When necessary bursaries should be given without any restriction as to future profession. A course of at least four years should be entered on at 12 or 13. After 15, when the intermediate or junior certificate is taken, there should be a partial differentiation of children remaining at school. Those who propose to take up teaching may now be required to decide, though they need not enter upon any special course, but should pursue the general course leading to a Leaving Certificate, or some equivalent examination.

The leaving certificate would evidence the completion of a sound and well balanced secondary education including at least two languages, general science, mathematics, drawing, manual work, and music, with history and geography up to 15 at least.

Students holding such a certificate would have carried their general education far enough to enable them to undertake class work with children up to 12 or 13. They might, therefore, enter at once upon a course of professional training, and would pass out after two years of professional work as teachers of the lowest grade. A certain number, however, will be desirous of carrying their general education further, and these should be allowed to do so by taking selected courses at the university, or in the case of the ablest students by proceeding to a degree in arts or science.

When the examination which marks the completion of the secondary course has been passed, the student, before proceeding to the professional work of the Teachers' College, might profitably spend two or three months in an approved school. Here his time would be spent in observing classroom methods and organisation, in occasional teaching under direction, and in a study of a simple text book on teaching methods.

This period would allow of the formation of an opinion by the head master of the candidate's temperamental fitness for teaching. Thus the entrance qualification to the college would be—(*a*) the Leaving Certificate in a prescribed group of subjects; (*b*) evidence of temperamental fitness and capacity to profit by a course of professional training. Such an arrangement would have the further advantage of drawing supplies of teachers from sources which hitherto have hardly been available.

It will be noticed that I suggest a smaller amount of time for professional work during this stage than is at present generally demanded. But I am convinced that it is the influence of the older system which has led to the retention of so much professional study at what I regard as too early an age. The young student is not fit for technical study, and the time given it lowers the level of general education attainable. And surely the general education of the teacher of whatever grade should be at least as good as that required for other professions. Any half-time arrangement is to be deprecated as unsatisfactory in the interests of the student and of his future efficiency as a teacher.

After the completion of a general education up to 17 or 18 the professional or college stage of training is entered upon. The characteristic of the college course is that it is mainly, though perhaps not exclusively, professional. In giving an account of the work falling to be done at this stage I propose to outline the organisation either actually in operation or very shortly to be introduced at the College for Teachers in Sydney.

The aim of the college course should without doubt be professional training. In the first period the general education of the student was the primary aim, the professional a subordinate one. Now the relative importance of the two elements is reversed. It is here that the task of the Teachers' College differs from that of the normal schools, which on the whole took for granted that the student knew how to teach as the result of his pupil-teacher training, and devoted their main energies to the improvement of the student's general education.

In my opinion the general culture of the student at this stage is best promoted by a simple introduction to philosophical and social science, and any further study of the primary school subjects which may be necessary is best made in a strictly professional interest.

These philosophical and social subjects may be studied throughout the course, and will give the young student a broader conception of society, and of the place of the teacher in society. Further, such studies have a cultural effect at this period which no linguistic or mathematical drill can now have.

Before considering the general nature of the college course it is necessary to note the various types of student for whom provision has to be made—

(*a*) Students who have not the capacity or do not wish to continue their general education further than the leaving certificate or senior standard;

(*b*) Students who have the capacity and wish to carry their general education further, but who cannot successfully take a degree course;

(*c*) Students who can profitably undertake a course of study leading to a degree in arts or science;

(*d*) Students who have graduated before entry upon the college course.

The students who form groups (*a*) and (*d*) should enter upon their professional course at once. Those of groups (*b*) and (*c*) only after two or three years of further general education. The professional course for group (*a*) should be a two-year course; that for groups (*b*), (*c*), (*d*), a one-year course.

Further, the two-year professional course would be simpler than the one-year course, and the more philosophical side of education would require to be omitted. Such a plan as I have just outlined must be adopted if the undue burden of a combined professional and non-professional course is to be avoided.

At present we have not reached this point in Sydney, where the university students representing groups 2 and 3 are required to undertake coincidently academic and professional work. But the plan I suggest will, in all probability, come into operation in a few years.

It may be noticed that it is being advocated strongly at present in Scotland.

I pass to consider the two-year course in more detail, as this is the one which, under present circumstances, the majority of the students will pass through.

During the first year the student should review the primary school subjects from the point of view of teaching method. At present in the Sydney College the first year is largely devoted to carrying further the general education of the student. But this will in a year or two become unnecessary, and the time will be occupied by a detailed study of the methods of teaching primary school subjects. The student should further be able to appreciate a simple account of the process of reasoning and the general nature of the course of experience. An endeavour should be made to connect such introspective psychology with observation of children in and out of school. Further, a study of the physical conditions of class work may well be undertaken during this year. All this work should be intimately associated with observation work in the classroom. The practical work may be divided into observation, criticism lessons, and continuous practice, though not much of the latter can be attempted. Sufficient connection with class work should be maintained to secure that the theoretical work in college is prevented from becoming mere theory without practical bearing.

The aims of a first-year course should then be—

(*a*) To review primary school subjects from the method point of view;

(*b*) A simple treament of logic, psychology, and school hygiene;

(*c*) Observation and practice under direction.

During the second year the subjects of study should be fewer and the methods more independent—the amount of practice should be greater and more continuous; and, further, there should be some differentiation of students for different types of teaching.

At present the Sydney College second-year students are required to take up four major subjects—two of which are optional, the other two being theory and history of education and English. So far the subjects, with the exception of education, have been studied quite as much for their own sake as from the point of view of being material for use in school. During the coming session much more attention will be given to the use of these subjects in the primary and higher primary classes. In each a special text book on method forms one of the books prescribed, and the student will be expected to draft single lessons and courses of lessons for class discussion, and in other ways will be practised in preparing his material for class use.

In education the student makes a simple study of individual and social ethics—the principles of general method are considered on the basis ,of the students' teaching experience and study of logic, psychology, and school hygiene. A beginning is made on the more abstract portions of educational theory, and a little history of education is read. All this work is valuable, not merely for its direct and immediate bearing on classroom teaching but because of its unique value in broadening the student's outlook and putting him in a position from which he can criticise, in the light of general principles, the definite methods inculcated in the first year. Some students gain little from such work—their minds are yet too immature; but even these I have found to take a keen interest in the discussion of ethical and social problems.

Towards the end of this year a study is made of the various problems of classroom management as well as of a variety of educational problems of importance to the teacher bearing on the relation of the school to the community. A short course of lectures is given on the organisation and working of a small rural school, although such work is not generally required until after the full certificate is issued.

The practice work falls into the same divisions as in the first year—(*a*) Observation; (*b*) criticism lessons; (*c*) continuous practice. Observation naturally occupies a smaller place. Criticism lessons take place weekly, and for this the students are arranged in groups of not more than 12—each group under the direction of a college lecturer. At a preliminary meeting the course of lessons is arranged for, the class selected, and books of reference are suggested. Each student is expected to make a study of the subject matter of the course and to arrange it in the form of teaching notes. The members of the group in turn give one lesson of the series, and thereafter a discussion follows—a record of which is kept by each student. At the end of the term the lecturer submits a report on the work done by each student, and the part taken by him in the discussions. These reports are filed along with the reports from lecturers and head masters on the continuous practice taken. Towards the close of the session the various reports are considered, and a mark representing the student's practical skill in teaching is awarded. By this means a much truer estimate of the student's teaching character can be formed than was possible when the mark was awarded by an Inspector who saw the student for a few minutes only, and under very unreal conditions.

During the coming session the whole of the third or final term will be given up to continuous practice, in conjunction with lectures and discussions. During half the day the student will practise under the direction of the members of the college staff, and for the rest of the day they will attend at the college for professional lectures and discussions. This arrangement will probably be extended gradually to the whole of the second year, as, in fact, is already the case with students taking the kindergarten and infant school course. It is only by very careful arrangements for extended and supervised practice that the foundations for practical skill can be effectively laid. To secure this the student must be free from the pressure of academic work, and his whole interest concentrated upon his professional training. Unless there is this close and continued attention to class-room practice the theoretical instruction in principles and methods becomes harmful rather than beneficial. For successful practice must never be allowed to become uncriticised; routine and theory must be continually tested by practice.

But even the most complete professional training leaves much to be done, and indeed some forms of classroom technique can hardly, if at all, be acquired, except when the teacher occupies a responsible position in charge of a class. Hence the college cannot completely form the teaching character of the student, and should not claim to send its students out as fully qualified practitioners. It is for this reason that a period of probation or ex-studentship is desirable.

Before referring to this third stage it is necessary to say something about the differentiation of students in their second year. During the first year all the students of group 1 pursue the same general professional course. But in the second year the following alternative courses are in operation:—

(*a*) Ordinary course, qualifying for work in middle and upper primary classes, the practice work being taken with children ranging from nine to fourteen years;

(*b*) Kindergarten and infant course qualifying for work with children up to about nine years of age. Practice throughout the year in selected kindergarten and infant schools;

(*c*) Hawkesbury Agricultural College Course qualifying for work in rural schools. The students taking this course spend two terms of the second year at the Hawkesbury Agricultural College, Richmond, and become acquainted with rural school work in the public school there;

(*d*) University course and graduate course qualifying for work in the upper primary and lower secondary classes. Practice work is taken with classes from 14 years upwards.

A few students who show special ability are granted a third year of training. Eventually a third or even a fourth year will require to be regarded as essential in the case of groups 2 and 3. At present students taking university subjects must combine their professional with their academic study. This arrangement is not satisfactory; but, until an extra year for training can be added, it can hardly be remedied. Probably for the abler students the stimulus of university study, even with the burden of professional work, is more beneficial than would be a simpler course which did not require them to put forth all their powers. But very careful arrangements are necessary in order to secure due attention to professional work. The burden of the double work has been lightened for the students in Sydney by the institution of a course of lectures on education as a degree subject. This will afford a much needed relief during the second year.

Third Stage of Training.

I pass to the third stage of training. This stage is one which has been unduly neglected in both England and Scotland. When the student left the normal college his professional education was looked upon as complete. His permanent certificate was awarded practically on the result of his college course. In this matter again the older method may be partially justified, since the student's teaching character was really formed before the college was entered. But the conditions are now altered, and it is as I have shown the main business of the college to lay the foundation of a good teaching character. It cannot do much more, for there are certain forms of skill which are only perfected slowly. Methods of handling class subjects can readily be acquired, but only within limits can powers of class management and control be developed. There are certain conditions of class teaching with which it is extremely difficult for the college to bring the student into touch. Hence the award of a permanent certificate should be deferred, and should only be given after a period of responsible practice, which will vary with the length of the course of training. It would be well if during the first few months of responsible work the college direction and advice could still be available. Further, for students who have not taken the advanced course in education, it would be desirable to require more advanced study of educational theory during the period of ex-studentship. Indeed it would be well in the case of all young teachers to secure continued attenion to theory in order to avoid the danger of falling into routine practices, which are a serious check to the growth of teaching character just after the college course is completed, and when practical problems are specially insistent.

One further question remains to be touched on. A teachers' college, with aims and organisation such as I have outlined, will do most effective work if closely associated with the university. The connection may take various forms; but, for my own part, I think that a high standard is most likely to be attained when the professional school for teachers is one of the schools of the university, and when all its students have passed an examination equivalent to, but, perhaps, not identical with the present matriculation examination. This of course does not mean that all students need pursue a course leading to a degree in arts or science. They may, as in the case of students attending other professional schools, enter immediately upon their course of professional study. It is hardly necessary to refer in detail to the many advantages which accrue to the student, the schools, the university, and the community, through such a connection.

Recent discussion has brought out clearly the main principles upon which the training of teachers should be based. Experiment will no doubt be required to secure an embodiment of these principles to suit local requirements. Especially during the first stage will difficulty be found in a sparsely populated locality in securing a general education of a sufficiently high standard readily accessible to all who can profit by it. But this difficulty is not one peculiar to the early education of young teachers. It is part of the quite general problem of the provision throughout the country of adequate secondary education. It is obvious too that the success of university and of technical education depends on a supply of students possessing a good general education, and to secure this a body of highly trained teachers is essential. More and more it is being realised that no element of the educational system is self-contained. The welfare and efficiency of each is dependent upon that of all. A defective primary system means defective secondary, technical, and university systems, and no efficient primary system is possible without a body of efficient, broad-minded, and enthusiastic teachers.

2.—FIFTY YEARS OF EDUCATION IN QUEENSLAND.

A Retrospect and an Outlook.

By J. D. STORY, Under Secretary, Department of Public Instruction, Queensland.

Seeing that Queensland will celebrate this year the fiftieth anniversary of her proclamation as an autonomous colony, it seemed to me that an appropriate paper for this occasion might be one reviewing, briefly, the progress which has been made in this State in the way of education during the past fifty years, and referring shortly to the problems which the future holds.

Fifty years ago Australia was almost an unknown land. Even ten years ago she was not regarded as a factor of any importance in the world of education, and British, American, and German educationists did not think that there was any feature in the Australian systems of education worthy of careful study. Up to that time Australia was looked upon as a land of empty spaces and magnificent distances; a land of vast potentialities and hidden wealth, but a land unpeopled and undeveloped; a land unknown in the realms of art, literature, science, and general culture. India was known; Canada was known; the war had brought South Africa into prominence; but Australia was not known. But during the last decade Australia has been unfolding. The opening of the first Parliament of the Commonwealth on the 9th of May, 1901, by His Royal Highness the Duke of Cornwall and York heralded the birth of a new nation; the trend of Commonwealth legislation has directed the eyes of the nations towards Australia; the Prime Minister of the

Commonwealth was the most notable figure at the Imperial Conference of 1907, overshadowing even the venerable Sir Wilfred Laurier. Australia was ably represented at the Federal Conference of Education held the same year under the auspices of the League of the Empire; the Franco-British Exhibition has brought the resources of Australia prominently before the British people and foreign visitors; and America has paid a graceful tribute to the young nation by sending her fleet to visit her shores.

Australia has emerged from her obscurity, but the passing into the light will bring its risks as well as its privileges.

During the past few years, also, a spirit of discontent and unrest, a sure sign of life and vitality, has arisen in the several Australian States in connection with their education systems, and many missioners have gone abroad to study the systems of other lands. These missioners agree broadly that the State-controlled, free, and compulsory system of primary education in Australia is not surpassed by the system of primary education in any other country; though there may be defects in details the general principles are sound. On the other hand, however, the consensus is that in other branches of education the Commonwealth is lagging behind. But she is now awake to her shortcomings; State is eagerly watching State in regard to educational developments, and a keen and healthy rivalry exists which should be productive of good. At the Federal Conference on Education held in London in 1907 it was announced that the Imperial Government was so convinced of the value of such Conferences that it was seriously anxious that they should be called regularly and that they should bear the Imperial imprimatur. The first of the Conferences on Education to be convened by the Home Government is to be held in 1911, and it is probable that quadrennial conferences will be convened thereafter. These conferences will doubtless play an important part in the development of the education systems of Australia. Through her chosen representatives she will be kept well informed as to the progress being made in Britain, and in other parts of the Empire, and the horizon of her educationists should be materially widened. But in many respects the directors of education in the Commonwealth will have to solve their problems unaided; conditions in Australia are so widely different from those in the older countries that the old has few lessons to teach the new in regard to some aspects of education in the new lands. Particularly is this the case in Queensland; she must work out her own salvation; she must plough her furrow alone.

QUEENSLAND.

From the 10th December, 1859, the date of the founding of Queensland, to the 30th September, 1860, primary education was under the control of a Board of National Education appointed by the Governor in Council. That board consisted of W. Hobbs, A. Raff, W. J. Munce, and W. H. Day. When the board took office there were only two National schools in Queensland. The system of primary education obtaining in New South Wales was continued, but the subject of education was one of the earliest matters which received the consideration of the first Parliament of Queensland, and, in 1860, an Act to provide for primary education was passed. The

Bill was initiated in the Legislative Council by Captain O'Connell, and Mr. R. G. W. Herbert had charge of the measure in the Legislative Assembly. The object of the measure was to provide primary education under one general and comprehensive system, and to afford facilities to persons of all denominations for the education of their children in the same school without prejudice to their religious beliefs. The Act provided for the appointment of a "Board of General Education" to consist of five members, together with a Minister of the Crown who would, *ex officio*, act as Chairman of the Board. The members of the first Board of General Education were:—A. Macalister (Chairman), R. G. W. Herbert, R. Pring, R. R. Mackenzie, A. W. Manning, and J. Panton. The scheme of primary education which the board framed was based upon the general principles of the National system in operation in Ireland. Schools were divided into two classes—Vested and Non-vested. The vested schools were unsectarian in character. The aid granted by the board towards the establishment, equipment, and up keep of schools varied from time to time, and ranged from one-half to two-thirds. The board appointed the teachers. The salaries of teachers were supplemented by school fees, ranging from 3d. to 1s. 6d. per week for each scholar according to his standard in the school work. When the board took office there were 10 teachers, 493 pupils, and 4 schools. The employees of the board were:—Inspector, Randall Macdonnell; secretary, R. Bourne; teachers, J. Rendall, J. Harris, J. Scott, A. Narracott, A. Stewart, J. Robertson, and Miss Berry; pupil-teachers, Miss Taylor, Miss Marshall, and C. Francis. The four schools were:—Brisbane (Boys); Brisbane (Girls); Drayton; and Warwick. The total expenditure in 1860 was £1,615 2s. 3d. School fees were abolished by Charles Lilley from the 1st of January, 1870, and since that date primary State education in Queensland has been free.

The Education Act of 1860 was superseded by "*The State Education Act of* 1875"; that Act came into operation on the 1st January, 1876, and is still in force. The author of the Act was Sir S. W. Griffith, the present Chief Justice of the Commonwealth, and he was the first Minister for Public Instruction in Queensland. The first Under Secretary was Mr. C. J. Graham. On the 31st December, 1875, there were 230 schools in operation, the aggregate attendance for the year being 33,643, and the average 16,887. The number of teachers employed was 595, and the total expenditure for the year was £83,219 14s. 9d. The new Act provided that the whole system of public instruction in Queensland, formerly administered by the Board of General Education, should be transferred to a department of the Public Service to be called the Department of Public Instruction. State aid to non-vested schools was withdrawn as from the 31st December, 1880. When this Act was passed it was regarded as the most progressive Education Act in Australia. Primary education was brought entirely under the control of the State; the incubus of vested rights was strangled in its infancy; and a system was evolved which the critical test of thirty-three years has proved to be in keeping with the highest ideals of a true democracy. The British Cabinet and the English Board of Education would feel the cares of office less irksome if they could find themselves in the same happy position to-day.

In 1895 a motion was moved in Parliament for the establishment of Superior State Schools with a view to providing higher education for children in towns and populous centres where grammar schools did not esixt. The ultimate result of this action was the passing of "*The State Education Act Amendment Act of* 1897," which gave the Governor-in-Council power to prescribe that any subjects of secular instruction might be subjects of instruction in primary schools. The Department immediately took advantage of this amending Act, and provided for the teaching of mathematics, higher English, and science in the fifth and sixth classes. The amending Act was passed at the instance of the Hon. D. H. Dalrymple, who was the Minister at the time.

So far as the resources at its disposal have admitted, the Department has done what it could to bring the means of primary education within the reach of the children of the State, and it may be safely claimed that wherever twelve children can be gathered together there exists a school. But if the children cannot be gathered into groups, the Department goes to the homes of the pupils. Itinerant teachers, fully equipped with buggies, camping-outfits, school requisites, and other necessaries, traverse the sparsely settled districs where the establishment of schools is not possible. The travelling teachers do not look for palatial schools with tiled floors and frescoed walls in those far western and northern lands; they look for the homes of the pupils, be those homes rude wayside inns, rough log cabins, or even tents. Where the home of the child is, there the school is—be it ever so humble. The Department does not claim to produce university graduates under this system; but it does claim to teach these little ones to read, to write, and to count. This is one of the furrows which the Queensland Department is trying to plough.

Three years ago the Department began to appoint trained teachers to the charge of all schools where the attendance exceeded twelve; by this process properly qualified teachers will soon be in charge of 90 per cent. of the schools of the State. One of the most difficult problems which has to be faced in England, Scotland, America, and also in some of our sister States, is the adequate staffing of small country schools by efficient teachers. Queensland has solved that problem. The day has gone by in this State when the school was a haven for the storm-tossed derelict who had drifted from calling to calling until he found a safe anchorage in a little school in some backwater. In all the literature which I have read, and the inquiries which I have made, I have not been able to discover that any State has done better than Queensland in this respect, and the magnitude of the task will be understood when it is realised that out of the 1,116 primary schools in Queensland 639 have an attendance of less than thirty pupils, that some of the schools to be administered are a three weeks' journey from the departmental base, and that Queensland is a territory so vast that England and Wales could be put into it about twelve times, and Victoria about eight times.

It has become almost a platitude that the well-being of a nation depends upon the efficiency of its education system; but the true and lasting efficiency of a system must depend upon the quality of its teachers. Organisation may be perfect; regulations and schedules may be faultless; buildings and equipment may be the best that lavish grants of money can produce; but unless the teacher is a skilled and sympathetic craftsman, happy in his surroundings, a high standard of excellence will not be reached and maintained. Assuming again that national well-being depends upon educational efficiency, it logically follows that education from the kindergarten to the university should be one of the chief concerns of the State; that the profession of teaching should be made one of the most attractive and honourable of the professions; that the highest intellects of the State should be culled for the teaching service; and that the well-being of its members should be carefully tended. The enthusiasm of the true teacher dies slowly, but no enthusiasm, however intense, will withstand the chilling blasts and biting frosts of neglect and lack of appreciation; the winter of discontent surely sets in, and its blighting effects rapidly and disastrously permeate a whole service. The teacher loses interest in his work; his main object becomes not the efficiency of his school but a desire to find a more congenial and a more remunerative field of labour; or, if he be devoid of ambition, to work with just sufficient energy to escape official censure. The teacher is but human. No more striking exemplification of these facts can be found than in the American system. In many respects the American organisation approaches the ideal; but in appreciation of their teachers and care for their material well-being Americans seem to be surprisingly neglectful for so astute and far-seeing a people. The Rev. Herbert Gray, Warden and Head Master of the Bradfield College, in Berkshire, and a member of the Moseley Commission which visited the United States in 1903, stated that he had been assured that not more than 7 per cent. of male teachers in secondary schools stay in the profession more than five years; and not more than 5 per cent. make it their life's vocation; the same remarks may be applied, but in a modified form, to the elementary school teachers in America. Writing in the "Educational Review" of April last, C. W. Bardeen affirmed that in the seven years ending 1906 the number of men teachers in the United States had decreased 24 per cent. Teaching is just as much a man's vocation as it is a woman's; indeed, for the higher education of boys it is the man rather than the woman that is needed. There must be something seriously defective in a system of education which fails not only to obtain sufficient good men for its service, but fails to keep the men that it does obtain. The defects are not hard to locate; the pay is poor; the prospects of promotion are bad; the tenure of position is insecure; teaching is not fully recognised as amongst the learned professions, and the lack of that recognition re-acts detrimentally upon the standing of the teachers.

The care which the Germans take of their teachers is in striking contrast to the policy of the Americans; and the tender regard which Prince Bismarck had for the teaching profession is characteristic of the whole German nation. On the occasion of Bismarck's seventieth birthday the German nation collected a large sum of money by public subscription, with which they bought back the estate which had once formed part of the family property of Schoenhausen, and made Bismarck a present of it. A sum of 1,200,000 marks beyond the amount required for the purpose remained in hand, and was placed at the Prince's free disposal to do with it what he might deem fit. He decided to devote it to a fund to be named after his birthplace, and to be administered for all time from Schoenhausen. The fund was to be devoted to provide assistance for deserving young Germans who had embraced the scholastic profession and might be in need of support prior to obtaining regular appointment; also to assist poor widows of German schoolmasters towards the education of their children. This trust is administered under the strict control of the State.

Teachers stand high in public estimation in Queensland, and that estimation is steadily rising; primary school teachers are officers of the State; and are not subject to the caprices of boards or local committees; they enjoy the protection and privileges of the Public Service Act, and the interests of no branch of the public service are more zealously protected by Parliament than the interests of the teachers. The pay on the whole is good—particularly that of head teachers; and the conditions of service are not unfavourable. Perhaps the surest proof of these statements is that the Department is able to keep its teachers. The appointment of primary school teachers to the Commission of the Peace and to be returning officers and presiding officers in connection with State elections is a sure indication of the confidence which the Government has in them. The wisdom of drawing teachers into the political vortex has been questioned, but their appointment to these responsible civic positions is at least a high tribute to their ability, integrity, and impartiality.

From the standpoint of the well-being of the teacher the most serious defect in our system, and it is a really serious one, is the want of a sound Superannuation Scheme; but we have now good reason to believe that the blemish will soon be removed.

So far I have written of the bright side of primary education in this State, but there is a dark side also. However, we know our weaknesses, and we know in what direction reform should lie. Perhaps the three most urgent reforms at the present moment are the amendment of the pupil-teacher system; the amendment of the compulsory clauses of the Education Act; and the establishment of a training college for teachers. These reforms have been advocated by the Department time and again, and time and again they will still be advocated, until the much desired reforms have been effected.

Professor Henry Jones, of the Glasgow University, on the occasion of his recent visit to this State, asked half jocularly, half sarcastically, whether Queensland regarded herself as a civilised country, seeing that she was without a University. The same question might reasonably be asked in regard to a training college for teachers. In the early years of its existence the Department obtained trained teachers from Great Britain, but since 1880 almost the whole supply of teachers has been obtained from local sources—mainly through the pupil-teacher system. Most of the teachers obtained from Great Britain, both males and females, have done highly commendable work in this State, and many of the largest schools are occupied by teachers who are graduates of the training colleges of the home land. The influences of these teachers, and through them of their training colleges, has saturated our system, and the value of the work done by the teachers directly, and by their colleges indirectly, in the moulding and training of young Queensland teachers cannot well be appraised. It is noteworthy that the Director of Education and nine out of the twelve Inspectors of Schools are college trainees. It may be partly due to these reasons, aside from financial considerations, that the establishment of a training college has been so long deferred. But the sands of time run quickly through the glass; the elder of the brotherhood of home-trained teachers are gradually reaching the allotted span of public service life; and with the passing of the home-trained teachers will pass the influences and associations of the training colleges. Therein lies our danger; because, however excellent the local material may be, and its excellence is not doubted, it is not fair to expect the native-born, without special training, to produce results superior to, or even equal to, the results produced by specially trained men.

Secondary Education.

The Director of Education in Victoria in his recent report upon observations made during an official visit to Europe and America vigorously applauds the steps which have been taken in Great Britain, France, Germany, Austria, the United States, and the smaller countries to provide efficient secondary schools. In these countries, Mr. Tate found, as other Australian educationists had found before him, a more or less completely co-ordinated system of schools, ranging from the primary school to the university, maintained or controlled by the Government or by public bodies. As a result of this organisation the schools are either free schools, or the fees charged are so moderate that higher education has ceased to be the privilege of the well-to-do. Mr. Tate scathingly condemns the apathy which has been shown in Victoria in regard to Secondary education. Compared with Victoria, or indeed with any Australian State, Queensland has little reason to be ashamed of the support which she has given to Secondary education. In 1860, that is within one year of her founding as a separate State, an Act was passed to provide for the establishment of grammar schools in which was to be given an education higher than that which could be given in the elementary schools. The remarks made by Mr. R. G. W. Herbert, who introduced the Bill in the Legislative Assembly, are very interesting. He said:—"The question of education might be considered under three heads as primary, grammar school, and collegiate. The Bill introduced into the other branch of the Legislature was intended to provide for primary education, principally under the national system, and would make adequate provision for imparting fundamental instruction at a cheap rate to all classes of youth without distinction of creed or religious profession. The Bill he now introduced was intended to provide for a higher order of instruction of a useful and thoroughly practical character by establishing grammar schools easily accessible to the colonial youth of all denominations throughout the colony. . . . It was desirable that the instruction to be afforded in the grammar schools should be afforded at a cheap rate, so that as many as possible might avail themselves of it, and that it should be such as would best qualify the youth of the colony for discharging the duties that would devolve upon them in after life."

Captain O'Connell, who introduced the measure in the Legislative Council, said:—"It was merely a sequel to the Primary Education Bill, and was designed to give those who might desire it a higher education than could be afforded by the primary schools. It was a matter of the greatest importance that a system of this kind should be established on a broad and permanent foundation, and therefore it was not difficult to perceive that the creation of primary schools such as were contemplated under the other Bill would be found extremely useful in carrying out the great objects now proposed to be accomplished."

Under the provisions of the Grammar Schools Act a grammar school may be established in any locality where a sum of not less than £1,000 has been raised locally, and the Governor in Council may grant towards the erection of school buildings and a residence for the principal a subsidy equal to twice the amount raised locally. An amending Act was passed in 1864, providing that when certain conditions had been complied with an annual endowment of £1,000 might be granted to each grammar school. Each grammar school is governed by a board of seven trustees; of these four are appointed by the Government, and three are nominated by the subscribers to the building fund; they hold office for three years. There are ten grammar schools in the State; seven in the South, two in the centre, and one in the north. The Ipswich Grammar School for boys was the first grammar school to be established in Queensland; it was erected in 1863. The last grammar school established was the school for girls in Rockhampton; it was founded in 1892. Each of the schools has qualified for the annual endowment of £1,000 per annum; of this amount the State pays £750 a year unconditionally, and £250 on the understanding that each school will receive a certain number of State scholars per annum; the scholarships held by these pupils are known as district scholarships. Queensland has always been liberal in the granting of scholarships, and at the present time eighty-six scholarships are granted per annum; of these fifty-seven are available for boys, and twenty-nine for girls. These scholarships include the district scholarships. Each scholarship has a currency of three years. The State also grants six bursaries to boys and two to girls. The bursary entitles the holder to free education at an approved Secondary school for three years, together with a cash allowance of £30 per annum. In addition to the scholarships granted by the State, the trustees of the various grammar schools also grant scholarships. In 1907 the number of pupils in attendance at the grammar schools was 1,044, and of these fully one-third were the holders of scholarships.

Free railway passes to the nearest grammar school are granted to the holders of scholarships. It is believed that in the past children of poor parents may have been prevented from competing for scholarships because, even if they won these prizes, their parents could not afford to keep them at grammar schools. To assist the children of really poor parents the Government intend to grant a living allowance of £12 per annum to the winners of scholarships provided that the income of the parents does not exceed three pounds per week, or £30 per annum for each *bonâ fide* member of the family. This rule will come into operation as from the 1st of January, 1909.

It is generally recognised that the Queensland grammar schools do good work; the success of their students in the Junior and Senior examinations of the Sydney University abundantly justify this conclusion. Each school constructs its own programme, but, broadly speaking, the curriculum of the several schools is designed to lead up to the Sydney University. As each school practically shapes its own course the success of the institution depends very largely upon the personality, efficiency, and vigour of the principal. In addition to the State-endowed grammar schools there are several other secondary schools. Some of the schools are denominational, and others are conducted by private persons. These secondary schools are not endowed by the State, but the winners of State scholarships or bursaries may attend these institutions if the Governor in Council is satisfied that they are of a sufficiently high standard.

As there is not a university in Queensland, the State grants each year three exhibitions to universities. The exhibitions are open to competition, and the test examination is the senior examination of the Sydney University. Each exhibition has a currency of three years, and is worth £100 a year. The winners may attend any University approved by the Governor in Council.

It will thus be seen that Queensland has been fairly liberal in providing the means of higher education for her children. A comparison with her sister States of New South Wales and Victoria emphasises this fact. During the year 1906-7 New South Wales, with a population of 1,526,697, and a revenue of £13,392,435, granted £12,945 towards secondary education; Victoria, with a population of 1,231,940, and a revenue of £8,345,534, granted £5,874; Queensland, with a population of 535,113, and a revenue of £4,307,912, granted £12,909; this amount is exclusive of £900 per annum granted on account of exhibitions to universities. In comparison with New Zealand, however, all the Australian States figure very poorly. In 1906-7, New Zealand, with a population of 977,220, and a revenue of £7,650,098, granted £64,528 in aid of secondary education; that amount includes the salaries of staffs of the secondary classes in district high schools.

Technical Education.

The system of technical education in Queensland is in its infancy, but no branch of education is likely to make more rapid and lusty growth during the next 50 years, or to have a more important bearing upon the industrial and commercial development of the State.

Australia has excellent opportunities of becoming a large manufacturing nation; Nature has dealt bountifully with her, and her products are many and varied. The Commonwealth Government, by means of a highly protective tariff and by industrial legislation, is encouraging and fostering Australian industries; and it is now for the people of Australia to make full use of their opportunities. The following few statistics may help to illustrate the possibilities which lie before Australians as a manufacturing nation. The value of apparel, textiles, &c., including boots imported into the Commonwealth in 1906, was £13,508,844; of metals manufactured, including machinery, £7,932,675; wood and wicker material, raw and manufactured, £1,698,766. The value of the wool exported in 1906 was

£22,645,769; of skins and hides, £1,597,343; of metals, ores, &c. (exclusive of specie), £13,379,488; of wood, &c., £1,044,043. When we consider the very large amount of raw material which Australia exports, and the large amount of manufactured material which she imports, material, be it remembered, manufactured largely out of the raw produce which she has exported, it is hard to see why Australia should not in time be able not only to supply many of her own requirements but to become a large exporter of manufactured material as well as of raw material. But to enable those results to be achieved, the intelligence of the industrial captains must be highly trained and their directive faculties developed; the operatives must be highly skilled, and the machinery made as perfect as man can make it. It is in this direction that the powerful forces of technical education will be called into action; for what technical education has done for Germany and America in raising them to the front rank of industrial and commercial nations it should do for the Australian States, if it is properly organised and skilfully directed and applied. Patriotic Queenslanders regard their State as the queen State of the Commonwealth, and they are not slow to proclaim her manifold glories or to discourse eloquently upon her many and varied resources. Certainly Nature has been very lavish in her gifts; but of all the States Queensland is possibly the one which may be benefited most by a properly developed system of technical education, and she must not only make her opportunities but seize those which she has. Her mineral wealth seems to be almost limitless, but proper methods have yet to be discovered of treating many of her refractory ores; her agricultural resources are great, but ways of combating destructive pests have to be evolved; drought itself has to be resisted. The vista of possibilities in the way of scientific research is boundless; and in the making of that research the technical institutes must act as accessories to the University when it comes. In the commercial, industrial, and agricultural departments technical education has an important part to play.

It is only since July, 1905, that the Department has been closely associated with the administration of technical education in Queensland. Previous to 1902 technical colleges, with the exception of the Brisbane college, were carried on in connection with schools of arts under the control of local committees. The Brisbane Technical College has been in existence as a distinct institution since 1882, and during the whole period of its existence it has been under the directorship of Mr. D. R. McConnel, M.A., who may be regarded as the father of technical education in Queensland, and one of the earliest pioneers of technical education in the whole of Australia. The State subsidised the technical colleges to the extent of £1 for each £1 paid in fees or subscribed for technical college purposes. In 1902 a Board of Technical Education was created; the board held office until 1905, when this branch of education was placed under the control of the Department, and a special officer was appointed to supervise the work. Endowment is now paid upon a differential scale, the distribution being based on the general and practical utility of the subjects taught; the subsidy ranges from 10s. to £3 for every £1 of fees collected. There were 16 colleges in operation during 1907, and the total number of individual students in attendance was 4,702. The technical colleges of Queensland are not comparable with the technical institutes of Britain, America, and Germany; and much of the work done is of a continuation class nature.

The importance of a highly developed system of technical education has been fully realised in this State, and in 1908 a Technical Instruction Act was passed. This Act provides for the establishment of a central technical college in Brisbane which shall be maintained by and be under the direct control of the State. It is intended that this college shall be the recognised technical institute of Queensland, and it is hoped that it may ultimately be one of the leading and most important institutions of the kind in Australia. The colleges outside the metropolis will be affiliated with the central institution, but will remain under local control.

The foregoing account will show that Queensland has not been unmindful of the advantages of a good system of education. But, though much has been done in the past to perfect the system, much still remains to be done. Though storm clouds gather from time to time, and rumours of war are flashed from shore to shore, the majority of us are hopeful that the differences of nations will be settled in future by the diplomacy of statesmen rather than by recourse to war; and that international rivalries will henceforth be confined largely to the struggles of commerce and manufactures, in which education will be one of the main factors and war and carnage will be unknown.

Already Nation is vieing with Nation for supremacy in education, and Britain, America, Germany, Japan, and other countries are bringing their educational Dreadnoughts to a higher and ever higher degree of perfection. Our sister States of the Commonwealth are awake to their responsibilities, and educational reform is being pursued vigorously. Queensland cannot afford to linger behind or to tread the primrose path of dalliance. It cannot be emphasised too often that with her vast latent potentialities it is indispensable that she should have a good system of education extending from the kindergarten to the university. Probably she has more to gain than any other State of the Commonwealth by a thoroughly efficient system of education, and possibly Queensland is in a better position than any other of the States to establish a truly national system which shall include every rung of the educational ladder. Primary education is entirely under the control of the State; technical education almost so; and secondary education largely so if the State cared to exercise its powers; the university has yet to be established, and as the larger part of the funds for its establishment, equipment, and maintenance must come out of the State Treasury, Parliament will have the opportunity of making the university the copestone of the national temple of education.

It is easy, comparatively, to review in a cursory way what has been done for education in Queensland during the past 50 years; it is not so easy to dip into the future and say with certitude precisely what should be done during the next 50. Time has worked many changes in this State since 1859; and the great reaper will have worked even greater changes by 1959, when most of us here to-day will probably have crept silently to rest. The old lands move slowly, but the new lands more with amazing rapidity, and we are hopeful that Queensland's development will proceed apace.

But dealing with circumstances as they now exist; analysing dispassionately the defects in our system as time and experience have revealed them; weighing well the further requirements in regard to education which the general development of the State, the expansion of her industries, and the growth of her interests have rendered necessary; and keeping prominently in view the progress of education in other parts of the world, it is not a hard task to construct a platform which will engage the attention of the most skilful of our educationists for at least a decade. There is the general correlation of the whole system—the forging of the chain of national education of which each branch of education shall form an indispensable link; the betterment, if not the abolition, of the pupil-teacher system; the establishment of a training college for teachers; the amendment of the compulsory clauses of the Education Act; the improvement of school furniture; medical inspection of children; the establishment of high-grade and superior schools; the linking of secondary with primary schools; the bringing of a secondary education within the reach of a greater number of children; the fostering of continuation classes; the development and expansion of a sound system of technical education; the establishment of a university. There is magnificent work in Queensland for educationists to do; it will be hard work; it will be wearing work; it will be dispiriting work; for difficulties are many, critics are legion; and funds, alas, too often run low; but surely one of the noblest works in which a man can be employed is in building a system of education which shall mould the character of the children of his country, efficiently equip them for the battle of life, and generally tend to the uplifting of the nation.

3.—THE EVOLUTION OF THE QUEENSLAND PRIMARY SCHOOL TEACHER.

By J. J. DEMPSEY, State School, Junction Park, Brisbane.

In 1859 separation from New South Wales left us with the legacy of the New South Wales system, and two public or national schools of our own. The Board of Education formed under the Act of 1860 had, at first, a difficult task. The material available for teachers was often of an unsatisfactory character. In public and private, the idea prevailed that only very humble and ordinary qualifications were needed, and for these the board offered a remuneration sufficient to attract just that kind of "teacher" (so-called). As illustrating the notions prevalent at that time, I recall the visit of the parent of a classmate who asked our head master "to make a teacher of her lad, for indeed, sir," said she, "he seems to be fit for nothing else." Fortunately for him, fate afterwards turned him into a very successful pioneer farmer. No one saw anything incongruous in that mother's remark at the time. It was made in all good faith, and accepted quite as a matter of course. Recalling it after nearly forty years, there seems to me to be a joke somewhere in it. [I may say it does not always take me forty years to see the point of a joke.] However, the position and popular estimate of the teacher shows slow upward progress during the first decade after separation. When Queensland had been ten years running as a separate State, it possessed a staff of 170 teachers and pupil-teachers in eighty-eight schools, who received an average salary of £67 per year. But of these, eighty-eight, or a little over half, had school fees which averaged £47 additional, so that the head teachers of those days had the princely average income of £114 a year. Wait! I must not forget to add that, in order to encourage the employment of the more reliable married teacher, the board, wherever possible, provided a residence which it was stipulated in the specifications "must contain at least two decent rooms and a kitchen."

At the time I speak of there were two classes of schools—vested or board schools, and non-vested or denominational schools; the figures cover the whole of the State-paid salaries in both classes of schools. When I state that the pay in the non-vested schools was usually much lower than in the board's schools, one gets an idea of the slender remuneration received by the teachers in the denominational schools. Small wonder that very great difficulty was experienced in retaining the services of the non-vested teachers. Those who amounted to anything resigned and sought admission to the board's service. The result was, in the denominational schools, a "survival of the unfit"; and quite naturally the quality of what was called "the instruction" was of a very inferior kind. Thoughtful citizens saw and deplored the two-fold waste—the waste of money on inferior teaching, and the irreparable waste of school years of a large section of the rising community. Hence arose an agitation for the amendment of the Act, which in 1873-4 culminated in a Royal Commission, and the introduction of the Act under which we now work. Before leaving this pioneer stage and its lessons, I have some other points to mention, and some conclusions to draw.

The average attendance was only a fraction over 50 per cent. of the enrolment, a fact which speaks volumes for the kind of "discipline" that obtained in the schools. Indeed, it was not uncommon for a large proportion of a school to go off on truanting expeditions of indefinite duration (on the principle of the safety in numbers). When I add that corporal punishment was extremely common, and severe to a degree now happily unheard of, I have summed up in these two facts the low ebb at which real teaching stood. Of all the cheap things a nation can invest in cheap teaching is the worst bargain. An effort had been made to "grow" a better supply by means of the pupil-teacher system; this was only partially successful for several reasons. In the earlier sixties Brisbane had no grammar school, and parents of the better class who desired an education, anything beyond the three R's, found it a good plan to make pupil-teachers of their children. But as these mostly resigned towards the end of their term of pupilage, no great permanent improvement to the staff resulted. Moreover, the then head of the only "model" or normal school was not a trained teacher himself.

Meanwhile population was flowing in, enrolment was increasing, and among the new arrivals were some pioneer teachers, men who were destined to leave the impress of their strong personality on our system. At first they battled almost alone. Even as late as 1st January, 1870, when primary education became free ("Report of Board of Education, 1869," p. 10), only one female assistant had as much as £100 a year, and a good deal more than half of the fifty-seven male assistants had just that amount each. Our best public men saw that the first step was to secure better remuneration, as a preliminary to attracting and retaining better men and women. In the middle sixties several strong men arrived in Queensland and took work with the Board. Mr. Anderson, Mr. Kerr, Mr. Ewart, and Mr. Platt were amongst the number, and by voice and pen they battled for better things, and gradually the leading men of Queensland were induced to see the need for more consideration for their teachers. Better salaries, buildings, and residences began to appear. The aristocracy of *intellect* among the pupils now turned towards teaching as an occupation—the aristocracy of money and influence had gone off to the grammar schools, but "scholarships" had not been begun. The board's outlay for prizes and scholarships in 1869 was £35.

The pupil-teachers joining about this time proved the best we ever had. Many of them hold leading positions as teachers and inspectors to-day. A most important new departure was made in the seventies, by which one or more assistants in certain schools were allotted "definite staff rank" as first, second, &c., assistant, with a share in the capitation allowance. For nearly twenty years this system was in vogue. It placed a premium on loyalty, diligence, tact, and superior skill in teaching, and it bred a class of assistant teachers now almost, if not entirely, extinct. It fostered a spirit and a degree of loyalty and self-sacrifice that united all ranks in the school in the heartiest co-operation for its good, and in pride in its success. It was an excellent preparation for the young man aspiring to the charge of his own school. But the custom lapsed, and gradually disappeared in the early "nineties," and few, if any, of the present assistants ever experienced the benefits of it or know anything about it. Then came the system of scholarships: the best blood was drained away to enrich the grammar schools, and almost never found its way back to assist in the work of teaching. This mistake has been persisted in ever since, but at last we are awaking to the fact that our pupil-teachers would be less trouble and be much more valuable if the grammar schools formed the only door into the education service. In 1871-2 came the pupil-teachers' training class under Mr. J. S. Kerr. For the first time the pupil-teacher got a fair chance to grow into something good. The work was continued by Mr. Platt for some years, during which he also did a good deal to help many adult candidates of more or less merit to enter and find a footing in the service, some of them born teachers, and not a few of them successful men and women to-day. The British teachers had begun to drop in in ones and twos and the intellectual and professional stamp of the teachers was rising steadily. At last it was felt that we had enough *good* teachers to take charge of the work of training "P.T.'s" as we know it, and in 1876 the "old training class" was discontinued. On the suggestion of a leading teacher the training fee of £5 per year per pupil-teacher was instituted. I think the gross amount paid in this way to head teachers must by this time be very large, indeed, probably £50,000 has been so paid, and probably, too, not five present-day teachers could tell you to whose suggestion these little annual windfalls are due.

But how was our Queensland teacher doing without a training college all this time? Well, several expedients were resorted to, and if our teachers as a body were not trained they certainly resemble Topsy in having "growed" (and "growed considerable"). Our early teachers had few subjects to teach; there was wonderful freedom from interference—the solitary inspector, who examined all Queensland, seldom troubled you more than once a year. But after a time things were shaped up, and the inspectors—for there were now two—began to act as Masters of Method. They were wonderfully kind, patient and considerate; they took immense pains, and little by little the educational army swung into line. Later Mr. Kerr took charge of the Normal School, where his influence, seemingly at first wastefully concentrated, was really in the end spread to the utmost limits of the colony, till now, wherever you find a man who has worked under the veteran training master, inspector, and master of the model school, there you have a man who has high ideals in his work, who is never afraid to work hard in the interests of his pupils, and who will hand down the influence of the "grand old man" of Queensland to untold generations of teachers. The addition of Messrs. Platt and Ewart to the inspectorate completed the guiding force which really shaped our system finally, inspired our teachers with their ideals, and set *everything in good going order.*

About this time it occurred to someone in authority that a little "tone" would be a good thing for the Education Service, and that a needed touch of refinement and erudition would be added by the appointment of an inspector with high university degrees. He came and he saw, but, alas! did not conquer, and after a very uncomfortable time he solved the difficulty by resigning. He did one good service in proving that not every learned man can be a teacher or a school inspector. About this period, too, the ranks of the college-trained men who had ventured in ones and twos to Queensland were reinforced by a steady stream of teachers drawn from Great Britain. There were some who proved unsuitable for the work, but the majority had enough "adaptability" to shake down in their new surroundings, and after acquiring the indispensable "colonial experience" they became a valuable element in the service. At their best they might have numbered a sixth of the whole staff; now, I daresay, they are not more than a twelfth, if so large a proportion as that. But even a little leaven, if it be of the right sort, cannot fail to leaven the mass. The professors and masters of the training colleges of Britain have spoken through them to our assistants, and our pupil-teachers are speaking to them daily now, and the influence, the impetus thus acquired goes on in ever-widening circles and spreads already even to the remote corners of the State. They did not found our first Teachers' Associations, but they have done much to strengthen and extend them. The work of these associations has completely changed the whole nature and outlook of the Queensland teacher, and much of this is due to the spirit of discussion, inquiry, and comparison of methods and views resulting from those friendly meetings of teachers hitherto almost unknown in Queensland. At the starting of one of these associations the veteran chairman counselled all to join and get rid of swelled-head by meeting their fellows and learning their hitherto unsuspected excellencies. He related a sort of parable of a new minister of a Scotch kirk, who asked the ruling elder how many true Christians there were in the somewhat numerous congregation. "Weel, mineester, there's just me and Sandy—and—well whiles, I hae my doots o' Sandy." That, he said, was what we wanted to alter. We all had our "doots of Sandy—we had none of oursel's, and had not any need to pray for a 'guid conceit' o' ourselves." When the history of the last two decades in primary education is written, the work of the Teachers' Union and its branch associations will be found to have done more than all other forces combined in breaking down that isolation which is so detrimental to the real advancement of teachers. A very strongly marked change came over the spirit of the teachers when passes to technical college and other lectures began to be used—the old isolation was at last completely broken up, the dry bones were stirred, the peculiar, reserved, semi-crank individual came out of his shell, and has never returned to it. In these lectures, and in the courses at Gatton, the influence of our present Senior Inspector, Mr. J. Shirley, was specially valuable.

To the forces already mentioned must be added the effects of the teachers' volunteer corps, and its later development, the cadet movement. If there was any tendency to priggishness left in the younger men this will, I think, effectually shake it out—or, at least, out of those who are wise enough to come within the beneficial influence of the movement. And if we have still any lingering "doots of Sandy," let us join some of the many courses at the agricultural colleges, and have our swelled-head systematically cured.

Some years ago it was hard to interest the young teachers in courses of study to break up stagnation; now the pendulum seems to have swung just as far the other way—there is a feverish rush to cram up subjects and get through the exams. as quickly as possible. This is due to a conviction (a mistaken one probably) that examinations are to be the main, if not the only road, to promotion. The training college and the university, when they come (and they are at hand), may be relied on to cure some of these delusions. But the old order is changing, and much that has served its day, and served it well, is passing. My paper is intended to emphasise the fact that we are ripe for both the changes named, and that the present officers and teachers have contributed their quota to the work of preparing for the day of greater things. I have seen the teacher grow from a mere drudge to a valued and esteemed officer of the State. It has not been done without hearty co-operation all round. In particular it has occurred in consequence of the sacrifices of the early teachers, and of the help of the officers of the Department in realising the aspirations of the teachers. Queensland has a body of trained teachers without the adjunct of a training college. All training is not done in a college: a teacher's training is many-sided, the result of many influences. I have endeavoured to show in turn what these were, and how they have evolved our present stamp of teachers, and how they have prepared the way for the training college and the university that are to mould the teachers of the future.

4.—THE EDUCATIONAL VALUE OF MUSEUM COLLECTIONS.

By ROBERT HALL, C.M.Z.S., F.L.S., Director, Hobart Museum, Tasmania.

The suggestions given here are offered in the interests of those who are about to extend or form a museum collection.

The wave of Nature Study which is quietly passing through our midst is causing more than ordinary interest in the subject.

A curator must be one who knows well, and who fully cares for, the objects under his care. There must be unlimited time available for such a work, with sterling interest. It is desirable to show, so far as is possible, the great chain of Nature, with its principal links; to keep in view an arrangement of its parts as a whole.

The purposes of a museum might safely be—

A. To stimulate an interest in (a^1) Physiography, (a^2) Nature, by means of life-histories of special utilitarian value;

B. To make it possible for the "man in the street" to identify (by means of a full collection) any object that awaits identification.

South Kensington is the most perfect exemplification of these points.

In Dublin, beautiful collections may be seen, illustrating the evolution and geographical distribution of animals.

In Berlin, extensive dissections are shown, with the specimens, to illustrate the anatomy.

In Paris (Jardin des Plantes), on the other hand, thousands of specimens are rigidly shown without reference to their natural surroundings or their utilitarian value.

In the museum—as we would have it—we would show clearly by means of specimens and descriptive labels—

(1) Indexes to the general plan of life;
(2) Its interesting phases;
(3) Its economic value.

The artistic effect of a museum should be kept in view from the first step onwards. First attract the eye, then arrest the attention, the rest will naturally follow.

It has been found that—

(1) Pale green is a good colour for the background of cases;
(2) Case-framings should be black or polished black;
(3) Black blocks are most effective in upright cases as pedestals for specimens;
(4) Dust-proof cases are essential;
(5) "Stephens's liquid stain," written with a pen in a clear, strong hand on a snow-white card, is the most effective for label-writing. It is important that the descriptions should be of an interesting nature.

We might learn from Continental museums the value of subduing the light on the specimens. In Berlin, not only the windows, but the cases themselves, have blinds. In many museums the damage wrought by over-lighting is irreclaimable—the deleterious effect on colour is noticeable in a year or so.

Particular attention should be given to our own country, with a view to the economic value of the flora or fauna.

A large room should be set aside for this purpose, illustrating—

- (a^1) Physical features (including stratigraphy), (a^2) minerals, (a^3) fossils;
- (*b*) Fauna;
- (*c*) Ethnology;
- (*d*) Prominent types of plant life;
- (*e*) Special studies—*e.g.*, animal life of a State. Under this head could be treated—(e^1) Bird life, (e^2) Useful and noxious insects, (e^3) Food fishes, (e^4) Shellfish (Mollusca).

In (a^2) the mineral collections can be well exhibited in flat glass cases.

The teaching series should be labelled "An introduction to the Study of Minerals." The cases should be consecutive, the specimens in each case being arranged from left to right. Over each specimen is placed a clearly-written name with a few words of description. Between each column of white card is a narrow length of wood (0·25″ × ·025″), painted black, which has an excellent effect. Many of the specimens should be placed on circular or rectangular discs.

I shall give the headings of several cases to indicate the method—

1. Examples of minerals.
2. Minerals, liquid or gaseous.
3. Occurrence of minerals.
4. Variations of certain properties in a mineral.
5. The angles of crystal planes.
6. Internal imperfections and impurities.
7. Isomorphism.
8. Pleomorphism.
9. Trimorphism.
10. Dimorphism.
11. Pseudomorphism.
12. Structure.
13. Cleavage.
14. Fracture.
15. Hardness.
16. Tangibility.
17. Specific gravity.
18. Electricity.
19. Magnetism.
20. Refraction and Polarization.
21. Diaphaneity.
22. Lustre.
23. Colour.
24. Streak.
25. Iridescence.
26. Tarnish.
27. Opalescence.
28. Asterism.
29. Phosphorescence.
30. Feel.
31. Taste.
32. Odour.
33. Fusibility.

These flat cases should occupy 11″ × 18″ × 4″ of space. In Part (a^3) an introduction to the study of fossils could be arranged in the same manner as the minerals.

I think in no part of the world is the "teaching series of fossils" so well exhibited as in the National Museum, Victoria. For example —What is a fossil? Examples of fossils, and ancient ideas of them. How animals and plants have been placed in the sedimentary rocks. Marine deposits. Estuarine deposits. Terrestrial and fresh water deposits. Fossiliferous rocks. Limestones. Bone beds. Flints. Ironstone. Parts generally preserved as fossils. Tracks and impressions of animals. (1) Fossils well preserved; why and how? (2)

Carbonisation—Moulds and casts. (3) Pseudomorphs, and how? (4) Distortion of fossils. Imitative forms. Evidence afforded by fossils. Typical fossils.

In Subsection *(b)* of Section A—

Fauna.—Each well-marked group of mammals should be placed as naturally as possible, in separate cases; the invertebrates in shallow upright wall cases.

In Subsection *(c)* of Section A—

Ethnology.—The wall cases might be 12 in. deep, with ordinary wire netting stretched across the middle of the case, painted pale-green to match a background of green. On this netting, the specimens may be hung and labelled with names or numbers to correspond with a key within the case.

In Subsection *(d)* of Section A—

Plant Life.—A series of wax models will be invaluable. It is possible to place an order with a French firm (Messrs. Deyrolle and Sons) for a set of models catalogued at £1,050 f.o.b., Paris. The collection is made up of parts, many of which are purchasable at a few shillings each.

Respiration; transpiration; nutrition; cultures; assimilation; movements of plants; certain of the common plants; plants that defend themselves against animals, or cold, or heat; plants deformed; plant parasites; textile fibres; resins and gums; histories of plants, as tea, chicory, &c.

A good working collection of models is available for £175 sterling, from the above-mentioned French firm.

In Subsection *(e^1)*, the part that most commends itself to the writer for some treatment in detail later is, *(e^1)* "The Bird Life of a State." Birds have a popular interest, and a more apparent economic value.

The *(e^2)* "Insects" come next for exhibition and life-histories.

This part should show special reference to the entomology of—(1) The forest; (2) the orchard; (3) the pasture lands; (4) the special crops.

In setting out the collection of *(e^3)* "Food fishes," it would be advisable to make two divisions—(1) Marine Food Fishes; (2) Fresh-water Food Fishes, with one or more life histories of each.

The Fisheries Board of New South Wales has issued handbooks on the "Fishes of Australia" and the "Food Fishes of New South Wales, containing many well-executed photographs—an admirable substitute for the actual specimens till such time as it is possible to obtain a full collection.

In Subsection *(e^4)* "Mollusca," the special cases in the South Kensington Museum show what a beautiful and interesting series may be obatined under this head. It is remarkable for colour, form, purpose, and distribution.

In Subsection *(e^1)* "Bird Life," we may take, for example, Victoria, finding it closely allied to that of adjacent areas. The following is one method of treatment, with each specimen and section, bearing short descriptive labels.

1. Introductory remarks upon the physiography of the country and characteristic birds.

2. Birds in relation to agriculture, fruit-growing, and forestry, *e.g.*—

(1) Silver Eye (Zosterops)
(2) Starling (Sturnus)
(3) Blue Wren (Malurus)
(4) Ibis (Ibis)
(5) Owls (Strix or Ninox)
(6) Masked Wood Swallows (Artamus)
(7) Home Swallow (Hirundo)
(8) Fairy Martin (Petrochelidon)
(9) Swift (Chætura)
(10) Honey-eaters (Meliphagidæ)
(11) Lorikeets (Glossopsittacus)
(12) Black Cockatoo (Calyptorhynchus)

3. Recognition marks—

3[1] Species—*e.g.*, Fantails *(Rhipidura tricolor, Sisura inquieta).* Robins (throats and foreheads), Lorikeets *(Glossopsittacus concinnus, G. pusillus).*

3[3] Sexes—*e.g.*, Tree Creepers *(C. leucophœa).* Chats *(Ephthianura).*

4. The making of a species—*e.g.*, Magpie *(Gymnorhina)*, Woodland, desert, and insular forms.

5. Distribution—*e.g.*, Short-tailed Petrel *(Puffinus tenuirostris)*, Fairy Penguin *(Eudyptula minor)*, Reed Warbler *(Acrocephalus australis)*, Helmeted Honey-eater *(Ptilotis cassidix)*, Bristle Bird *(Sphenura)*, Chestnut-eared Finch *(Tœniopygia castanotis)*, Mallee Fowl *(Lipoa ocellata)*, Lyre Bird *(Menura superba)*, Bower Bird *(Satin and spotted):* Each of the above species to have a distribution map card.

6. Migration—

6[1] Partial or internal—*e.g.*, White-fronted Chat *(Ephthianura albifrons).*

6[2] Complete—Little Sandpiper (Stint) *(Heteropygia acuminata).*

6[3] Accidental—*e.g.*, New Zealand Shoveller *(Spatula variegata).*

7. Flight—

7[1] The Tail—Home Swallow, Pigeon, Quail.

7[2] Wing—Stint, Gull, Quail.

8. Plumage—

8[1] Seasonal change—

(*a*) Tuck pointing
(*b*) Moult

e.g., White-shouldered Caterpillar Eater *(Lalage tricolor).*

(*c*) Pigment alone—any dull-brown bird;
(*d*) Pigment and transparent cells—Green Parrot;

(*e*) Subjective—Bronze-wing Pigeon;
(*f*) No colour—Albino;
(*g*) Combination of colour.

8^2 Varying periods of maturity—*e.g.*, Satin Bower Bird; White-throated Thickhead; Crow.

8^3 Types—
(*a*) Owl and Hawk—Plumages soft and hard;
(*b*) Cormorant—Note tail and contour feathers;
(*c*) Penguin—Wing-feathers and plumage;
(*d*) Emu Wren—Tail-feathers partly decomposed, as in emu;
(*e*) Duck—Oily plumage;
(*f*) Scrub-bird (Pilot-bird)—Overmantling;
(*g*) Migratories—Stint's inner secondaries.

9. Protective Colouration—
9^1. Varying with country—Pipit *(Anthus australis)* and Southern Stone Plover *(Burhinus grallarius).*

9^2. Constant with surroundings—Little Lorikeet *(Glossopsittacus pusillus).*

10. Mimicry—*e.g.*, Frogmouth *(Podargus).*

11. Courtship—
11^1. Blandishment—Blue Wren; Bower Bird.
11^2. Battle—Spur-wing Plover.
11^3. Song—Reed Warbler *(Mirafra).*

12. Song—
Inherited and acquired—*e.g.*, Starling *(Sturnus);*
Song muscles present, but not used—Crow *(Corvus);*
Day Singers—Song Larks *(Cincloramphus);*
Night Singers—Reed Warbler *(Acrocephalus);*
Day and night—Bush Lark *(Mirafra).*

Seasonal—
Summer (call-notes)—Summer Bird or White-browed Wood Swallow *(Artamus).*
Autumn—Butcher Bird *(Cracticus).*
Winter—Lyre Bird *(Menura).*
Spring—Magpie *(Gymnorhina).*

13. Types of Nests (specimens or photographs with surroundings).

13^1. Primitive—Plover.

13^2. Earth—
(*a*) Below the ground—Mutton Bird *(Puffinus);*
(*b*) Above the ground—Mallee Fowl *(Lipoa).*

13^3. Mud Nests—
(*a*) Open, upon the ground—Albatross; open, above the ground—Welcome Swallow;
(*b*) Retort—Fairy Martin.

13. Types of Nests—*continued.*

13[4]. Fibre Nests—

(1) Upon the ground—(*a*) A Colony—Pipit; (*b*) A Colony—Gannet;
(2) Upon the water—Grebe;
(3) Cup-shaped—Wood Swallow *(Artamus)*;
(4) Domed—Blue Wren;
(5) Hidden in forest—Lyre Bird;
(6) Hidden in creek bank—Diamond Bird *(Pardalotus)*;
(7) High in tree—Shrike Tit *(Falcunculus)*;
(8) Varying architecture—Thickhead *(Pachycephala)*;
(9) Relatively large structure—Finch *(Ægintha temporalis)*;
(10) Suspended—Lunulated Honey Eater *(Melithreptus)*;
(11) Placed in strange positions—White-faced Tit *(Xerophila)*;
(12) Associations of species—Petrels, *Terns.*

13[5]. Specialised Fibre Nests.

13[6]. Tree Hollows—Tree Creepers *(Climacteris)*, Parrots *(Platycercus)*.

14. Eggs—

(*a*) White once, as lizards now;
(*b*) Needing protection, they eventually got colour;
(*c*) Some were later placed in trees, both white and coloured;
(*d*) Some eggs, being placed in hollows, needed colour and lost it—Diamond Birds *(Pardalotus)*;
(*e*) Certain eggs are highly coloured, and may be protected by the birds themselves *(Ptilotis)*;
(*f*) Certain birds cover their eggs with—(f^1) down for protection (Duck); (f^2) water weeds (Grebe);
(*g*) Natural incubator—(g^1) on land; perfect—Mallee Fowl *(Lipoa)*; (g^2) on water—partial—Grebe *(Podiceps)*;
(*h*) Period of incubation, 10 to 60 days—10, Silver Eye; 60, Mallee Fowl;
(*i*) Exact meaning of colouration is unknown, though its value is evident in many cases—*e.g.*, Bronze and Narrow-billed Bronze Cuckoos, Plovers, and Gulls.
(*j*) Forms—Plain Wanderer *(Pedionomus)* (pointed); Kingfishers (round); Pigeons (oval);
(*k*) Number—Quail, Plover, Mutton Bird *(Puffinus)*;
(*l*) Attention to eggs—♀♀ mostly, ♂♂ occasionally or always, in Plain Wanderers. ♂ share labour in certain species—Magpie Lark *(Grallina)*.

15. Pleasure ground (Specimen or illustration)—*e.g.*, Bower and Lyre Birds *(Chlamydodera* and *Menura)*.

16. Birds—

16[1]. The public parks of the city; native or introduced;

16[2]. The River Yarra.

17. Birds of—

17[1]. Ocean—*e.g.*, Diving Petrel, Wilson's Petrel, Albatross;

17[2]. Bay—*e.g.*, Silver Gull, Pacific Gull;

17[3]. River and Swamp—*e.g.*, Darter *(Plotus)*, Duck, Reed Warbler *(Acrocephalus)*;

17[4]. Mountain—*e.g.*, Black Cockatoo (*Pycnoptilus)*, Lyre Bird;

17[5]. Plains—Wattled and Southern Stone Plovers, Song Larks *(Cinclorhamphus)*;

17[6]. Lightly timbered country—*e.g.*, Tree Swallow *(Petrochelidon)*, Tree Runner *(Sittella)*.

B. In a second room there should be—

B[1]. A general zoological series and the principal types of minerals and fossils from all parts of the world.

In the general collection of fossils, each specimen should be mounted on a board of a standard size, and coloured pale-green, blue, or pink, to indicate the Primary, Secondary, or Tertiary Divisions. On the adjacent wall, a large chart should be placed, showing the classification in detail, with the three divisions in corresponding colours.

B[2]. Collections to illustrate Evolution or the History of Races, Geographical Distribution, and Migration.

This subsection should illustrate (by means of specimens in wall cases) the history of animals.

Such examples as magpies, crows, magpie larks, hawks, gulls, frogs, and bandicoots, with descriptive matter to each label, would illustrate what is meant by—Species, Genus, Family, Order, Class, and Sub-kingdom *(Phylum)*. Variation of species could be shown in the comparison of Tasmanian magpies with those of Victoria; specimens with reference to the struggle for existence (herring and flesh fly) and natural selection (parrot) should be near at hand.

Examples to show the different ways of getting a living—*e.g.*, cockchafer—grub and beetle—with others showing structures for offence and defence—*e.g.*, plover (Spur-wing), scorpion; others, again, to show instincts for defence—*e.g.*, sepia, certain crabs; concealment by colour—flatheads *(Platycephala)*; protection by warning colour—katipo spider, lady-bird beetle *(Leis)*; mimicry—bees and wasps, mimicked by harmless insects; and, in the case of birds, drongo shrike and cuckoo.

Similar parts of different animals, showing modification from a common type—Sea squirt and frog, sea urchin and star-fish.

Life history of individuals—Barnacle *(Lepas)*, white-throated thickhead *(Pachycephala)*.

Life History of Races.

(1) Descent without modification—Lamp-shells, oysters.

(2) Progress (models of parts)—Horse, salmon, shell-snails.

(3) Difference in Sexes—Size (in hawks), colour (in robins), form (Huia crow).

Geographical Distribution and Migration.

A series of cases, illustrating the geographical distribution of animals, forms a fascinating study. It may be a salmon or a trout, a fox or a rabbit, that interests us. A study of their distribution will be found to be economically profitable. Man is the principal agent in the distribution of certain animals. His parasites are being transplanted into every habitable part of the globe. A large amount of material is necessary to form a perfect collection, so that gaps might be temporarily filled by sketches or photographs. Small distribution maps should be well in evidence, the areas of distribution being coloured red—

i. Temperature is a strong governing factor in distribution—*e.g.*, goats, whose presence practically defines the altitude. The earth, but for mountains, would probably be arranged, zoographically, in zones.

ii. Barriers to migration and emigration (Australia)—

(*a*) The desert extending from the west coast of Australia to Central Australia;

(*b*) Bass Straits.

iii. Difference of faunas. Faunas of—

(*a*) Continent and island—*e.g.*, Australia and Lord Howe Island;

(*b*) Continental and Oceanic Island—*e.g.*, Tasmania and Kerguelen Island.

(*c*) Two adjacent islands—*e.g.*, Bali and Lombok.

(*d*) Nearest continent and anomalous island—*e.g.*, Australia and New Zealand.

4. Distribution—

(*a*) Continuous—Cats (*Felis*), Silver Eyes (*Zosterops*).

(*b*) Discontinuous—Platypus, lung fishes.

(*c*) Local—Marsupial mole, helmeted honey-eater (*Ptilotis cassidix*).

(d^1) Of an order—Marsupialia.

(d^2) Of a family—*Pittidæ* (Ant Thrushes).

(d^3) Of a genus—*Acanthodrilus* (Earth Worm).

(d^4) Of a species—*Pycnoptilus* (Pilot Bird).

(*e*) From a common centre of origin.

(e^1) Galaxias.

(e^2) Casuarius.

(e^3) Edentates.

(e^4) Antelopes.

(e^5) Lemurs.

(e^6) Marsupials.

(e^7) Placentals.

(f) The fringe of a coast—South East Australia—*e.g.*, Estuary perch.

(f^2) Fringe of oceans—Lancelets.

(f^3) Course of a river-system—Murray River golden perch.

(g) By migration.

(g^1) Complete (from continent to continent)—*e.g.*, Barracouta *(Thyrsites)*.

(g^2) Partial (within the continent)—

(1) At regular periods—*e.g.*, Home Swallow (*Hirundo neoxena)*.

(2) At irregular periods—*e.g.*, Masked Wood Swallow *(Artamus personatus)*, rats and mice *(Mus)*.

(h) Fossil, France—

(1) Living, Queensland—Spur-footed Cuckoo *(Centropus)*. Fossil, Victoria—

(2) Living, Queensland—Lung Fish *(Neoceratodus)*.

(i) Of allied genera—

(i^1) Associated—Acanthiza, Acanthornis, Seriocornis (Tasmania).

(i^2) Dissociated—Kagu (New Caledonia), Mexites (Madagascar), Sun Bittern (tropical America).

(j) Relation of continents, *e.g.*—

(j^1) Australia with South America, genera common to each: Fresh water fishes, Tortoises, Buprestids, Sand frogs, worms, Tasmanian "wolf" (fossil in South America).

(j^2) Australia with Asia, common to each: Many genera of Passerine birds, "Tabbies" and the so-called "land-crabs" of our highlands.

It would seem that the foregoing remarks point strongly in the interests of Geography. To-day, the science of Geography covers a very wide field.

A small museum may do a wonderful amount of good work by keeping in view collections to illustrate the following:—

A. 1. Geomorphology.

Anthropogeography, Zoogeography (less above)—evolution of life-forms.

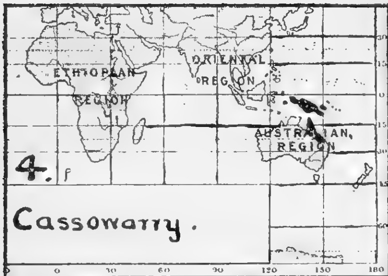
2. Biogeography.

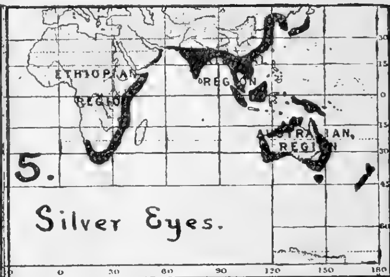
2^1. Zoogeography.

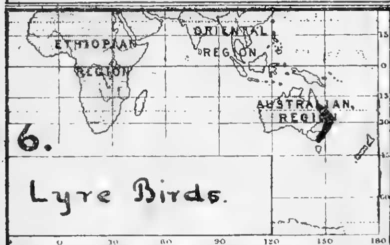
2^2. Phytogeography.

B. Economic Studies (well illustrated).

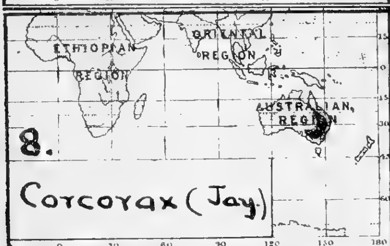
A large museum has its collections as perfect as possible. The smaller museum supplies in its collection the outline of a broad outlook, while the larger institution holds, in addition, the body of it.

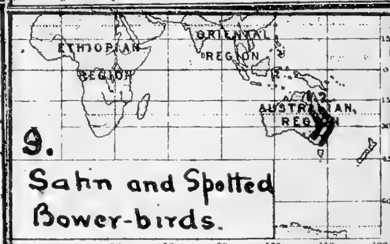

ETHIOPIAN REGION
ORIENTAL REGION
AUSTRALIAN, REGION
4.
Cassowarry.

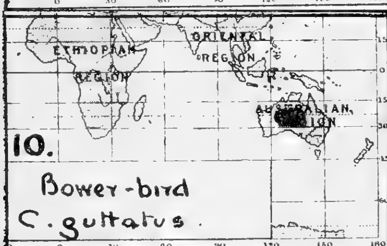

ETHIOPIAN REGION
REGION
AUSTRALIAN, REGION
5.
Silver Eyes.

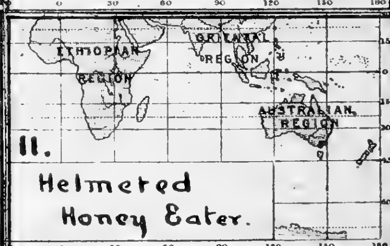

ETHIOPIAN REGION
ORIENTAL REGION
AUSTRALIAN, REGION
6.
Lyre Birds.

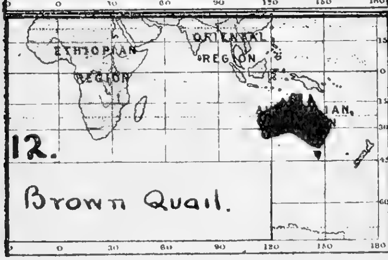

ETHIOPIAN REGION
ORIENTAL REGION
AUSTRALIAN, REGION
7.
Coach-whip birds.

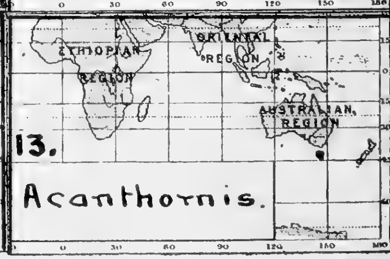

ETHIOPIAN REGION
ORIENTAL REGION
AUSTRALIAN, REGION
8.
Corcorax (Jay)


ETHIOPIAN REGION
ORIENTAL REGION
AUSTRALIAN, REGION
9.
Satin and Spotted Bower-birds.


ETHIOPIAN REGION
ORIENTAL REGION
AUSTRALIAN, REGION
10.
Bower-bird C. guttatus.


ETHIOPIAN REGION
ORIENTAL REGION
AUSTRALIAN, REGION
11.
Helmeted Honey Eater.


ETHIOPIAN REGION
ORIENTAL REGION
12.
Brown Quail.


ETHIOPIAN REGION
ORIENTAL REGION
AUSTRALIAN, REGION
13.
Acanthornis.

SOME TYPES OF THE GEOGRAPHICAL DISTRIBUTION OF BIRDS.

1. The areas of distribution of 13 species of swallows and swifts, with the approximate courses of migration of two species—an English Swallow and Australian Swift *(C. pacificus).*

2. The northern and southern homes of a Song Thrush *(Turdus musicus)*, with an adopted country.

3. Isolated distribution of Ant Thrushes.

4. Broken distribution *(Casuarius).*

5. Extended littoral distribution: Silver Eyes *(Zosterops).*

6. Coast range distribution: Lyre Birds *(Menura).*

7. East and west distribution of a genus: Coach-whip Birds *(Psophodes).*

8. Hinterland distribution: Jay or Chough *(Corcorax).*

9. Parallel distribution: Bower Birds—(1) Spotted *(C. maculata)*; (2) Satin *(P. violaceus).*

10. Desert distribution: Guttated Bower Bird *(C. guttata).*

11. Local distribution: Helmeted Honey-eater *(P. cassidix).*

12. Broad distribution: Brown Quail *(Synœcus australis).*

13. Island distribution: Great Scrub Tit *(Acanthornis).*

5.—THE PSYCHOLOGIC BASIS OF ETHICAL TRAINING.

By Mrs. LILIE A. WRIGHT, Warwick, Queensland.

The subject of this paper is so exceedingly complex that, to deal with its various parts even in a condensed manner, would require, not a single paper, but a number of volumes. I can only attempt to offer a few suggestions on a subject of intense social importance. My apology for doing so lies in the fact that these suggestions are the outcome of many years of more or less patient endeavour to put into practice the theories laid down by modern authorities upon psychology, and more especially upon that branch of the subject known as "Child Psychology." If any of these suggestions are so fortunate as to gain elaboration at the hands of someone more competent to deal with them than I am; if, in a word, they pass from the hands of a tyro to those of an expert in mental science, the object of this paper will have been attained.

To avoid any misunderstanding, let us begin with a definition of the terms "ethics" and "ethical training," as they will be used throughout this paper. By "ethics" we mean, right conduct. The science of ethics aims at discovering, from man's mental and social constitution, how and why certain actions are beneficial, and certain other actions detrimental to man and to society.

By "ethical training" we mean the application of this science to the education of the young. We imply by the term "ethical training" that, just as children can be trained physically, so that in adult life they shall possess healthy and graceful bodies; just as they can be taught to read fluently, and to write legibly; just as the growing mind of a child can be trained to observe accurately, and to reason clearly; so the emotional nature of a child can be trained to feel rightly, to love what is good, and to recoil from what is bad.

In other words, the term implies that the adults of one generation have the power of consciously moulding the nature of the generation to come after them. We can make our children, not only more healthy in body and keener in intellect than we are, we can also make them nobler in character, we can endow them with an emotional hygiene.

The origin of ethical training lies in a remote past, among the earliest forms of human societies. The most primitive parent would make some attempt to qualify his child for the society in which he had to live. As the society became more organised, the attention given to the training of its future members received more attention. Along with the other functions arising out of social life, the function of the educator became more and more specialised in character. But from the beginning, the aim of training has been to produce fit members for the next generation of society.

Until a quite recent yesterday, the means employed to attain this desirable end were empirical in essence and objective in method. But, during late years, the basis of ethical sanction has been undergoing a radical change. The objective sanction for right conduct is being superseded by a subjective sanction. The old order relied upon an arbitrary "Thou shalt not," supported by the entire weight of the ecclesiastic and civic powers. Under this order, ethical training consisted chiefly in the inculcation of maxims regulating conduct. These maxims were designed to impart a categorical knowledge of things to be done, and things not to be done. Underlying the system was the mistaken assumption that an intellectual conception of right conduct would lead to the practice of right conduct. The only effectiveness which the system possessed was derived from the potency of the authority by which the rules of conduct were enforced. It was believed that whenever this authority failed to sway the mind, the categorically imparted maxim failed to sway the conduct. During late years the general acceptance of scientific knowledge has tended to weaken every form of objective authority, and has led us to seek for a more stable sanction for right conduct in the mental and social nature of man himself. The savage father, who, on the birth of a boy, submits to long sustained torture, in order that his son may be endowed with courage; the royal Hebrew poet and sage who declared that to spare the rod was to spoil the child; and the man of to-day, who asserts that the moral conduct of the future adult can be influenced for good, by making the child commit moral maxims to memory, have one point in common. They all fix their attention upon something outside the child. Each of them would use objective means to gain ethical results. An alliance of the sciences of psychology and sociology has provided us with an ethical conception which has superseded the earlier conception which marked the childhood of the race. Under the old order the moralist was the prophet and seer; under the new order the moralist will be the man of science.

With the object of right conduct this paper is not directly concerned. We will, therefore, simply accept the conclusion arrived at by the study of sociology:—That right conduct is that conduct which leads to individual and social well-being. Ethical teachers of every school of thought agree as to this essential aim of right conduct. Happiness, either immediate or remote, is the great objective.

We are here concerned with the means by which the individual may be guided to act rightly under the varied and changing conditions which social life imposes upon its members.

A further limitation of our subject has to be noted. Actions in general result from two sets of causation—internal and external. Stimuli from the environment, acting upon a sentient being, compounded of a complex system of psychic forces, produce certain actions which are determined by the totality of the conditions. And any change in either of these compound factors of causation—the internal and the external—will determine a change in the resulting actions of that being. In this paper we are mainly concerned with the internal or psychical factors in this dual control. Our object is to discover by what means we may best secure a psychical condition in the growing mind which will respond ethically to the stimuli it receives from its social environment. Although we may not be able to more than touch upon the external factors, their importance must ever be kept in mind. For the average adult the social environment is a powerful factor in determining conduct. And it is probable that the individual adult will always be so permeated with the collective spirit that his actions will be more or less in accord with the social ideals of his time, country, and station in life. Hence it is important that there should be clearly formulated an ethical ideal which would meet with the approval of all sections of the community; an ideal which could be placed before the parents and teachers of our children, not in vague terms, but in definite outlines. So that throughout the State our future citizens would receive the same education of the emotions and sentiment, and would be more or less subjected to the same form of moral suggestion.

Our subject is more intimately concerned with the special bearing of psychology upon the practice of ethical training. It is, therefore, not necessary to attempt a technical discussion of psychological theories beyond pointing out such general principles as serve our purpose.

One of the most clearly established psychological laws enunciates the direct connection which subsists between emotion and action. It has been demonstrated that not only does the quantity of the emotion determine the intensity of the action; but also that the quality of the emotion determines the nature of the actions. As a proposition, it would seem that this law barely requires stating. But while generally admitted in theory, it is commonly disregarded in practice. It is, however, abundantly shown in our daily experience and observation. As it is an important factor in the psychological basis of ethical training it calls for closer attention. We have already noted that the defect of the old method of moral instruction lay in the fact that it appealed chiefly to the intellect, and that this was the logical outcome of the assumption that to know the right was to do the right. That this assumption is still common among us is shown by the fact that many well-meaning people are working zealously to perpetuate the old method by establishing it more directly in our State schools. It is, therefore, necessary to reiterate the law demonstrated by psychology. Intellectual cognition cannot of itself initiate actions of any kind; much less can it initiate those complex actions classed as moral. Only when a cognition calls forth an emotion can action follow. And this action is not the result of the cognition, but of the emotion. The nature and intensity of the action does not depend upon the quality and quantity of the cognition, but does depend upon the quality and quantity of the emotion called forth. Psychology, therefore, provides us with the elemental principles that knowledge does not directly determine action; on the contrary, action is determined by feeling and emotion. Let us consider a concrete illustration. An explosion has occurred in a coal mine. Living men are imprisoned by the *débris*. A thousand workers throng to the pit mouth. Knowledge of the conditions is general among the group. Their daily toil has made them acquainted with all the minute details which go to make up the horror of the situation. Strong emotions are called into being. The desire to help a mate in distress is throbbing through each consciousness. These, and kindred emotions, would urge a simultaneous rush to the rescue. But emotions of a deterrent nature are also present. The rescuer must risk his life, and emotions of fear and self-interest arise. This man has a wife and family dependent upon him; and a quick imagination pictures what his death would mean to them. Another is the support of an aged mother. Dare he leave her destitute? The whole crowd is swayed by conflicting emotions. The rush to the rescue does not take place. But here and there a man steps out from the crowd—"I will go," and "I," and "I." Twenty men out of a thousand offer themselves. In what respect do the twenty differ from the crowd? Not in knowledge; for practical knowledge of the conditions is equally open to all. The line of divergence lies, not in superior knowledge, but in superior emotions. In the minds of the twenty the altruistic emotions were stronger than the egoistic emotions. And that fact determined their conduct. Many and varied were the causes which led to this dominance of the altruistic emotions. A few of the men may have inherited a stronger sympathetic mental constitution. Others have loved relations, or respected friends imprisoned in that house of death, and the mental concepts of these call forth still more complex emotions, which, uniting with like impulses already present, determine the nature of action, in spite of strong counter emotions prompting to self-preservation. The experience of each of us provides similar illustrations. All serving to show that no amount of knowldge, *per se*, will determine a man's action in any given direction. And emphasising the fact that emotions, good or evil, determine conduct.

Ethical training, therefore, is resolved into a training of the emotions. And in no branch of the teacher's art is such careful and sincere thought called for as in this. The emotinal responsiveness of a child's mind varies greatly. The individual capacity to benefit by the best training is ultimately dependent upon inherited qualities. But even the least promising can be wonderfully influenced by right methods. On the other hand, wrong methods may not only be unfruitful ethically, they may actually be harmful.

Imagination will play an important part in the training of the emotions. In a young child this faculty is very strong. Through it the latent sympathetic emotions, which are at first dormant, may be awakened and strengthened. These emotions will result in conduct marked by kindness and consideration. Conversely, through the imagination, savage instincts, which, in a young child are easily aroused, may be stimulated, resulting in conduct marked by callousness and cruelty. Let us take a concrete example. A class of children are having a first reading lesson; a primer is put into their hands, and they meet with the picture of a cat springing upon a mouse. The teacher talks to them about the picture, thus arousing their interest in the chase. The writer of this paper has seen a Government Inspector call out two children in order that one, simulating the actions of the cat, should first crouch and then spring upon his prey, the prey being represented by the second child. This was done to rouse the "interest" of the children in the subject matter of their lesson. At first sight the objection to this may seem a quibble. It may be argued, the cat and mouse incident is a familiar one, and not on account of its cruelty, but on account of its familiarity is it chosen. But Professor Bain, who is no mean authority on this subject, has this remarkable passage in his "Education as a Science," page 224:—"Predatory pursuit excites from our earliest years; and any interests embodying it will waken up the feelings, and exercise the imagination in a blood-thirsty chase; thus enlivening the dull and dreary exercise of learning to read and spell." And he goes on to suggest that a cat's torturing play with a mouse before eating it, is, to the child witness, "one of his rarest treats," and, therefore, because it is blood-thirsty and cruel, he recommends the subject as one suitable to the infant mind. Professor Bain is correct in his statement that such stories will create a lively interest in the child's mind. This is because savage instincts are easily aroused in the young. These emotions were suitable to barbaric social conditions. They are unsuitable to present society, and to introduce them in order to make an effort of the intellect more agreeable is a deliberate sacrifice of the moral nature to intellectual culture. A reading lesson given on scientific lines will not be "dull and dreary." The necessary intellectual effort it calls forth ought to afford pleasure. But granting that learning to read is inevitably "dull and dreary," such a subject as the cat and her kittens would awaken interest, although of a different kind from that recommended by the Professor. Sympathetic interest will exist between beings having similar experiences. Kittens love to play just as children do; kittens have a mother to care for them as well as children have. In the first instance a stimulus is given to the bloodthirsty anti-social instincts, which, for the welfare of modern society should be discouraged. In the second an interest in subhuman life is stimulated; and emotions are called forth, which, later on, will tend to the kind treatment of all sentient beings.

Stories about the fierce carnivora, in which their savage traits are portrayed, are ethically unsuitable subjects for children's reading lessons. A little six year old girl said the other day, after reading one of these lessons, "Stories about wolves make a little child nervous in the dark." They arouse the undesirable emotion of fear, and tend to the inculcation of cowardice.

This criticism will not be considered trivial when we remember that there is only a limited amount of nervous energy stored up in any individual. If that energy is expended in calling into force an emotion which is useless or harmful to the organism, there is a correspondingly smaller amount of energy which can be used to bring into activity emotions which would be beneficial to the individual himself, and to the society in which he lives.

Object lessons again are channels through which the young receive ethical or unethical stimuli. Let us take an example: Two teachers are giving a lesson on an egg to classes of small children. They will each begin with the form and structure of the egg. Then one teacher will pass on the uses of an egg. That is, to the usefulness of the egg to man. We eat eggs; they are boiled, fried, put into puddings and cakes. The other teacher ignoring the culinary value of eggs, passes from a consideration of their form to a consideration of their life history; and unfolds before the children a chapter in biology more wonderful than any tale of fairy or wizard. The young imaginations revel in this magic story of transformations, and a tender emotion towards bird life springs up in every child mind. Two psychological effects have been obtained. In the first place the stress laid upon the use we make of eggs is a direct appeal to the strongest form of child selfishness—namely, that which has to do with gastric activities. And the psychological result of such a lesson must be to strengthen the egoistic emotions which would regard every phenomena from the vulgar standpoint of personal advantage—emotions which inevitably tend towards selfishness and cruelty. In the second lesson an interest has been awakened in a form of life which differs from the human form, and that interest is quite independent of any advantage man may derive from bird life; it is, indeed, the sympathetic result of perceiving the beauty of these little creatures' lives. Little children are naturally very self-centred, and every time their interest is fixed upon something outside themselves this self-centred mental condition is weakened. In other words their natural selfishness is repressed, and a stimulus is given to altruistic rather than to egoistic emotions. Ethically this second lesson is a good one.

The practical use of eggs comes fittingly in a lesson on cookery or domestic economy. Then the child's intelligence is engaged in learning something which will be useful at home, and the emotions are correspondingly healthily exercised.

As everything which enters into a child's environment tells for or against a proper training of the imagination, and consequently emotions, story books are of great importance. Let us notice their influence upon the growing mind. An intelligent child of six years, alert and eager to know life, receives a volume of fairy tales. It is highly coloured and grossly sensational. Here for the first time he meets with Bluebeard, Jack the Giant Killer, Jack and the Beanstalk, Ali Baba and the Forty Thieves. He is thrown into a world of wonders far removed from the scenes of actual life—giants and fairies, bold warriors and lovely ladies, cattle and forests, and a goose which lays eggs of gold. All these mix and mingle with the facts of everyday life, and out of this queer medley the little fellow draws his happiness and shapes his conduct. Imagine the ethical result of such a mental experience? Our children are the descendants of a long line of barbaric ancestors. In them lie latent instincts of cruelty, hatred, revenge, treachery, and cunning; qualities which were useful when our progenitors were fighting their way towards consolidation, freedom, and peace, but which are harmful to modern society. Ethical training requires the repression of these anti-social instincts, and the stimulation of more moral emotions. We know that by exercise an organ becomes strong and supple, and that by neglect and disuse it dwindles into powerlessness. This organic law determines the method of ethical training. The undesirable anti-social instincts must be persistently ignored, and the cultivation of the opposite ethical emotions increasingly carried on.

After reading Ali Baba, a boy's mind is full of shifting scenes which call into play the most barbaric instincts of his nature; emotions of greed, cunning, and revenge alternate with thoughts of bloodshed and cruelty. He draws a mental picture of that delightful cave filled with the plunder of the forty thieves, from which Ali Baba helps himself so lavishly. He enters into the spirit of that little scene at home, where the robbery is called "good luck," and Ali Baba's wife gloats over the plunder and counts the money piece by piece. Cassim's misfortune would lead an imaginative boy to try to picture a man killed and quartered. The child's fancy being stimulated by such details as "when Ali Baba reached the cave, he was surprised to find bloodshed outside the door." Ali Baba's horror at discovering the mangled body of his dead brother did not prevent him from seizing more plunder. It may be sad to lose a brother, but it is splendid to find gold. The little reader learns all this by implication, and, with the unquestioning faith of childhood, thinks it is all as it should be. Later on comes a double intrigue, in which cunning is matched against cunning, and revenge is the emotion stimulated in the mind of the boy. He delights in the clever Morgiana, as she outwits the robber chief, who by cunning has obtained a hot supper and good bed from Ali Baba. The cruelty of her deed, and the lies she tells, escape all notice, because the instinct of revenge is satisfied. The last scene is facinating; bright lights, festive music, a gaily dressed dancing girl, who suddenly stabs her enemy. Then comes her reward, culminating in marriage. The whole story is a powerful chapter from the gospel of hate. It belongs to the barbaric period of our history, and its tendency is to call into activity those anti-social emotions which should be left to perish through disuse.

Jack and the Beanstalk may be taken as a further example of a distinctly unethical story. The hero pleases himself, disobeys his mother on every occasion, and eventually leaves her broken-hearted. Yet nothing but good results from his behaviour. After a life of exciting free adventure—killing giants, and being petted by fairies—he settles down in adult life, a worthy and estimable man. Emotions of disobedience, disrespect, callousness, selfishness, and deceit, are called into activity. Further elaboration is unnecessary, beyond noting how all this indirect training conflicts at every point with the direct teaching the boy receives. At home, in school, and in church he is told to love his enemies. To do good to those who hate him, and never, under any circumstances, to seek for revenge. He is told that lying is a sin, that the prison awaits the thief, and unhappiness the disobedient. But these facts are imparted more or less as moral maxims, and in the form of an appeal to the intelligence, whereas the unethical influence of his story books is a direct and delightful appeal to the emotions. We must reverse all this, and train the young through their imagination to truer relationship with the society of which they are members. We must eliminate from their environment all artificial stimuli to latent anti-social sentiments, and in their place we must substitute natural stimuli to those emotions best fitted to modern life.

The enchanted realm of nature can be made more delightful than the wildest fairy tale, and its portals stand invitingly open to the young intelligence. Lead him to see and to seek the wonders which lie hidden in the life story of the humblest plant, or the lowliest insect, and you will surround him with a glamour exceeding in glory all the fairy tales that ever were told; a glamour which the coming years will only deepen. Moreover, along with truer perceptions of the life around him, and of his relation to that life, emotions of an ethical nature will be stimulated, and the foundations of a moral character established.

What applies to the elementary stage of ethical training applies with equal force to the more advanced stages. In every case, even in the most complex, direct appeal must be made to the emotional nature. Nor is this so difficult as it appears. If from their earliest childhood children have been subjected to an ethical training of the emotions, they will respond naturally, and ethically, as an ever increasing data bring more complex stimuli. Let duties of self control and self respect, of patience and perseverance, of courage and truthfulness, be emotionally enforced. By constant care, let the latent tendency towards these virtues be kept in full activity, and the counter emotions as constantly repressed, and at last will come a time when the children will show a tendency to become automatically self-controlled, patient, truthful, persevering, courageous. This is the dawn of true morality, which is spontaneous and natural. The truly moral agent is unconscious, not only of any compulsion from without, but also of any compulsion from within. The sense of duty no longer painfully urges him along the right path. He acts ethically without effort, because he acts naturally. This is the ideal state which George Eliot dimly foresaw as the state in which it would be as natural for a man to do right as it is now for him to grasp some object when in danger of falling.

When children have arrived at this mental condition with respect to the elementary emotions, right actions with which these emotions are concerned will be performed with the minimum of expenditure of emotional energy, leaving a reserve of energy to be expended in stimulating the emotions upon which depend the more complex ethical functions, kindness and thoughtfulness for others, finding expression in relation to members of their own families; then extended to immediate acquaintances, then to fellow citizens, especially to the less fortunate members of society, the poor, the sick in body, and the sick in mind. Every consideration of work and duty must be approached through the delicate avenues of the emotions. And for a long time this will require the persistent care of the teacher. Nor should this stage be left until the children show by their general conduct that the required emotions are becoming less and less dependent upon objective stimuli. Spontaneous acts of kindness and consideration towards human and subhuman creatures, conscientiousness in the discharge of daily duties, and thoroughness in completing their tasks, are unmistakable evidences of a still more complex morality.

When this stage is reached we may proceed to create or deepen an interest in social, national, and international affairs, and in the material, artistic, and moral achievements of mankind in the past. Here history and biography, myth and legend, supply rich stores of illustrations for the use of the teacher, and the delight of the scholars. A series of illustrative ethical stories, historic and legendary, have been compiled for the use of teachers, by Mr. F. J. Gould. That these books are largely used in England, points to the fact that scientific ethical training is passing from the theoretical to the practical stage. The scholars should be encouraged to cull for themselves other examples from the records of daily life. For it is well that we should become permeated with the conviction that the good, the brave, the true, the generous, are not all dead. Many are alive to-day, and we may join their ranks. These examples will be brought before the notice of the children, who, assisted by the teacher, will classify them according to the several emotions expressed by the respective actions. This was a generous action. Why? That was a wise action. Why? Here the critical faculty, which has been growing with the growth of the intellect, enters into more definite association with the emotions. It becomes, in fact, their valuable agent.

This method of filling the mind with emotional concepts has a profound psychological justification, which must be noted. Preceding any volition we must have a "conception" of one or more courses of action capable of securing some desirable end; this end being already represented emotionally to the mind. Following the conception comes a period of "deliberation," during which conflicting emotions are presented to the judgment, and compete for acceptance. The deliberation culminates in a "choice" of some possible course, either to do, or not to do, and the mental process passes into action or inhibition. It is during the period of deliberation that the moral nature of the agent asserts itself. If by early training the mind can be educated to feel strongly, and with wide sympathies; if it can be inspired with active desires to play a useful part in society; then there will be a persistent tendency for these desires to be always presented among the competing emotions which ultimately determine the choice. Moreover, the attention of the individual will be repeatedly directed towards those actions of himself and of his fellows which he recognises to be in accord with these desires.

Thus there will be formed a group of elements habitually entering into every deliberation—a group which will always be favourable to right conduct. Hence it is of paramount importance that we should give the young correct reasons for their conduct, instead of the arbitrary and irrational reasons too often given. It is essential to teach them to explain their actions, and to show in what respect they conform to general ethical principles. The knowledge of rational choice and coherent action gives satisfaction, and a sense of stability of character, which strengthens the feeling of personal dignity in the individual.

In weak and simple minds actions follow almost immediately upon impulses. The mental processes do not reach much beyond proximate desires. Our object will be to produce minds imbued with the widest possible range of sympathetic emotions, so that the conception of any desirable end will call up such a complexity of motives, that the choice of action will be delayed; and the process of deliberation will take in so wide a range of data, that calm judgment will become the normal mental condition—a condition which is universally regarded as the best guide to right action; a condition, moreover, which supplies the individual with a very definite pleasurable satisfaction in the attainment of moral ends.

A psychological system of ethical training requires that some attention should be given to the subject of rewards and punishment. In this paper we can only scan briefly the merest outlines of these important factors in ethical training.

Let us glance at rewards. They exist in various forms and degrees. We will take the simplest and most popular form, that of indiscriminate praise. In a Birmingham State school an inspector was holding an examination in arithmetic. Before him was a group of seven year old children. After time had been given for the working of their sums, he called for a show of slates and went round the class drawing a chalk line through every error. Children who received no chalk mark on their slates knew that they had passed, and all were anxious to succeed. On finishing his round, the inspector ordered all marked slates to be held up, and all unmarked slates to be placed on the floor. In one corner of the group four unmarked slates were held up. "You have passed," said the inspector, "put your slates down."

"We have failed, sir," came the answer. "One sum is wrong." On further examination this was found to be correct. In going round the class the inspector had, accidentally, omitted to look at these sums. During the show of slates the children had been able to compare their answers with those of the others, and, without any hesitation, had owned up to their failure. The inspector began praising them for their honesty. The teacher asked him to desist. "Honesty," she said, "is the normal condition of the class. We are shocked when it fails to be acted upon. To praise these four children would be a tacit insult to the character of all the others." This incident took place in a slum school. The majority of the children who attended it were surrounded by some of the worst results accruing from the overcrowded, underpaid, sweated conditions prevailing in the industrial centres of the Old Land. Two of those children lived in a street through which policemen were forbidden to walk alone, the regulations requiring them to patrol in pairs for mutual safety. Daily contact with a young teacher of ethical principles, and some knowledge of psychology, had taught these little ones to walk uprightly among their fellows. This teacher had created for her scholars an ethical atmosphere in which the elementary virtues were persistently regarded as normal, and the unethical tendencies as abnormal. There can be no doubt that public praise for ordinary moral conduct is detrimental to ethical progress, because it implies that such conduct is unexpected. Praise should be reserved for special occasions.

The natural emotions are the only healthy stimuli to ethical growth. They may be classified under three heads: First, there is the functional pleasure experienced in the acquiring of knowledge. If this emotion is not present, if, on the contrary, the child shows indifference towards or distaste for his lesson, something is wrong. The intellectual faculty has been overstrained, or he is ill, or the subject presented is not suited to the stage of mental development he has reached, or it is not presented in a fitting form. The acquisition of knowledge, under proper conditions, is always pleasurable. In the second place there is the gratification experienced in applying knowledge already acquired, and in the third, the pleasure of earning the approbation of teacher and parent. In other words, of giving pleasure to persons who are loved and respected—an emotion which has its foundation in affection, and which differs essentially from the vulgar love of applause. We pass on to note that the system of prize-giving is injurious in two ways—one negative, the other positive. By diverting the attention from the emotional pleasures which are the normal reward of effort it prevents the formation of an important association of ideas; and by creating a desire for something over and above the natural reward of effort, it gives rise to an artificial craving. The boy who crams at school, triumphantly beating his classmates, and who brings away with his prizes a more or less disguised contempt for knowledge, has received a serious ethical blow on the threshold of manhood. Gifted with a retentive memory, or with abnormal powers of application, he has succeeded where others have failed, and glories in his success, without feeling any sympathy for those he has beaten. The selfish egotism of youth has been strengthened; the feeble altruistic sentiments have been repressed. The prizes may be placed upon the parental shelf and soon forgotten; but this stimulation of the egoistic emotions at the expense of the altruistic, may leave results, which, in after life, will tend to make that boy an indifferent friend, a selfish husband, a careless father, and a citizen who puts the consideration of personal advantage before the higher consideration of civic duty. But the harmful results of prize-giving do not end with the prize-winner. In a class of forty boys, let us suppose that half the number possess nervous, excitable temperaments, while the other half possess lymphatic temperaments. The former are thrown into an excited state of keen pursuit, by this competitive system of prize-hunting. The instincts of the chase are aroused; they work for that alone. Their intellectual horizon is narrowed; they are receptive of nothing but what relates to the prize; and when success attends the efforts of one of their number, the nineteen unsuccessful nervous competitors, lashed by disappointment, are secretly suffering from jealousy and envy. The twenty lymphatic boys, constitutionally incapable of sustained nerve strain, have been discouraged from the beginning. Their emotional tendency of languid indifference or hopeless self-depreciation has been strengthened. Instincts have been allowed to dominate which will tend to make these boys develop into craven-hearted, dependent men, incapable of meeting the complex responsibilities of adult life. If the object of ethical training be the cultivation of all the generous and pleasurable emotions beneficial to social life, and the repression of all the mean, selfish, pain-causing emotions detrimental to social life, then we must remove from our schools not only prize-giving but every other form of artificial stimuli, substituting in their place the helpful stimuli of natural emotions. We can do this in the full assurance that we are not only removing obstacles, but are also placing stepping stones in the upward path of national morality.

The same general principle holds true with respect to punishments. Natural not artificial means of correction must be employed. If a suitable environment has been created for the cultivation of the ethical emotions, temptations to wrong doing will be greatly reduced. Unethical conduct is frequently the result of an unethical environment. When it occurs in an ethical environment it is a manifestation of emotional unfitness on the part of the transgressor. To punish him for this unfitness in any arbitrary way will be likely to arouse feelings of resentment, defiance, or self-depreciation. Emotions which will tend to make him more unfit. If a boy tells a lie how can a thrashing, or an imposition, or the loss of a holiday, or a diet of bread and water make him tell the truth?

The lie is a manifestation of an emotional condition out of harmony with his surroundings. As long as that condition continues he will be untruthful. The condition must be altered. He must be made to experience the emotional pain resulting from being distrusted and suspected by his fellows. Only an emotion can counteract an emotion. If necessary, take him before the class, discuss the matter openly with his schoolmates—"This boy cannot be believed; statements he makes we must verify for ourselves," &c.; and this not done in a cold critical manner, but with a sympathy which the culprit must feel. When he shows signs of remorse, put him on social trial for a given period. If, during that time, under the constant supervision of his fellows, he is truthful and sincere, he can be fittingly reinstated among the honourable members of the community. He, too, can be trusted.

Punishments of an arbitrary nature are essentially vindictive, they express in one form or another the spirit of revenge, and are absolutely unethical in tendency. Remedial punitive measures are alone psychologically justified. They require to be administered firmly and openly, but always with sympathy towards the offender. This does not apply to congenital criminals, who require special treatment, and should not be allowed to mix with normal children.

All this implies such an appalling amount of work that the "practical" teacher may well exclaim, "It is Utopian, and unworkable." Under present conditions it may be impossible to give a thorough ethical training in our schools. That constitutes the strongest argument for altering the conditions. Under our present system too much nerve energy is directed towards intellectual activities, and this results in a general starvation of the emotional centres. Our children suffer physically and morally from this one-sided method of education. They need less time spent in instruction, and more time devoted to training. The majority are rushed through a series of subjects, as if the one idea was to discover how much the memory of a child can carry. Wearied with the pursuit of knowledge, they cease to follow her as soon as the objective restraint of the schoolmaster is withdrawn, and for the most part settle down in adult life undisciplined in emotions, and confused in intellect.

We need to recognise practically, as well as theoretically, that "to be" and "to do" are greater than "to know." The application of psychological laws to education will then have far-reaching results. We have already stated that a common ethical ideal is needed for progressive social life. In addition, we need the formulating of an ethical educational ideal which will serve as a guide to the emotional training of the young; and, above all, we need the psychological teacher. General scientific knowledge is desirable in a teacher; the knowledge of psychology is an imperative necessity.

When a psychological basis of ethics is universally established in our schools then will our teachers rise to the dignity of their calling. Ceasing to be merely instructors, they will become, in truth, the educators of our children: the living channels through whom a nation will be trained to be strong in body, keen in intellect, ethical in emotion, fitted to fulfil the functions and to enjoy the pleasures of a complete human life.

6.—INCIDENTAL EDUCATION.

By D. R. McCONNEL, M.A., Director, Brisbane Technical College.

It is difficult to find a term to convey accurately the idea which I wish to present. "Incidental" has somewhat a meaning of uncertainty. But there is a principle involved which is, I think, a psychological law. Another term expressing the idea fairly well might be borrowed from a sister science; we might say "induced" education. But "induced" conveys the meaning of purpose and effort, and describes the process from the teacher's side. As I am dealing with the pupil's side, I shall retain "incidental." The idea needs only to be expressed to be at once familiar. It is that process of education which goes on involuntarily in the child, of which the child is almost unconscious. Through the thousand little activities of the day, so important as they seem to him, so important as they really are, and as his activities bring him into relation with others of his household world, he learns his place, truthfulness, fortitude, punctuality, even affection, or the expression of it. What he learns, of course, depends upon those around him. He may learn, woe to him, the opposite of these virtues. But what he learns of these things, and of many others, he learns incidentally alongside his main life. His reasoning is incidental. The same principle underlies, of course, the kindergarten, though I have not seen the term definitely used in connection with kindergarten work. The child plays with his coloured beads and strips, and incidentally learns number, colour, form. The virtue of the kindergarten is that the child learns while playing. Now there is a host of things that a boy learns at school which are incidental to his school life, and apart from his books. He learns to respect, certainly his superiors, possibly himself; he learns courage and ambition in his games, if not in class. So much so, indeed, that it has been one of the most persistent faiths of England that a boy does not go to school to learn knowledge so much as how to behave in the world among his fellow men. Knowledge, if it comes, is said to come afterwards. This faith of the English parent may not be so far from the truth after all, at least for the average boy, or the boys below the average. It may be well founded on experience, that is possibly not the boys' fault. This widely held idea of education among Englishmen is probably the common-sense recognition of the very process of incidental education to which I am referring. Average boys are, after all, the boys that will become the most numerous kind of men. The rarer, intellectual boy will learn under any circumstances, or in spite of them. But cannot the average boy be made to gain much more knowledge than he usually does at school by an incidental process applied in school subjects? And how far can the process be applied? If we consider our own adult knowledge, we shall be astonished to find how much has been learned by incidental processes. The important things of life, when we think over them, have been mostly learned incidentally, in the vast recesses of our experience.

What has brought the idea of the application of this process irresistibly to my mind has been a short visit among educational institutions in the United States. There, if anywhere, education is a living, almost a palpitating thing. In studying it and reflecting on it there has grown in me an almost subconscious realisation of some principle, evolving, not yet expressed in words, but finding expression in practice. Among such keen observers and experimentalists as the Americans it would not be surprising to find the evolution of ideas in education as close to Nature as those of Pestalozzi. In Honolulu, under American Government, I found an education in its first stages almost incidental. That is to say, round some mental process, in itself attractive and comparatively easy, more difficult learning is linked. The main occupation is observation of natural phenomena, always delightful to a child. The life history of wasps, mosquitoes, bees, and other living things, is closely and accurately observed. Incidentally, the children learn drawing without copies, writing without copy-books, expression without grammar, and Nature study without books, and learn all these things admirably, and with marked individuality. I did not find a hand written like another in the school, yet I saw no bad writing. Indeed, the writing was exceptionally good, and personally expressive. Even sums are contrived to be linked around the persistent inquiries of a child's mind, such as why floor matting is joined lengthwise down the room instead of across. Here is a principle with prodigious results in its application. The process is absolutely natural. And is not the discovery of natural processes the end of all our inquiries as educationists? I do not mean to suggest that the incidental principle is to be pushed to an extreme. There are times, later on, when the direct application of the learner's mind to acquiring knowledge, the learning of which is, perhaps, distasteful, is good discipline, as well as necessary acquisition. But would it not be an immense advantage if at least the earlier processes of education gave pleasure instead of arousing dislike? Would it not be better to recognise right out that the methods common in schools are unpleasant to many children, and to many a tiring effort, and kindle in some a positive hatred of school and all that belongs to it? And are not the minds thus affected sometimes the most valuable, because most individual and most perceptive?

One application of the incidental principle in the case of adults I met also. The method had flashed upon the teacher, a very able man, after many weary efforts and failures. He had come across that stumbling block known so well in night technical classes, even in America, the mechanic who has left school at the minimum school age, and after two or three years wakes up and wants to learn about his trade. The particular mechanics in question were engineers, like any others, shy, diffident, anxious, easily frightened off, and lost. How in heaven's name to get these men to learn mathematics and applied mechanics, and to go on learning them, and how to get—the city was Chicago—more than a dozen to attend? Here was the stroke of genius? He dropped the hic, hac, hoc, adhoc; mathematics disappeared—from view—and he taught engine. He had up a model on the platform. He let the men alone, and talked to the engine. He took it to pieces, he made his drawings, his plans, his calculations on the black board, discussing with himself and the engine as he went. After forty minutes he would say, "Now, men, you'll find a man in the next room who will tell you how that's done." They had another forty minutes there. In six months the men had learnt all the mathematics and mechanics they needed, and did not know they were learning one or the other. In two years the college had not rooms large enough to hold the hundreds of men—men, not boys—who wanted to know about engines. That instructor—no, not instructor, master-teacher—is now head of all the night work of the great Lewis Institute of Chicago, and I left him firmly convinced that the method could be applied all round. This is incidental education. It is applicable at least to early education, and later in beginning a new study. I have tried to express the principle as I have gathered it among those American enthusiasts, in the belief that there is value in it, and in the hope that this expression of it may arouse some thought or trial among co-educationists in Australasia.

7.—THE SCIENTIFIC STUDY OF THE CHILD.

By A. W. RUDD, M.A., Principal, Clayfield College, Brisbane.

A Child Study Association has recently been formed in Brisbane, and the committee of that association are desirous that some attempt should be made to show what bearing the scientific study of the child has upon the subjects which are likely to be dealt with in this Section.

That is why I am reading this paper, but I cannot claim to speak with the authoritativeness and completeness which is begotten of exhaustive study. As a member of the Child Study Association, I am interested in the question of child study. I trust that I may succeed in interesting some of you.

Ever since there have been educational systems and educators the child has always been in a sense an object of study, but the child-study of to-day is different from what it has been in the past. You will have to look in the supplement of Webster's Dictionary to find the term. Child-study is carried on with considerable enthusiasm in America, and the psychologist Baldwin goes so far as to say that it has become a fad to be pursued by parents and teachers who know little about the principles of scientific method. Even if that is so, it does not detract from the value of the work done by eminent scientific investigators, chief among whom is G. Stanley Hall, President of Clark University, who began his work in America a little over twenty years ago.

There is a British Child Study Association which has been in existence, I think, about ten years, with several branches in England and Scotland.

There was a Child Study Association in Sydney, but that has been transformed into a Parents and Teachers' Union. The subject of child-study is now referred to in the course of logic and mental philosophy prescribed for students of the University of Sydney. We may speak of the science of child-study as a new science, but it is for all that the product of older ones. From the sciences of physiology, embryology, medicine, psychology, and anthropology, we have learnt much about the child, but the facts culled by each science have remained as isolated groups, until by the new science of child-study they have been brought together to form a systematised branch of knowledge having reference to one specific object, the child.

The scientist pursues knowledge for its own sake, as well as for any practical purpose. Science is interesting as well as useful, and in the science of child-study we need not draw any sharp distinction between its purely scientific and its utilitarian aspects. As a pure science it is full of interest to the student, keeping him in touch with such sciences as physiology, psychology, anthropology, heredity, ethics, and education. As an applied science it is of especial value to the parent, the teacher, and the social reformer.

The newly-born child has a little over one-quarter its adult height, but only one-nineteenth part of its adult weight. In two and a half years it should have about half its adult height, and nearly one-fifth of its adult weight. As the child grows its parts do not grow in equal ratio. If they did, the adult, according to our notions, would be a monstrosity, with enormous head, long trunk, huge paunch, short arms and legs. The skeleton grows in weight twenty-six fold, the muscles forty-eight, the lungs twenty, the heart twelve, and the brain three and a half. The brain almost ceases to grow in size and weight before the age of puberty, but other organs, like the heart, lungs, and liver, keep on growing till old age. Man is not built like the "one-hoss shay." As children grow in height they cease to grow in weight; as they grow in weight they cease to grow in height.

Sometimes the bones grow and the muscles remain stationary, and *vice versâ*; then the child has growing pains. The legs grow faster than the trunk. Up to the twelfth year in girls and the fifteenth year in boys, a large part of the growth in size occurs in the legs, but after these ages in the trunk. In the leg the thigh often has the greatest growth; the lower part reaches its limit at about sixteen years, while the thigh continues to grow for at least three years longer. The forearm grows most slowly when height is increasing most rapidly. The growth of the child is not a steady, harmonious development, but it is a case of "here a little, and there a little."

The growing energy of one part is exhausted, and that part ceases to grow until it gathers a fresh impetus and forges ahead once more. There is a diminished rate of growth in both height and weight for about six years before puberty, beginning at the period of second dentition. Just before puberty, however, there is a great outburst of growth energy, which in girls precedes that in boys by about two years. Girls from thirteen to fifteen years of age are taller than boys of the same age, according to some American measurements, and at one stage girls are heavier than boys of the same age. The thorax becomes relatively broad and flat as the child advances from infancy to puberty, and at the latter age its circumference increases most rapidly. The circulatory system at puberty becomes more expressive—blushing, losing colour, change in rate of heart heat. All now occur in response to mental states. Length of face is the head dimension, which increases most rapidly at the same age, and there is a gradual increase in breadth of skull in boys from the age of fourteen to eighteen, and from twelve to fifteen in girls. The vascular system is exceedingly variable in its growth, and great changes take place at this time. Before the time of puberty the blood-vessels are large, and the heart small. After that time the heart is large and the vessels small. This enlargement of the heart is so great that it would lessen to a considerable extent the vital capacity were the reduction not compensated by the increase in lung power. The infant breathes at the rate of about forty respirations per minute; by the age of fifteen that rate has slowed down to about half that number. This is a meagre outline of some interesting features of the phenomena of growth—the explanation of many of which is still to seek.

Before we proceed further, it is necessary to refer to a theory which is regarded as fundamental by the votaries of the new science of child-study. This is the recapitulation theory of the evolutionist. The individual more or less repeats in his development, physical and mental, the chief stages in the development of the race. "Ontogeny is a recapitulation of phylogeny." This principle of recapitulation has been more prominently recognised in connection with the science of embryology. And, indeed, the argument from embryology was one of the most convincing proofs of the "descent of man." But the principle is now being extended further, in so far as it is held to apply to the development of the individual up to maturity. The individual is not fully grown till he he has reached the maturity of the adult. As there is a natural development before birth, so there is a natural development after birth, and the recapitulation theory gives us the clue to the procedure to be followed in the education and upbringing of the child. The babe is the most helpless of all animals, and the evolutionary process has brought it to pass that the child must learn to perform most of the acts which enable it to live. Its equipment of instincts is very incomplete. An animal's instincts take it safely through life—the child has a much greater capacity for learning, and this capacity takes the place of instinct. It has, however, like some of the higher animals, an instinct to imitate, and it makes great use of its power. In time, too, it has reason, which an animal, according to Lloyd Morgan, probably has not. "Reason in the child is a substitute for millions of instincts, each of which would need for its evolution and maintenance a separate process of natural selection." Years, however, must elapse before its experience and reason enable it to look after itself. Hence the post-natal period of development is necessarily long. The child is dependent upon the adult, and this has led to family life and ultimately to social life with all that is therein implied. It has much to learn, and requires a long time in which to do this. Its muscular equipment, too, is of little use at birth. Many animals can walk and procure food for themselves soon after birth. A child's muscular system must develop. That is why childhood is the period of play. Play, according to the recapitulation theory, is the repetition of acts which were necessary in the history of the race. Running, throwing, chasing, all the old fighting and hunting activities, are reproduced in the activities of the child. This conception has been used to explain many of the innumerable acts and tendencies to action which we notice in a child, by reference to the prehistoric and even to the (suggested) anthropoid and aquatic ancestry of man.

By its instinctive activities the child is developing its muscles and establishing muscular co-ordinations which will enable it eventually to look after itself. The child would die if it did not play. After birth the child is dependent upon those around him, and there are many problems which the parents, who are primarily responsible for their own child, ought to face. Usually they do what other people do. The child is reared according to the recognised methods, and at the usual age is handed over to the care of an educator—parent and educator henceforth being responsible for the welfare of the child. Whether their methods are right or wrong, probably neither of them knows. In some cases the child turns out all right; in other cases he does not. In the one case the result is due to his up-bringing, and in the other it is due to his inherent defects—physical, mental, or moral.

In some cases excellent results are obtained; in others they are most deplorable.

Now, the science of child-study asks:—May it not be possible to avoid these deplorable results, and build up a better social fabric by an education based on a systematic and scientific study of all the facts relating to the child that can be precisely and accurately ascertained?

Here are a few general problems which the science of child-study would deal with:—

1. How to feed the child so that it will derive the greatest benefit from its food, and, incidentally, what is the matter with the teeth of the rising generation?

2. How to clothe it, having regard to climate.
3. What amount of sleep does it require at different periods?
4. How to form correct habits in the child, what tendencies to check, and what to encourage.
5. What is the nature of the mental and physical growth of the child?
6. At what age should it go to school?
7. What should the child be taught, and what methods should be employed?
8. What are the periods in the development of the child, and what should be the treatment of it by the parent and educator during these periods?
9. How is its moral character best developed?—What are the characteristic differences between girls and boys, and in what respects should their education differ?

These problems are capable of indefinite subdivision, and an exhaustive study of the child must necessarily be difficult and prolonged.

The relation of food to health is but imperfectly understood. I suppose years will elapse before we have satisfactory knowledge on the subject. Nature leads the doctors here until they get more definite results from researches in physiological chemistry. We shall have to go on as we have been going for some time to come, but the question is worth watching by the student of the child, for the importance of proper nutrition cannot be over-estimated. Want of nutrition checks growth both in weight and height.

The physical development of the child is a matter of like moment. The muscular system comprises about 43 per cent. of the average adult male body. All muscular movements are controlled by nerve processes, so that there is an intimate connection between nerves and muscles. Every nerve impulse results in muscular movement. Even the mental states play upon the muscles, and the effects are seen in the twitch of a muscle in the face or finger, or simply in a change of muscular tension.

There are two systems of muscles controlled by the central nervous system. They are the visceral muscles controlling the functions of the viscera, the heart, lungs, intestines, &c.; and the skeletal muscles, producing the movements of the limbs, trunk, head, and organ of speech. The latter are under the control of the will—the former are not. When we speak of physical development, we refer to the development of these muscles. These muscles are the organs of will. Character, habits, dispositions, all we know of our fellow men, are inferred from the results of their muscular activity. Conduct, as muscular activity, is more than three-fourths of life. These skeletal muscles are classed as fundamental and accessory. The fundamental ones man possesses in common with animals; they are the muscles of the trunk, large joints, neck, back, hips, shoulders, knees, and elbows. The accessory muscles are those of the hands, face, tongue, speech organ, and eye. In the course of evolution these muscles are later acquired, and many of them are peculiar to the individual. They are associated with mental activity. Mental disorder shows itself in these movements, and they are liable to derangement by fatigue and excitement. Naturally the fundamental muscles must be developed first, and they are, as a matter of fact, up to a certain stage. The child's greatest efforts are put forth in using the muscles of his limbs, and trunk, and head, and it is a long time before he establishes control over their movements. It is some time before a child walks, and longer still before he runs. The development of the accessory muscles is not neglected by the child. It has hundreds of spontaneous movements which are quite sufficient for the development of these finer muscles of the fingers, feet, lips, tongue, hands, mouth, jaws, forehead, and face, and they are all developed without the excessive expenditure of nervous energy. The young child is exceedingly active, but its activities are prompted by its inherited instincts, and not compelled by any outside agency. The question for the child student is at what time may he take the child from his play activities and begin his work of instruction. The Queensland Education Department requires attendance at six, but provision is made in the regulations for the teaching of children of five years of age. As far as I can ascertain, authorities are not in favour of sending the child to school before seven or eight. Hall reluctantly says eight years. It is the accessory muscles which are used in school, and the development of the fundamental muscles is checked if the child is sent too soon. There is the natural retardation in growth at about seven or eight, and this seems to fix relatively the time for beginning school life. The rule of Nature is—the fundamental before the accessory. We must remember that, besides the checking of the development of the fundamental muscles by disuse in school, the use of the accessory muscles involves an increased expenditure of nervous energy, and an extra drain upon the blood supply, so that the child loses both ways.

Professor Scott, writing in the "Popular Science Monthly," with reference to reading and writing, says these acts require a more exact control of smaller muscles than any other act the individual is ever likely to be called upon to execute in after life. The eye is adapted for long sight when at perfect rest, and in reading and writing the plastic organism of the child does not feel the strain, but the result often is that the eyeball assumes the shape of the short-sighted eye. Professor Scott says, too, that the loss of nervous energy, necessitated by reading and writing at the ages of from five to eight years, is an unwarranted drain upon the health of the child.

Statistics are badly wanted in Queensland, but even without them I am sure no one can view with complacency the number of children who are compelled to wear glasses. Since the medical inspection of London schools, the out-patients' departments at the hospitals are unable to cope with the number of children who attend from the London schools with defective sight. A spectacled race, I am sure, is not desired, and it is about time we began to attend to the eye problem.

In the body of the male adult more than half the muscles of the body are connected with the legs, and it is obvious these do not get much exercise in school. Some parts of the body—*e.g.*, the ear, the tongue—do not grow by use, but the muscles do, and if the child is to grow it must do so by the exercise of the great fundamental muscles. The child's impulse to play and its instinctive self-activity is Nature's provision for the proper development of the great and small muscles during early childhood. I do not mean that nothing should be done with the child up to the age of eight years in the way of education. His education should be through his play activities pure and simple. Let him drink in knowledge from Nature and objects around him through the senses of sight, hearing, and touch, without recourse to books. Pleasant playgrounds with shady groves, where children may gather and play under supervision, form, perhaps, all the educational facilities children up to the age of eight years require. Perhaps organised games could be introduced for the development of the social and moral instincts. Children are naturally selfish, and if they can be taught to subordinate their own interests to that of the group, then their moral nature will be better developed than by going through the complex process of drawing a "moral" from a fairy tale, and applying it to their own conduct. By doing what is right spontaneously in games they may learn to do it under other circumstances, for up to the age of seven or eight morals are imitative rather than of a good conscience. Play, as a matter of fact, is necessary for the child of any age. The adult man himself is only too glad to be able to play. You have seen the delight even old men take in bowls, and generally when a man gets rich he buys something to play with, such as a billiard table or a motor car.

If work can be done with zest and pleasure, it becomes play, and one of the problems of education and life is to break down the distinction between work, as zestless toil, and play, in which it is significantly admitted by business men a man is at his best. Children are very conservative over their games, but I should think it would be worth while for the Education Department to gather information about games—both ancient and modern—with a view to introducing them into schools. There are, after all, very few good field games that are played, and those that are played are dependent often upon too expensive preparation of ground and apparatus.

After eight years of age a new period begins. Says Hall: "The years from about eight to twelve constitute a unique period in human life. The brain has acquired nearly its adult size and weight, health is almost at its best, activity is greater and more varied than ever before or than it ever will be again, and there is peculiar endurance, vitality, and resistance to fatigue. The child develops a life of its own outside the home circle, and its natural instincts are never so independent of adult influence. Perception is very acute, and there is great immunity to exposure, danger, accident, as well as to temptation. Reason, true morality, religion, sympathy, love, and æsthetic enjoyment are but very slightly developed."

Hall suggests that this period of childhood represents some stage in the remote ages when the young shifted for themselves, and when this age was the age of maturity. "Memory is quick, the senses alert. Never again will there be such susceptibility to drill and discipline, such plasticity to habituation, or such ready adjustment to new conditions. Reading, writing, drawing, manual training, foreign tongues and their pronunciation have now their golden hour. The method of the teacher should be mechanical, repetitive, authoritative, dogmatic." All this involves the training of the finer muscles, but the "inexorable condition precedent" of their development is the development of the great muscles. If a man learns to write by the use of the finer muscles, he can wield the pen rapidly and for any length of time only by the proper development of the great muscles of his arm.

The development of the body should still go on, and in this connection the respective merits of technical training, industrial occupations, gymnastics, arts and crafts, sports and games should be considered. Sports and games are probably best, not only for their physical, but also mental and moral effects.

With all this muscular development of early childhood there is going on at the same time the development of the brain. The brain weighs at birth nearly 14 oz., at maturity about 49½ oz. It increases between two and three fold in weight during the first year of life, about 10 per cent. more in the second year, a little more during the third, and in the fourth year it increases more than it will during all the rest of life, and has nearly completed its growth by the sixth year. It grows a little after eight years, but very slowly till twelve or fourteen. (Changes in structure, however, proceed; certain parts may diminish and others increase, and perhaps chemical changes may be characteristic of increasing age.)

By the age of fourteen the cells of the brain have about doubled in number. The number at that age is approximately 3,000,000,000. After fourteen it is doubtful if new cells are formed. They, however, grow in volume, and are developed out of granules, many of which never do develop.

These cells as the child grows become connected one with the other by millions of fibres, and they also form groups in the brain, each group undertaking a special function. Different parts of the brain are known as the motor, visual, auditory, tactile, and olfactory areas. Portion of the cortex is supposed to be the physiological basis of the mental processes involved in reason, and the perception of moral and esthetic relations.

The functional values of all parts of the brain therefore vary.

Dr. Hughlings Jackson, the English neurologist, has supposed there are three "levels" in the nervous system. His lowest level consists of the gray cells of the spinal cord and the medulla oblongata. This is the oldest level, being the first established in the brain in the evolutionary process. It controls the purely reflex actions of the involuntary muscles, those involved in the respiratory movements, the beat of the heart, movements of the intestines, and the secretion of the glands.

The intermediate level is a more complex arrangement of nerve processes. These processes control muscles which may be stimulated reflexly, but which may also be controlled by the will. Breathing goes on automatically, but I can hold my breath if I wish. I walk without conscious deliberation, play the piano, and perform numerous actions without any effort of will, though consciousness accompanies these activities. Complete co-ordination of muscular movements has been established, and control by will is no longer necessary. In early childhood the child acquires the use of many of its great muscles by conscious effort, but after a time many of its bodily movements can go on automatically, and its will is released gradually from exercising control over coarser muscular movements, and can begin to exercise greater control over those finer muscles which are used as the instruments of the higher mental functions. It is this level, then, which is developed before the age of seven or eight, and which has little to do with the higher mental processes. The child's muscular education must precede the mental. In a rabbit, for instance, almost the whole of its brain consists of a system of this level. The highest level is the organ of the higher activities of mind which are involved in conception, judgment, and reasoning. This level has itself been subdivided into layers. Some of these layers develop about the eighteenth year, and from this fact it appears that the development of this highest level has its proper period at the time of adolescence.

We often overlook the fact of brain growth and development and the fact that there is an accompanying development of mind. Dr. Clouston, Lecturer on Mental Diseases in Edinburgh University, in his book, "The Hygiene of Mind," says: "Any attempt to forestall Nature in developing the higher mental or moral qualities is apt to be afterwards followed by the paralysis of the qualities fostered by a forcing-house treatment." Hall's view of the proper treatment of the child from eight to twelve is, I think, contrary to the view commonly held. We like the child to think for itself. A child hates thinking because, I think, it feels that it cannot. It does reason early in life, but it is not forced reasoning; it never attempts to reason beyond its power. Hard thinking obviously is not easy for anyone, and hard thinking on an empty brain is not generally of much use. The mind must have material to work on, a great and varied stock of ideas, instantaneously obedient to the call of the thinker, and by the laws of association coming before his mind into the "wave of consciousness" from every point of his mental horizon.

It is at this age, from eight to twelve, that cells are growing and accumulating fast, and this fact is the physiological basis of a mental stock of ideas. The growth of cells necessitates a drain upon the blood supply, sufficient without an extra drain involved by too much hard thinking. Reason, love, true morality, religion, esthetic enjoyment all involve intellectual processes impossible without ideas and their associations. That is why I think Hall insists more on drill, repetition, memory, and dogmatic methods. See that the child gets ideas. This is by no means the final word on the matter. There is a big field for investigation in child psychology, especially up to the age of puberty.

It must not be forgotten that the brain requires an enormous blood supply. Each cell has a capillary near enough to allow it to absorb from the blood the nourishment it requires. The capillaries are more numerous and their walls are thinner than those of any other tissue. This means that the nourishment must pass from the blood vessels to the cells more quickly than anywhere else. The demand for blood in the brain is more urgent than it is elsewhere. Now only a certain quantity of blood is manufactured by the body. If blood goes to the brain in excess there is a diminished supply elsewhere.

Sleep is Nature's sweet restorer, and all children require plenty of sleep, especially if they are doing brain work. It is agreed by medical writers that the time usually allowed to the growing boy is too short. Dr. Clouston says that even up to the age of twenty the time for sleep should not be less than nine and a half to ten hours. How many boys working for scholarships and the Sydney Junior get that?

At the age of puberty a new life begins. We all know that the subsequent period is the critical time of youth. We know the unstableness of character, the uncertainty of direction in which it will develop, the difficulty of treatment. We know something also of its dreams, its deep desires, its emotional ferment, and its opposing tendencies. To quote Hall again: "Adolescence is a new birth, for the higher and more completely human traits are now born. The qualities of body and soul that now emerge are far newer. Development is less gradual and more saltatory. The annual rate of growth in height, weight, and strength is increased, and often doubled, and even more. Important functions previously non-existent arise. The range of individual differences increases. Some linger long in the childish stage, and advance late or slowly, while others push on with a sudden outburst or impulsion to early maturity. Bones and muscles lead all other tissues. Nature arms youth for conflict with all the resources at her command—speed, power of shoulder, thorax, hips, makes man aggressive and prepares woman's frame for maternity. Some disorders of arrested, defective, and excessive development and function are peculiar to this period, and every step of the upward way is strewn with wreckage of body, mind, and morals. Modern life is hard, and in many respects increasingly so on youth. For the complete apprenticeship to life youth needs repose, leisure, art, legends, romance, idealisation, and in a word humanism, if it is to enter the kingdom of man well equipped for man's highest work in the world." Hall pleads with us to cease to inject the youth with the fever of our life. You have heard what Hall says he requires, and we give him—examinations.

In truth, we do not know precisely all that we should aim at. Are we aiming to produce a Thiers, who at periods of his administration could work all day, and keep his colleagues' bureaux almost all night. He says: "At night my servants undressed me, took me by the feet and shoulders, and placed me in my bed, and I lay there like a corpse till the morning." Work like that at times is necessary, I admit, but only a sound physique can stand it. It, however, is not an ideal; its corollary is the brutal doctrine that a man is "done" at forty. Do we hold with Browning when he says: —

> Grow old along with me!
> The best is yet to be
> The last of life, for which the first was made:
> Our times are in His hands
> Who saith, "A whole I planned.
> Youth shows but half; trust God; see all nor be afraid.

Arnold said in his time:—

> Most men in a brazen prison live
> Where in the sun's hot eye,
> With heads bent o'er their toil, they languidly
> Their lives to some unmeaning task-work give.

Are we aiming at breaking through these brazen walls?

Our civilisation has very much that is unnatural. It requires little in the way of muscular development, and makes no imperative demand for a body of the utmost vigour. The use of machinery is reducing the necessity for muscular work in many departments of life; but bodily development is absolutely necessary if we are to get the best brain work. Galter, in his work, "English Men of Science; their Nature and Nurture," shows us that the great scientists were men of remarkable physical powers. Some could walk sixty miles in one day, and others hardly knew what fatigue was. I do not for one moment mean to imply that all our boys are overworked. I refer more specifically to the boys who go through the examination courses. I do say this, that our examination system, in which the pace is set by the university, is incompatible with the best development, physical and mental, of our youth. They are to do less as boys because they are to do more as men. He who overdraws at fourteen goes short at forty. University standards are being raised, and all subordinate ones likewise. Boys are still expected to get through scholarships and the university examinations at the same age as in older days, when the standards of examinations were lower. We are trying to do too much in a given time. We are so obsessed by the idea that all knowledge is good that we have not the courage to say of any particular branch of knowledge, "No, it does not matter about that. We want to teach the primary school child everything. The child cannot hug the universe." We attempt to teach the minutiæ of knowledge, and not the great fundamental impressive truths. The possession of a great idea is worth the knowledge of a thousand trifling facts. To hear the wind make music or to hear the music of the spheres is better than to know the technicalities of musical theory. A bird's-eye view of the great peaks in a panorama of the world's history is better than a knowledge of the changes in party government. Minutiæ are all right in their place, but the question is what shall a boy take away with him from school? To understand the great idea of evolution is better than to understand the anatomy of a butterfly. To know that trees have "tongues" is better than to know their botanical names. English literature, I hold, is not for youth a good subject for examination. The beauty of literature is felt in the blood and the heart, and such feelings are difficult to express, most of all by our youth. Feeling outruns the power of expression, and to be compelled to express kills the emotion. A cram in literature for an examination is one way of hardening a youth's heart. Youth should be supplied with great ideas and great ideals, and all literature should be ransacked for such. Books of golden deeds and biographies of knightly men should be available in abundance, but they are not—at any rate not in Brisbane.

We are not well disposed to admit that the deplorable facts in our civic life are the results of our educational systems. Why not admit these as well as the good results, so that we may know what we are fighting against, and what to avoid? We regard with fearful complacency things which blight our civic life. Half of our Statutes would be unnecessary if men were educated properly and really honest from within, or were allowed to be honest—honest enough for

Diogenes. Inspectors are everywhere except in the Departments of State. You have seen, for instance, the inscription over a butcher's shop. "All stock slaughtered under Government veterinary inspection." Now, that means that butchers are assumed to be too ignorant or too dishonest to be trusted with the comparatively simple task of supplying the public with meat. The milkman has to be watched, and this sort of thing is too typical of our industrial and social life. Our education is a failure if a pillar in society has the morals of the Merry Monarch, if a prominent statesman would rather not pay his debts, if a prominent citizen is the manufacturer of adulterated food. You all know Arnold's sermon on the text, "Wragg is in custody." Well, Wragg is still in custody, and how to keep her from going there we hardly know. The problem of moral education is still to be solved. The first essential, however, is to face, not to shelve it.

Shall we take life as we find it, and warp and strain the nature of youth to suit it, or shall we so endeavour to educate so that the result will be seen in a better social life—a life that shall satisfy a man's deepest needs and his best cravings, and which at the same time will inspire him to do his utmost for the welfare of the community?

The church hammers away at the adult with little effect. The State has all it can do to keep him straight. Why not try to do more with the child and the youth? He is plastic and mouldable, and responsive to the best influences if only we can bring them to bear at the right time and in the right way. I should have liked to touch on the question of the education of girls, but there is no time. This is not a medical congress, but I believe that if a doctor were here to speak on the question he could tell a sorry tale about girls and examinations.

We are supposed to be beginning a new era in education, and the flush of a new dawn is in the sky. But I submit we must know clearly what we are to aim at, and how we are to get there. One of the surest guides, I believe, in all sincerity, is an exact and complete knowledge of the strange, interesting, and lovable creature—the little child.

8.—A PLEA FOR THE AUSTRALIAN CHILD BODY.

By J. D. C. ELKINGTON, M.D.; D.P.H., Health Officer, Hobart.

Over fifty years ago Mr. Herbert Spencer made a certain famous classification of knowledges in terms of national value. He placed at the head of the list the self-protective knowledges as of most importance to the individual and to the race; then came the knowledge relating to the preservation and perpetuation of infant life. Last in order of value came the ornamental knowledges, the brain-decorative accomplishments to which the meaning of Education is limited in the minds of 99 per cent. of the public. Mr. Spencer took this classification as a basis for a bitter criticism of the educational methods of the day in English public schools. In following up the subject he pointed out that a student in another star endeavouring to arrive at an understanding of the British people in the nineteenth century from a study of the books used during their systematic introduction to the duties of citizenship, would be inevitably forced to the conclusion that they were a celibate and childless race.

Since Mr. Spencer's day a vast alteration has taken place in school methods and in pedagogic study. The study of the child brain as interpreted by many learned educationists, and not a few medical specialists, has become an integral part of pedagogic training. The newest product of a Training College will fire off abstruse psychological terms on the slightest provocation, and will demonstrate the Herbertian reasonings with excellent aptitude. The beauty of the child-brain bursting into blossom like a garden of flowers is a never-ending subject for rhapsody by any student of the New Education. With a little prompting the enthusiast will readily admit that educationists are the builders of the ship of the nation, and that upon the faithfulness and skill of their work will depend the safety and progress of the race.

Nevertheless, if one applies Mr. Spencer's classification to the curriculum and methods of teaching in almost any Australian school, the ornamental knowledges will be found to occupy at least nine-tenths of the available brainspace. A cynic may derive some quiet amusement from checking the school work against the morbidity tables of the local hospital. Anybody with the cause of Australia at his heart will rapidly doff his cynicism for quite another feeling as he recognises that during the eight years or so in which the youthful citizen is undergoing his initial preparation—or is starting his civic career, as many educationists will have it—he is given practically no instruction in anything which will tend to protect his body. As nine-tenths of these children will depend on their bodies, not upon their brains, for their happiness and success in after life, it scarcely appears reasonable to adopt the methods of the Stoic philosophers in preparing them for that after life. It is not economical—for example, all the clay modelling, the nature study, the Sloyd-work, the recessional hymns, the singing, reading, writing, arithmetic, English, poetry, geography, history, and other lessons which young Australia is apparently believed to require as a necessary equipment for fighting the battle of life, may be soon wasted by fatal typhoid fever for want of sufficient knowledge to keep flies away from his food. The knowledge could be easily taught as nature study. How many teachers can explain the peculiar utility of a fly's foot as an effective filth-transferrer, and indicate simple and effective means whereby it can be prevented from washing those feet in the milk-jug after a constitutional in a neighbour's closet pan? The girl who in a few years will produce her first young Australian will find her years of compulsory education of very little value in feeding and looking after that particularly helpless and easily damaged individual. It is useless to argue that such knowledge will "come to her by instinct." It will not, any more than dressmaking or playing the piano will.

Similarly in many other aspects of everyday matter-of-fact existence it is not admitted in practice that life is now an artificial affair, that the business of keeping the body in good working order must be learnt. The artificiality is freely taught, but not the means of overcoming its bad effects on the individual. The educationist is in very truth the builder of the ship, but he is putting in a vast amount of inferior material for the good reason that so long as the bolts and planks are of the proper official size and shape when they leave his hands, it is matter of indifference to him whether they be of good iron or wood or not. It is emphatically his business to insure that the material is as good as possible.

Herein comes the opportunity for that heartfelt protest which arises from teacher, parents, and Press whenever the systematic protection of the child body is mooted. "It is introducing a new subject," we are told, "and the curriculum is already too full. There is no time for any more." This may be readily admitted, but by applying Spencer's relentless classification cannot room be found for the higher knowledge by abolishing some of the less useful ones? Over 300 years ago the Emperor Akbar looked into the matter in India, and found that an unconscionable time was spent in teaching very little. He cut down school time by one half, explaining that the other half could then be employed in making the race strong and healthy, and acquainted with the real things of life. I am fully aware that this is heresy, that the most beautifully rounded arguments can be advanced to show that every subject in the curriculum is of greater necessity in nation-building than any other subject which can be suggested. My answer to this can be found in the vital statistics of Mr. Knibbs, and the morbidity returns of any Australian hospital. It can be found in full detail in the schools themselves, where children in thousands are being carefully trained to develop short sight and curvature of the spine, where the partially deaf are treated as "stupid" or "dull" where teachers pass their lives applying stereotyped psychological formulas to physical problems of infinite variation.

It will be urged that school buildings are erected nowadays on more or less hygienic lines, that physical development (of a kind) is being taught in many schools, that systems of medical inspection are being talked about in some States and have been actually applied in others, that teachers are instructed in matters relating to school hygiene, that elementary physiology and health and temperance are often taught to the children. It is all true, but the fact remains that teachers themselves as a class do not yet accept seriously and conscientiously the care of the child body, nor does educational officialdom so accept it. There are individual exceptions, and noble ones at that, but they are mere drops in the ocean of ignorance and indifference which envelopes the body of young Australia, that body with which he will make his individual living and live his individual lfe, and which may have to be used to protect Australia in a decade or two from now. If life were a succession of newspaper readings and parlour tricks, if disease were abolished, and accidents rendered impossible, if enemies could be kept away by a strong letter from "Constant Reader," and a mass meeting in a local town hall, if everybody were as good as they should be, and if the Golden Age returned on earth, the present methods would be admirable. Pending this desirable time, we might with advantage be practical, and give young Australia as good an opportunity as we can to grow up a broad-chested, keen-sighted, hard-fisted race, respecting its body, and better equipped mentally than is at present possible.

"The chief reason for this discrepancy between the ideal and the real is simple ignorance." It is heresy to accuse an educationist of ignorance as Professor Butler has done, but indifference would be a worse charge. Ignorance of the physical side of child life hangs over our educational systems like a pall, blotting out from thousands upon thousands of teachers the real object and value of their life's work. Operating a physically unnatural system—for all modern methods of education are of necessity unnatural—he makes no attempt to fit the delicate growing organism to its physical environment. That physical environment is an all-controlling factor in the development of the spiritual side, yet he takes no account of it, for he does not know how to observe it. So he continues for a lifetime to attempt to force impressions through eyes which cannot see, and ears which cannot hear, to reach brains somnolent and unresponsive from carbonic acid poisoning. Worse, he may punish the victims for the physical defects for which they are not responsible. Here are some observations made during an examination of a large number of school children before our Tasmanian system of Medical Inspection of State Schools was instituted. In all these instances the teachers were particularly skilful and experienced "educationists," really interested in their work.

A.B., age $11\frac{1}{2}$. Teacher notes: "Position low, improving very slowly, often complains of headache, not fond of work, very regular, well-behaved, dull." Condition found on examination: Eyesight $\frac{6}{10}$ both eyes, probable astigmatism, history of severe headaches, evident strain; hearing defective, history of mattery discharge and "sore ears;" health appearance bad, thin, frail, flat-chest; poor chest measurement.

C.D., age $10\frac{2}{12}$. Teacher notes: "Mental capacity medium, position low, no physical defects." Condition found: Filthily dirty, and insufficiently and raggedly clad; body and head verminous; eyesight bad ($\frac{6}{15}$ and $\frac{6}{10}$); post nasal growths marked; enlarged tonsils; defective hearing; lateral curvature of the spine.

E.F., age $11\frac{1}{12}$. Teacher notes: "Good mental capacity, regular in attendance, no physical defects." Conditions found: Eyesight $\frac{6}{10}$ lateral curvature of the spine; profuse discharge from both ears, and mastoid tenderness; treatment very urgently required.

In these, and scores of other similar cases, noted during the same series of observations, there was nothing to prevent any teacher possessing the most reasonable powers of observation from detecting the conditions found by the medical examiner. The only explanation is ignorance of the physical part of the child. It is useless to argue that these matters should be attended to by parents, for the only person intimately connected with the average child who is less observant of its physical condition than is the average teacher is the average parent. Since the inception of our medical inspection system the percentage of defective children originally reported by teachers, in our City schools, is steadily rising, a further proof, were proof needed, of the previous ignorance of such matters. It is also a satisfactory proof that such ignorance can be overcome with beneficial results to the children.

At the end of June, 1908, we "took stock" of the results of some fifteen months' work of the three medical inspectors in Tasmanian State schools. Tasmania, it will be remembered, possesses certain natural advantages which would *a priori* lead us to expect that her children would be physically superior to those in most other States. Definite comparison is as yet impossible, as in no other State are comparable data yet available, but the results are amply sufficient to set every conscientious Australian teacher thinking. Tasmanian children are as healthy looking as any other young Australians, they show as good a proportion of chubby red cheeks, and sturdy limbs and bodies as would be found anywhere else. Probably they are as healthy and sound as their brothers and sisters in any other State.

Yet, out of 11,287 children examined, 4,158, or 36·83 per cent., were found to be physically defective to an extent which was either actively interfering with their educational progress, or would, in all human probability, so interfere with it in the near future. This estimate was arrived at on no arbitrary basis, but from the independent and closely checked observations of three specially skilled medical officers working on a definite system with definite and lenient standards.

A special examination was made of 10,136 of these children to avoid "selection" influences; 2,116 (20·88 per cent.) were visually defective in some degree, 973, or 9·59 per cent. being defective to an extent actually interfering with educational progress. These latter could not read ordinary blackboard writing from back seats, or could do so only with much strain. Boys so affected could not learn service rifle shooting until fitted with proper glasses. Nine hundred and fifty-two children were deaf to an extent interfering with their educational progress; 1,956, or 19·29 per cent., were suffering from post-nasal growths to an extent interfering with their educational progress. Every one of all these could be readily detected by teachers by simple and effective means, if they knew how, or cared to know how.

Of the whole 11,287, 142 suffered from dangerous suppuration in the ears; 100 had pronounced curvature of the spine; 71 were mentally defective; 149 had pronounced anæmia, 66 had other serious defects easily recognisable by teachers, and of great moment to their health and success in life. The teeth were so uniformly bad that a clean sound mouth was a rare exception.

Is this the kind of young Australia which our gigantic system of free secular and compulsory education is striving to develop? Much of it is directly traceable to school conditions, to the Australian school system which in the past has striven so hard to exclude everything which has to do with the body and its needs. It is for the perpetuation of this condition of affairs that those strive who cry out against the introduction of medical inspection of schools on the score of expense and lack of time, whilst Australia's education bill for ornamental subjects piles up at the rate of many thousands each year. It is for this that those alleged educationists strive who grumble about the introduction of a "new subject," that cult of laziness, of ignorance, of indifference to their stewardship.

In the name of common sense let us Australians look this thing in the face, and admit our past faults, with a view to future improvement. New school buildings are of little avail if teachers will not, or cannot, manage them properly. Their management is a technical matter which must be learned. New pedagogic methods are largely waste of time unless the physical material on which they are to be used is first brought into a reasonable condition of receptiveness. The waste of school time arising from unrecognised physical defects is enormous. Book knowledge and parlour tricks in frail or defective bodies are of little avail in these days of hard competition and strain. Life is artificial, and children should be taught, above all other knowledges, how to live it in reasonable physical comfort and safety. The protection of the body is merely applied common sense, expressed in simple physical terms, that of the bodies of others is the application of the "golden rule" in similar terms.

If the educationist is to become worthy of his name let him take a reasonable view of his position, and recognise the fact that he, as a class, knows little or nothing as yet about the really important part of the material he works in. Then let him take steps to acquire the necessary knowledge to employ and impart it, and thereby to lift himself from his present position as a wholesale or retail manufacturer of physical defectives and of mental *ignorami* to that which his self-claimed title implies.

9.—THE RELATION OF A UNIVERSITY TO PRIMARY AND SECONDARY SCHOOL TEACHERS.

By REGINALD H. ROE, M.A., Principal of the Brisbane Grammar School.

The announcement, made by the Queensland Government that a university is to be established here in the present year, renders the present occasion appropriate for the discussion of the more important questions which have to be decided in order to place our university, from the start, in its proper relation with our existing school system. Our new university must not stand alone in majestic isolation from all other educational agencies: it must be the heart which sends the life-blood pulsating through our whole educational system. There is probably no phase of its beneficial activity in which it will have greater possibilities of developing and quickening the intellectual intelligence of our community than in its influence upon the training of our primary and secondary school teachers, and, since the Minister for Public Instruction has announced his intention of establishing a training college for teachers simultaneously with the foundation of the university, there is good hope that there will be a close connection between the two institutions from the first. It is by no means implied that all primary school teachers shall be graduates, though certainly we may hope for a larger percentage of graduates amongst our primary teachers than we can show now; but we may hope that in future all primary teachers will have direct contact with university life and training during some part of their course, to enlarge their mental culture and widen their outlook upon life. Schoolmasters should avoid becoming a special caste. Their friendships and interests should be closely connected with those of other men engaged in the various forms of intellectual work in which education tells. By this means they will gain a width of sympathy and force of character which will enable them better to win the respect and sympathy of their pupils and of the public. The segregation of the future schoolmaster into special pupil-teacher schools, or into isolated training colleges, is to be avoided, if under more liberalising conditions, such as the secondary schools and the university afford, the special requirements for his professional training can also be adequately provided.

The work actually done towards the professional training of teachers in English and Australasian universities is at present small. Oxford and Cambridge still do little or nothing in this direction, but the new universities at Leeds, Liverpool, Birmingham, Sheffield, Durham, and Manchester all provide instruction in the theory and practice of teaching for students intending to become teachers in secondary schools, and also have established in close connection with them training colleges for the completion of the personal education and the professional instruction of those pupil-teachers who have finished their four years' apprentice-work. Still this university training of primary teachers is gained by comparatively few. In 1907, whereas 4,000 boys and 17,000 girls presented themselves for the closing pupil-teacher's examination, only 178 men and 156 women from the training colleges in all the new universities presented themselves for an examination leading to a degree. Still this little leaven will spread its influence, and the numbers are steadily increasing.

The connection between the universities of Melbourne and Sydney and the primary school teachers has been very insignificant; but in New South Wales, since the publication of Messrs. Knibbs and Turner's masterly report on education, there are evident signs of improvement. In South Australia the condition of affairs is much more satisfactory. Pupil-teachers, after two years' study in pupil-teachers' central school, and two years more spent in practical teaching, are admitted to the university training college for two more years, the State granting maintenance allowance. In New Zealand all the pupil-teachers, on completing their period of service, are brought into the four State training colleges situated in the four university centres, where their work is continued in the closest possible connection with the university. New Zealand spent £30,000 last year upon this work of the complete education of her primary teachers. Little has been done in Australian universities hitherto for the professional training of secondary teachers, but this university training of primary teachers will produce a supply of masters well fitted to take secondary school work, and other university men seeking employment in secondary schools will, in face of this competition, find it necessary to qualify themselves more fully by a course of systematic training in educational methods. The complete nature of the university training demanded of the secondary school teacher in Germany necessitates the postponement of wage-earning until at least the age of 24, this would prevent its adoption here, for the present, in view of the more lucrative and more attractive employment obtainable in other callings.

In conclusion, it was urged that care should be taken to make the connection of our training college as close and sympathetic as possible with our university, of which our training-college students must form an integral part in all phases of its social, physical, and intellectual life. We must avoid, as far as possible, the years of apathy towards elementary education and its teachers through which other Australian universities in their early stages have passed. Here our university must from the outset have the roots of its influence planted, through the primary teachers, right down in the lowest primary schools. By this means the full power of our university work would be of highest excellence, for the university would be constantly fed with our best native-born intelligence, and the whole State would also be best brought under the influence of its quickening energies.

10.—PUBLIC INTEREST IN EDUCATION.

By J. DENNIS, M.A., Inspector of Schools, N.S.W.

Among all the subjects that come before this Congress, education is pre-eminently a people's question. Some of the others may safely be left to experts. Engineering, botany, chemistry, mathematics, and the rest no doubt concern the people, inasmuch as it is they who ultimately enjoy the benefits of any discoveries that may be made in these sciences. But in the case of education the people do not merely reap a harvest which has been sown by a few, they must themselves take an active share in the process of cultivation; and this they must do as individuals as well as in their collective capacity through the State. For a child is educated not merely by the lessons he learns at school, but by everything he sees and hears and does; in the home and in the street, in working and playing, just as surely as in learning, his mind and character are being formed; all the persons he meets have, consciously or unconsciously, a share in his education; so that every individual in the community is, willy-nilly, an educator, good, bad, or indifferent.

In this respect education bears some resemblance to hygiene. It is for men of science to investigate the laws of health, and for the State, by legislation and administrative action, to apply them; but, while much good may be accomplished by these means, it is not till the people themselves, as individuals, take an intelligent interest in hygiene and follow its teachings in their own personal and domestic habits that the best results can be achieved. If the people themselves must thus work out their own physical salvation, it is even more necessary that they should take an active personal part in achieving their mental and moral well-being by means of education.

Experts may investigate the laws of mind, the principles of education, and the methods of teaching; the State may establish schools and train teachers, but the children can never be fully educated without the active co-operation of the people in their daily lives. Let us inquire to what degree the people recognise and fulfil the obligation which thus rests upon them.

In their corporate capacity through the State they have done much for education, more than most men a century ago ever dreamed of. Every civilised State has recognised the need of popular education, and has undertaken, more or less thoroughly, the task of training its children to be good citizens. The nations which discharge that duty most efficiently gain such advantages in industry, in commerce, and other ways, that the rest in sheer self-defence are obliged to improve their educational systems and methods. The pressure of international competition is one of the sources of the interest taken in education, and is a common ground of appeal to popular opinion. That the internal development of a nation, as well as its external status, depends on education, is acknowledged by all. The statesman, the captain of industry, the social reformer, all look to education as the surest instrument with which to accomplish their ends; and the man of science finds in the growth and workings of the human mind, and the way of acting upon it, a fascinating field for research. Thus a great and ever-increasing number of men are being brought to take an interest in education. The violent educational controversies that have been raging in England, controversies upon which the fate of Ministries depends, serve to show how education has grown in public importance. Who would have imagined fifty years ago that the very existence of the House of Lords might be at stake in its treatment of an Education Bill?

Though there is no standard by which the growing interest in education can be exactly or approximately measured, yet there are ways of forming a rough and ready estimate. The money test naturally suggests itself as a means of comparing State with State, period with period, or interest in education with other interests. The expenditure on education has everywhere increased enormously during the last generation, and is still increasing both absolutely and *per capita*. Australia compares fairly well with the rest of the world in the amount spent on primary education, but not on that spent on secondary and higher education. As a comparison of interests it is noteworthy that the nations of Europe spend many times as much on their armies and navies as they do on education. There may be some justification for their doing so, but it nevertheless appears strange that so much more should be devoted to the means of destroying men than to educating them. Whatever may be the sins of Australia, that is not one of them. But what of the following comparison, which is given for what it is worth. In New South Wales £1,000,000 a year is spent on education, and £4,000,000 on drink; and a similar disproportion holds in the other States. It is also worthy of mention that the comparatively small amount of private benefactions to educational institutions in Australia does not say much for the interest our wealthy citizens take in education.

Passing from the money test, which is a family one, let us take the Press as an education barometer. This, too, indicates unmistakable advance. For one book on the theory and practice of education that was published thirty years ago, there are many published now, and the number of readers is probably increasing still more rapidly. The Education Departments in Australia now issue periodically gazettes, which, in addition to official information, contain much valuable matter, and these gazettes are sent to every public school. The volumes of special reports on educational subjects issued by the

English Board of Education during the last few years form quite a library in themselves. Numerous educational periodicals are published by private firms to meet the demand for fresh knowledge. It must be admitted, however, that the readers of this copious literature consist mainly of teachers and others professionally engaged in education, and that, after all, in comparison with the total output of books, the educational portion is exceedingly small. Perhaps the daily newspaper is a better test of public interest. Until lately the leading journals of Australia contained only an occasional article on an educational subject; now each of the Sydney morning newspapers devotes a column once a week to schools, and judging by the present trend the weekly column will before long become a daily one. We rejoice at the promotion, actual and prospective, but here again, applying the method of comparison, we find how small a foothold education has gained on the journalistic ladder. Sport, or what is called sport, fills, day after day, without fail, not a column merely, but whole pages of the newspaper, and not satisfied with that, invades the poor weekly education column. If this test be a fair one, sport outweighs education in the public mind by, say, 50 to 1. We cannot blame the newspapers, whose business it is to cater for the public taste, not to correct it. To the credit of the editors, it is fair to say that they are generally ready to print any reasonable quantity of educational matter that may be communicated to them. While the sporting news hold the pride of place in our daily newspapers, there are many other topics that rank far above education in journalistic value and inferentially in public interest. Even the rearing of pigs and poultry receives more earnest attention than the rearing of citizens.

If the reading of the people affords some clue to their interests, so also does their daily conversation. Though here the evidence is difficult to estimate, it is not, I fear, reassuring. By the domestic fireside, around the hotel table, at the street corner, in the tramcar, how often is education the subject of discourse? And could we peep into men's minds and follow the course of their thoughts from hour to hour, how often should we find them concerned with education? Those of us who are actively engaged in educational work naturally become so engrossed with our work that we are apt to over-estimate the place it occupies in the interest of the general world. We receive an unpleasant shock when the conviction is forced upon us that, after all that has been done for popular education, there is still a great mass of indifference, which, like a heavy drag, checks the wheels of progress.

The small attendance at churches is often quoted as proof that the popular interest in religion is waning. Is it right to apply a similar test to the school, and judge the people's interest in education by the frequency of their visits to the school? Perhaps not, for, it may be said, parents send their children to school to be taught, but need not go themselves. Yet it would be a good thing if parents did visit the school. One of the records kept in the Public Schools of New South Wales is the Visitors' Book, and on my annual visit of inspection I turn with much interest to this record. In most cases I find that for year after year not a single parent has visited the school. After making every allowance for the parents' preoccupation in their ordinary business, surely those blank records betray a certain lack of interest. Of course, the ordinary parent in a general way wishes his children to "get on" well at school, feels properly proud when they win prizes, and rejoices when their education enables them to obtain remunerative employment. But he is little concerned with the process of education, and still less does he realise that he himself plays an essential part in it. He considers that he has done his duty when he has sent his children to school.

Unfortunately, even that duty is often discharged very imperfectly. And here we come to a region where exact statistics are available. In New South Wales the average attendance of pupils is only a little over 70 per cent. of the quarterly enrolment, and barely 80 per cent. of the weekly enrolment. Compared with England and some European countries we are backward in this respect, and the reason is not to be found in the sparseness of our population, for the school attendance in our towns is no better than in the bush. Some improvement may be effected by more stringent compulsory legislation, but complete reform in the attendance can only be hoped for when the people become more fully alive to their responsibilities.

If we seek for further evidence of public interest in education, we shall not gain much encouragement from our experience in regard to evening schools, the small proportion of our young people that receive secondary or higher education, the condition of our country schools of arts and similar institutions, and the difficulty of persuading people to accept university extension lectures. All these topics would afford scope for interesting discussion, if time permitted.

The interest in technical education needs to be stimulated, especially in the country districts. The Superintendent of Technical Education in New South Wales has made canvassing tours through the State, urging upon meetings of the citizens the advantages of technical education, and offering to appoint teachers if only classes were formed; but the response was so poor that it was frequently found impossible to find twelve students to form a class.

In our partial and cursory survey of the educational field we have seen enough to prove that public interest in education does not reach a very high pitch. This is the more disappointing when we remember that most of the grown-up people of today have themselves passed through our schools, and might, therefore, be presumed to appreciate the value of education.

What is the explanation of the phenomenon? For one thing, the school systems of Australia have not encouraged local interest and local activity. In some States school boards are appointed, but the unimportant functions assigned to them possess little interest for the members themselves, and none at all for the rest of the community. In England and other countries the local election of boards, local levying of school rates, and a real measure of local administration have aroused a good deal of local interest. Our more centralised systems have their advantages, but have not fostered popular interest. The example thus set by the State has been widely followed in the schools; as a rule little inducement has been offered to the parents to visit the school except on special occasions, such as a picnic, a concert, or a distribution of prizes.

Another cause is more fundamental, and lies in the character of the school itself. Has the work done in our schools been such as to impress the people with a sense of its value, and inspire them with enthusiasm? Has it been closely associated with what is taking place in the great world outside the school, and especially that part of it in the immediate neighbourhood of the school? Has the instruction been practical enough in its aims and methods? And has it been thoroughly efficient? I fear that we cannot return a fully satisfactory answer to those questions.

It remains to consider some means of quickening the public interest in education. As in other propaganda work, something may be done by public meetings and the Press. One of the duties laid upon inspectors of schools in New South Wales is that of assembling parents and citizens, and addressing them on education. The pressure of other duties prevents this one from being discharged very effectively, but wherever such meetings have been held the result has been beneficial. The Press also may be used with advantage to bring educational topics before the public mind. Letters and contributed articles, written by competent hands, and published in newspapers or magazines, would help to turn the thoughts of the people in the right direction. Of the effect of publicity and free discussion an example was furnished by the conferences which were held after the report of the New South Wales Commissioners of Education was published; no small impetus was then given to the popular educational movement.

But it is through the school itself that most can be done to popularise education. I do not mean that we are to wait until the children that are now attending school grow up and replace the present adult population. The need is a present one, and does not brook such long delay. But by making the school more efficient, by bringing it into closer relation with the activities that are going on around it, by eliminating the dead-weight of useless lumber that now encumbers it, and by demonstrating to the people its practical helpfulness, we shall win from the community a hearty support and co-operation beyond what we have yet enjoyed, and without which the best school cannot fulfil its mission. For the school is but one factor in education. The other great factor, the home, must do its part, and the two must work together in harmony, which they cannot do without mutual understanding and mutual goodwill. How often do teachers complain that their difficulties are increased and their teaching nullified by the adverse influence of the home, which, when it is not actually hostile, may be indifferent or unsympathetic, and not uncommonly indulges in careless criticism or ridicule of the teacher and his work. The people realise very imperfectly as yet the nature and importance of education. Parental affection is not wanting; with better knowledge and the interest that comes with knowledge the parents will perform that part in the education of their offspring which is peculiarly their own, and cannot be delegated to the teacher. Let us endeavour to impart that knowledge and to arouse that interest. Of the two chief partners in education, the home and the school, the school has the advantage in knowledge. Can it not by some means enlighten its less favoured partner. The teacher might induce the parents to visit the school and witness a demonstration of his methods. This might be followed by a consultation as to the best mode in which school and home can collaborate. The question of home lessons, regularity and punctuality of attendance, and many other such matters could be considered. In many cases within my own observation the school has reacted for good upon the home, but by some such means as I have suggested the effect could be deepened and extended. It may be objected that in bringing the public into closer intercourse with the school we run a risk of their unduly interfering with the teacher; indeed, many teachers on account of that objection have kept the people at arm's length from the school. With a reasonable degree of tact, however, the risk would be small, and it might well be incurred for the sake of the prospective benefits to be gained.

Any active help which people render to their school deepens their interest in it. Of this we have of late years had some striking examples in New South Wales. On the promulgation of the new syllabus in 1904 it was found that certain materials and appliances would be required beyond those which were supplied by the Government. The teacher wanted tools for gardening and for manual training, paints and brushes for art work, books for supplementary reading and the school library, sets of weights and measures, sand trays, and so on. Finding that the periodical school concert, which had long been the means of raising funds, was unequal to the new demand, he called the parents and citizens together, explained the situation to them, and asked them to devise ways and means of improving the school equipment. In that way originated many of the Parents' and Citizens' Associations which have been springing up throughout New South Wales. Some of these hold regular meetings, and besides providing funds and organising picnics have undertaken direct educational work, such as the holding of debates or arranging for courses of lectures on hygiene and other subjects for the benefit of children and adults alike. In this way the school becomes a centre of intellectual life and combined educational effort.

By the means I have indicated, and in other ways, the public may be brought to enter more freely into the education movement, to rally round their school and take a pride in it, to understand more fully its aims and methods, and to perform their part in the great work of education. Until they do so, a great auxiliary educational force remains unutilised. We look at education too much from above, and are in danger of forgetting that the regeneration of society, which is the purpose of education, can only be accomplished through continual improvement in the social units, that, to borrow a term from physical science, the process is molecular. We need better organisation, more thorough training of teachers, an improvement in the matter and method of instruction, but we must have also the head and heart of the people on our side. Our difficulties are great; on the one hand those who administer our educational systems cannot obtain sufficient funds for carrying out their well-planned measures, and on the other hand the work that they actually perform is rendered more or less ineffective by the inertia or the passive resistance of the people. Let us strike the rock of the public mind with the rod of interest, and the monetary stream will flow bountifully. Let us sow our seed in prepared ground, and we shall reap an abundant harvest.

Who is to do the work of preparation? Who but the teacher, who is the key to nearly all our educational problems. And what the teacher needs for this work is something more than professional knowledge and professional skill; he needs also professional zeal; nay, more, the missionary spirit, glowing with enthusiasm for the betterment of man. Working in that spirit he will not only win for himself fuller recognition, higher appreciation, and more adequate remuneration, but he will awaken the people to the possibliities of national improvement that lie in true education, and fix in their minds the determination to convert these possibilities into realities.

11.—NOTES ON THE FEDERAL CONFERENCE ON EDUCATION, 1907.

By ESTELLE CRIBB, M.A., Ipswich Grammar School.

To all who are genuinely interested in the advance of education, the year 1907 must be regarded as marking an epoch. For the first time in the history of the Empire, a conference on education was called, to which were invited representatives from each State in his Majesty's dominions. This conference was summoned by the League of Empire to meet on Empire Day, 24th May, 1907. It is noteworthy that the Conference of Premiers, which it is hoped has strengthened the bonds of Empire, was held in London during the same month. But, perhaps, in hardly any direction is the Imperialistic idea so full of promise as in educational matters, and the gathering together of enthusiasts in a common cause from such various States must result in immense benefit to the Empire as a whole.

This conference was summoned to discuss primarily a scheme for a Federal Council of Education for the Empire. To it were invited:—(1) Representatives of each part of the Empire, nominated by the several Governments or educational departments; (2) delegates appointed by the universities, museums, and other educational bodies of the Empire.

As I was to be in London at the time, the Queensland Government kindly appointed me to act with Sir Horace Tozer as its representative.

The meetings were arranged in three classes:—

1. The official conference, attended only by the representatives;
2. The full general conference of representatives and delegates;
3. The open and sectional meetings, which all persons interested might attend.

Great interest was taken in these last-mentioned meetings, and at them papers were read or speeches made by well-known men, such as the Right Honourable Arthur Balfour, Sir Gilbert Parker, Dr. Parkin, Professors Saintsbury, Sonnenschein, Bury, and Madame Bergman-Osterberg.

On Friday, 24th May, the representatives and delegates were received by the President of the League of Empire, Lord Tennyson, after which the conference was formally opened by Lord Crewe, President of the Privy Council, the only department of State which is concerned with the Empire as a whole. The opening speech was followed by others from representatives of widely different parts of the Empire. After this came the official luncheon, and a reception by Lady Tennyson.

The real work of the conference began on Saturday, 25th, and we were kept very busy for the next week, as the League of Empire had provided us with a great deal of matter for discussion.

On going to the first official meeting I was very much alarmed to find that I was the only woman among fifty men, who were all directors of education, inspectors, or agents-general, and all unknown to me, as Sir Horace Tozer, who had shown me great kindness, was too busy to attend the meetings. The door was guarded by a policeman, and no one was admitted without a ticket; indeed, the Prime Minister of one of the States, who had forgotten his ticket, was refused admission until a friend known to the policeman was found to identify him.

At the first official meeting it was decided that the larger subjects which it was desired to discuss should be taken in full conference, and that certain subjects of a more special or technical nature should be discussed in three committees, consisting respectively of those representatives in whose countries such subjects were of the chief importance.

Committee A, on which I sat, discussed problems affecting parts of the Empire in which there are large English-speaking populations—for example, the provisions of specific agricultural education for rural areas; B, problems affecting English-speaking populations in remote and isolated portions of the Empire—for example, the provisions of higher education (1) by co-operation between neighbouring colonies, (2) by the establishment of scholarships tenable in larger centres within the Empire, also native-race problems; C, the bi-lingual problem, both languages being European.

It was also decided that resolutions should only be put when it was clear that the conference was prepared for a unanimous decision. This was considered necessary by the members of the British Board of Education, lest the Government should be compromised in any way.

On Monday, 27th May, the first subject of discussion was "The mutual recognition of teachers' certificates." After a considerable amount of information as to the manner in which certificates in the various countries were awarded, and their value equated, the conference came to the conclusion that "the variety of local conditions, especially in regard to such matters as the tenure of office by teachers, their method of appointment and promotion, and similar points, made it impossible to arrive as yet at any complete system of mutual recognition of the teachers' certificates issued by different educational bodies in various parts of the Empire."

The next subject to be considered was "The interchange of teachers and inspectors." After discussion, it was resolved:—"That the conference considers it desirable that financial and administrative arrangements should be made for enabling teachers and inspectors of schools to acquire professional knowledge and experience in parts of His Majesty's dominions other than their own." In this connection I should like to add, that in visiting schools at the conclusion of the conference I met several teachers who expressed a keen desire to effect an exchange with some of our teachers for a year or two, if it could be arranged.

On Tuesday, the subject of discussion was "The possibility of closer uniformity of curricula, nomenclature, and methods of presenting official educational statistics." Some uniformity of curricula seemed to be desired by the League of Empire, but the representatives were unanimous in considering "that it is not desirable or necessary to take any steps to bring about uniformity of curricula or text-books for the different school systems of His Majesty's dominions."

On the remaining part, it appeared that what was needed was not so much a greater degree of uniformity in presenting statistics as a clearer understanding of what is connoted by the terms used, and the definitions employed, and it was resolved that "It is desirable that the different Education Departments of His Majesty's dominions should define year by year with precision the terms used in the regulations and statistics that they publish, and the basis upon which their published statistics are prepared."

The next three sittings were devoted to a careful investigation of the various ways in which the interests of education in the different parts of the Empire could be furthered by encouraging closer relations and a more effective and continuous exchange of information between the several education departments. It was felt that the actual meeting together in the conference of persons engaged in the administration of education for the purpose of personal interchange of information and ideas was of the highest possible value, but that there were also great advantages to be derived from having a permanent machinery to further this end. The following motion was agreed to:—"That the delegates desire to express their appreciation of the value of this conference to the work of education departments throughout the Empire, and resolve (1) that a quadrennial conference is desirable, (2) that the representatives sent to the conference should be selected by the Governments, and (3) that it is desirable that the first of such conferences should be convened by the Imperial Government." It was further resolved that "the conference is unanimously agreed as to the importance of a permanent central bureau of educational information."

At the next two sittings there was further discussion, but no important resolutions passed. The representatives were, however, delighted with the announcement from Mr. Morant, on behalf of the Imperial Government, that, in reply to the expressed desire of the conference, His Majesty's Government was willing to arrange for an official educational conference to be held in the year 1911.

The full conference of representatives and delegates also passed the following resolution:—"That it is desirable that the Colonial Office and the Board of Education should co-operate in issuing, officially, particulars as to the courses of study, fees, expenses of living, &c., at colonial universities, technical and agricultural colleges, together with statements of the advantages attaching to their degrees and diplomas; and that information should be circulated in the colonies as to similar advantages and facilities which exist in this country."

In these official meetings you will have noticed that very few resolutions were passed, but there was a great deal of very interesting discussion which led to no resolutions, as there was not the complete unanimity desired.

I was particularly struck by two things at these meetings: First, the eagerness shown by the colonial representatives to pass a great many (often ambiguously worded) resolutions, and the contrasted caution of the British representatives which made them reject the majority of the proposals; also the extreme value of an able and tactful chairman, Mr. Butcher, M.P., who occupied the chair at these meetings, and frequently interposed to reconcile differences, explaining that there was no essential disagreement in the proposals moved by the two differing members; and his services were often of the utmost value in helping the colonials to reconstruct carelessly worded resolutions so that they might be accepted by the more cautious home members.

The following resolutions were also passed by the sections:—

Nature Study Section—"As Nature study gives that wide knowledge of the world and its products which is required throughout life, it should be inculcated at all stages of sound general education, and this section recommends its earnest encouragement in the home, in the school, and in the outside world. Furthermore, this section trusts that the education authorities of the Empire will endeavour to extend and encourage knowledge self-gained from original observation as a vitalising factor in the progress to full intellectual efficiency."

"That the supply of teachers acquainted with true methods of Nature study being the greatest present requirement, special efforts be made to provide facilities for the proper preparation for the work of students and teachers in training."

Museum Section—"That the formation of school collections illustrative of science or art is a valuable aid to education."

"That when school collections are made to illustrate natural history or other branches of knowledge, arrangements for the exchange of such collections between various parts of the Empire will assist the objects for which the League is instituted."

"That teachers and others should discourage the making of such collections as might tend to the extermination of rare plants or animals, and should assist in preserving such objects by fostering a knowledge and love of Nature."

"That this conference recognises the value of arrangements for the circulation of museum objects, as organised at the Victoria and Albert Museum, South Kensington, and at the Dublin Museum of Science and Art, at Sheffield Museum, and elsewhere; and warmly advocates an extension and development of the system."

"That this conference recommends the organisation of a permanent collection of objects specially interesting and useful to those engaged in educational work, in connection with one of the great museums in London. That such a collection should include typical school museums and the outlines of a local educational museum."

University Section—"That it is desirable that a committee representing universities should be formed to investigate the question whether it is possible to facilitate the exchange of information as to their courses and standards between the universities of the Empire, and to take action accordingly."

Teaching of English Section—"That this conference urges the importance of the study of the English language and literature as an essential part of school training, on the grounds of practical utility, an enlightened patriotism, and the humane ideal in education."

"That in the teaching of living languages the direct system be used, with occasional explanations in the mother-tongue of the pupil, when it is evident that the latter has not understood the teacher."

"That the object of the teaching of English should be to develop in pupils the power of thought and expression, and the power of appreciating the content of great literary works, rather than to inculcate a knowledge of grammatical, philological, and literary detail."

"That fairy tales, skilfully used, provide a valuable means of literary education for young children."

On three afternoons, scenes from a children's historical play, "The Story of the Armada," written by Miss Amice Macdonald, were acted by the boys and girls of St. Margaret's County Council School, Westminster. I believe the performance was very good, but, unfortunately, I was not able to attend it, as other meetings were being held at the same time.

Before proceeding further, I should like to express here my warm appreciation of the services of Mrs. Ord Marshall, the honorary secretary, to whom fell the chief work of organisation in connection with this conference.

The League of the Empire showed its wish to help the representatives from the colonies in a very practical way by securing for us invitations to pay visits, which proved both pleasant and instructive, to Oxford, Cambridge, Eton, Winchester, and Birmingham, and also to the training ship "Exmouth."

The visit to Birmingham I should like to mention in some detail, as in that city there is so much of educational interest to a young State. The people of Birmingham had very hospitably invited the representatives who could spare the time to spend two days in their city. There, as Mr. Chamberlain was too unwell to perform the duty, we were received by Sir Oliver Lodge, and conducted by him over the grand new university, of which he is vice-chancellor. At this university nearly half a million sterling has just been spent in the building and equipment of the engineering school. There is a faculty of arts, but it has to be content with the old and much smaller building. We also visited the two King Edward VII. High Schools—one for boys, the other for girls. At these schools I noticed particularly the excellent arrangements for the science lessons.

Next day I paid visits to a school for cripples, a school for the mentally deficient, and one for the deaf and dumb. At these schools, though saddened by the sight of so much suffering, I was both surprised and delighted to see how much care and patience had been able to accomplish in partially curing the ills and in brightening the lives of the pupils. Except in the class for the worst cases of imbeciles, I was met everywhere by smiling faces. In all these schools dinner was provided free to the pupils, and in most cases prepared by the pupils themselves.

An indirect result of the conference was that, by introducing us to leading educationalists, an entry was secured to us into the schools of England and France.

During the session of the conference several very pleasant entertainments were kindly given for the members. The Duchess of Northumberland gave a garden party at Syon House, the Earl and Countess of Crewe a reception at Crewe House, the Chancellor of the London University a conversazione in the University buildings, and Mr. Beerbohm-Tree a special theatrical performance, followed by a reception on the stage. At these functions it was our privilege to meet men and women whose names are well known in all parts of the Empire, some of them, indeed, coming from the different countries of Europe, and even from Asia.

On all who attended this conference its influences must be great; the meeting with educational enthusiasts and the interchange of information cannot but have given fresh inspiration and a wider outlook to those who thus met together, which, it is to be hoped, will be of a great assistance to them in solving the educational problems in their own States.

Further, we hope much from the fact that the Imperial Government has consented to call an official conference for 1911, the results of which, certainly far-reaching, who can foretell.

12.—ASPECTS OF TECHNICAL EDUCATION FROM A QUEENSLAND POINT OF VIEW.

By E. C. BARTON, M.L.A.

In bringing before you a paper on "Technical Education from the Point of View of a Queenslander," I must ask you to bear with me if my point of view should seem to be pre-eminently that of an engineer. After having spent half a lifetime in dealing with problems from a particular standpoint, I may find some difficulty in treating them as part only of a wider subject. I trust, however, that my lengthy experience in connection with the Technical College, both as a teacher and as a member of the council, will enable me to some extent to rise above my immediate surroundings and make my observations interesting and perhaps instructive to those who are engaged in the work of technical education.

Before treating of our local technical education requirements it will be advisable to review the conditions prevailing in some other countries and at other periods, although under our industrial conditions and in our remoteness from the great manufacturing centres of the world the problem of technical education calls for solution by methods of a somewhat different character to those adopted by the nations of Europe and North America.

In England at the present time there is a notable tendency to copy German methods in regard to education, especially since the industrial development in Germany has placed that country ahead of England in the steel and some other branches of trade.

As the Germans have trade schools where handicrafts, such as weaving, spinning, and metal-working, are taught to workmen, it has been thought that the establishment of such schools would benefit England; but Germany established those schools in order to rapidly create a large number of skilled artisans at a time when the corresponding industries did not exist in the country. Men were sent to England to learn trades, and they came back to their own districts to teach their countrymen in schools erected for the purpose. It should also be remembered that the present position of the steel trade of Germany is largely the result of their having more modern equipments, as is only natural in the case of people recently entering into a new field of industry. The converse holds good in the supply of electricity. The price of electricity is far higher in the United States and in Germany than in England, for the simple reason that the German and American towns are supplied from plants which were, in most cases, laid down in the early nineties, while the British towns are supplied from modern plants of greater efficiency, and purchased at half the price. The trade schools just referred to served their purpose admirably, but at present the complaint arises at Crefeld and such places that the trade schools, although more magnificently endowed than ever with apparatus and machinery, are not attended by more than 2 per cent. of the young workpeople. This result is to be traced to the same causes which have led to the decay of the apprenticeship system in England.

At the outset it will be well to recognise that certain events have taken place in the industrial world which have permanently altered the demand for skilled labour, and affected the opportunities for acquiring skill and technical knowledge; and, in shaping our methods of technical instruction, we must remember that:—

Firstly, the apprenticeship system has broken down under modern shop-methods;

Secondly, the use of special machinery in every trade has depreciated the value of the skill which it was the chief object of that system to impart; and

Thirdly, the conditions of every trade, its processes, its raw materials, its products, are changing so rapidly that no trade can at the present time be learnt, in the same sense as it was possible to learn a trade in olden times, when the changes took place more slowly.

Taking the above matters in their order, and considering first the causes which have contributed to the failure of the old apprenticeship system, we find that chief among these is the fact that it no longer confers on the employee the same benefits as of old. Up to the end of the eighteenth century the skilled tradesman who had served his time to a recognised trade or craft was in a strongly protected position. No man could come into his district and compete with him, as we see from the tale of James Watt's sufferings when he came to London thinking that the guilds would let him work there. This condition of things was rapidly altered under the new school of ideas arising out of the French Revolution, and the process was completed by the advent of the steam engine and the railways, with their resultant methods of manufacturing in centralised factories; but the industrial supremacy of Britain and the strong organisation of the great trades unions kept up the value of skill until the general use of special tools in America, and subsequently in Germany, undermined the supremacy of Britain, and drove the British manufacturers to adopt similar methods.

This movement culminated at the end of the nineteenth century in a fierce struggle between the federated employers and the powerful trades union of the "Amalgamated Society of Engineers." That great strike, which was a final protest on the part of skill against the machine, resulted in victory for the machine. Since then, in the British engineering trades, the use of highly specialised tools to replace skilled handicraft has made rapid headway, and it is safe to say that the highest wages paid in Britain to-day are earned by men who operate machines. Thus it has come about that the great engineering works are filled with special tools, and offer to an apprentice little opportunity of acquiring skill, or of using it when acquired. Some philanthropic and public-spirited employers on the north-east coast of England have recently made a vigorous endeavour to restore the apprenticeship system to its ancient position, but it is doubtful whether it can be galvanised back into life in the engineering trade any more than it can in the boot or watch making trades. The skilled turner who could in former times turn up a journal to satisfy any engine-maker, would at the present day cut a sorry figure in competition with a machinist who grinds a shaft to a degree of accuracy unattainable by the use of the old-fashioned turning tools. The fitter who prided himself on his skill in making a key-seat would not earn a boy's wages in competition with a "key-seating machine." Of course, there are a few trades which survive in such a form that they require and still retain the apprenticeship system in its highest form. Such are the ironmoulding, the bricklaying, the ship-riveting trades, and several of the wood-working trades; but even in these the position is being undermined by the introduction of machinery to do that which at one time could be done only by highly skilled men.

In a State such as Queensland, which is remote from the great manufacturing countries, there is less need for the teaching of special trades and processes than in those countries, the market for specialised skill being very limited when compared with that offered to the youth of the great manufacturing nations of the world; but, on the other hand, the demand for resourceful men is here relatively greater, and a system of technical education, in order to be suitable to our wants, must impart general skill and general knowledge. Unfortunately, in the matter of technical education, as in primary education, the existence of well-developed text-books and apparatus suitable to the requirements of older countries, renders it difficult to widely depart from the methods which have in other countries achieved success, although the conditions be so widely different as to make those methods quite unsuitable to our requirements. Hence our teaching of technical subjects is apt to be more suited to the requirements of Europe than to our own, and probably at the present time we are turning out from our technical colleges numbers of young men who are doomed to a life of disappointment, owing to their having followed courses particularly suited to the requirements of industries which are developed elsewhere, but which scarcely exist in these States.

During a recent tour in Europe, I was struck with the fact that quite a number of Australians filled prominent positions in the engineering world. These young men, having in their youth studied subjects for which there was no scope in Australia, were forced to leave their country in search of employment in their particular branch of industry.

At the end of last century the demands of technical instruction had, in this State, outgrown the possibilities of the original organisation, and reached conditions which called for a complete reorganisation. Successive Ministers have tried to solve the difficulties, and in 1905, under the present Minister, a general syllabus was evolved, which, owing to its elasticity and the moderation shown in applying it, has produced very satisfactory results. Much remains, however, to be done, especially in the direction of co-ordinating the secondary education of the State with the primary, and the Government has this year obtained powers, by the Technical Colleges Act of 1908, which should enable the Department to deal amply with the matter.

The first beginnings of technical education in Queensland were made in connection with the local libraries or "schools of arts," and in many of the smaller centres the work is still controlled by sub-committees of those institutions. In larger centres the teaching institutions have become independent, but their management and their financial arrangements still bear the imprint of their evolution. The assistance given by the Government is still in the nature of a percentage on the fees received, and they are managed by committees which are generally more in touch with the commercial than with the industrial interests. As a consequence of this, and of the fact that classes on commercial subjects call for less costly equipment, the tendency has been in the past for these institutions to develop on the commercial side to the detriment of the industrial side. Typewriting, shorthand, bookkeeping, together with continuation school work, have been the chief field for their energies. In 1906 a new system of endowment was introduced, which gives increased aid to the industrial and technical subjects. The results have been very satisfactory to those institutions which have art and science classes, and has also acted as an incentive to an increase in the number of classes teaching subjects other than commercial. At the present time the chief defect of our system is that the committees are driven by it to charge higher class fees than they would charge if they were receiving an attendance endowment, as in New Zealand, or a fixed annual endowment. This will probably be remedied in the larger centres by the State assuming complete control of the technical education as is now proposed for Brisbane. With the resources of the Education Department at its disposal, technical education may be expected in the near future to make rapid strides in Queensland, and hence the importance of the lines to be laid down now in regard to the future course of development. The first question to decide is the degree of specialised teaching which is to be aimed at. Shall we follow the lead of Birmingham, and try to replace the apprenticeships by practical work at the colleges, or shall we follow London and provide the means for our youth to acquire theoretical knowledge at our colleges while he acquires skill in the ordinary workshop.

The prohibitive cost of the former would be fatal to its adoption in this State, but even though our taxpayers were willing to face the great expense involved, it is open to question whether the result would justify it.

The latter is open to the objection that the practical man and the employer are not, in this country, well-disposed towards the lad who comes to them holding an exaggerated idea of the sufficiency of theoretical knowledge while absolutely lacking in skill. As our inspector of technical colleges writes in his report of 1906, "The dissemination of technical knowledge depends upon the appreciation of its value by parents and employers." I am of opinion that our technical colleges should provide means for imparting a certain degree of skill to every youth who intends following industrial pursuits, but it should not be specialised. Although some class of work must be chosen for the purpose of teaching, skill should be taught to all by nearly the same processes. Every industrial student should attend wood-working classes, even though he intends afterwards to be a brassfinisher, an electrical engineer, or a housepainter. In woodwork he has an opportunity of acquiring command over the muscles of his hands, while learning to interpret drawings and other instructions. He should learn familiarity with the every-day applications of chemicals as exemplified by the use of fluxes in soldering and welding, acids in dissolving metals, alkalies in dissolving fats and oils.

He should become familiar with the electric current sufficiently to realise that current flows in a circuit, and that a broken circuit interrupts the current, while a short circuit increases it. He should learn physics to the extent of becoming familiar with the properties of ordinary solids, liquids, and gases. He should know enough concerning algebraic and trigonometrical symbolic methods of expression to be able to use any ordinary text-book formulæ. He should already possess, or should acquire at the technical college, a knowledge of arithmetic, and this knowledge should be of such a kind as to enable him to think clearly in figures, without being over-loaded with niceties of the recurring decimal type. This brings us to a consideration of the primary school education in so far as it fits or unfits the future technical college student for his work. (But this matter I shall deal with at the close of the paper.) He should learn to use a file on brass and iron, but only for the purpose of easing a fit, or nicking and breaking a rod. He should learn to use pliers in a reasonable manner to cut wire or to hold it. He should learn to tin a soldering bolt, and to prepare surfaces for soldering, and know what flux to use for lead, brass, copper, zinc, or iron. He should be able to dismantle a common lock and put it together again. He should be able to cut a screw thread on a $\frac{3}{8}$-in. or $\frac{1}{2}$-in. pipe or iron rod with stocks and dies. He should learn mechanical drawing of a rough and ready kind, without much use of instruments, and above all he should be able to interpret drawings.

A course in carpentry and wood-working is especially valuable even to the future worker in metals, because he can in wood-working obtain a familiarity with accuracy of measurements, interpretation of drawings, appearance of true planes, correct angles, neat fits, and the holding of tools, which could not be acquired in metal work without an excessive expenditure of time.

Knowledge on such practical points as I have mentioned would go far towards placing the technical college student in a better light in the eyes of employers and their foremen. It would in most cases save him from being set to the ignominious duties of sweeping and cleaning, which at present are necessarily imposed on every beginner in order to give him time to become accustomed to his surroundings, and sufficiently familiar with elementary portions of the work to allow of his being entrusted with any tools or material upon which to operate. It will not give him that skill which an apprenticeship will give, but it will be less restricted in its utility. It should be realised by parents that much of the value set upon apprenticeships is empty prestige. A lad enters a workshop at the age of fifteen or sixteen. He is too young, and generally too thoughtless, to be entrusted with any work. His occupation is indefinite. He is put to menial work to keep him out of mischief until he has learnt, by observation, sufficient to become useful to a journeyman, running errands, heating or sharpening tools, looking on while the man does the work. The man has no time to teach the lad, and seldom has the faculty of imparting knowledge. Eventually the lad takes to some particular work and shows aptitude for it. Foreman and journeyman are all pleased to let him keep to that work. His employer is getting remunerative work out of him, while the lad is acquiring quickness at this one particular operation. If at the end of his time he obtains a substantial increase in wages, he generally settles down to work in the one groove, and his mental progress ceases. If his employer cannot see his way to give him the necessary wages, he leaves the shop, and soon realises how little he has learnt. He finds there is far more work to be done outside the workshops than inside them, that there are more men employed in erecting and running machinery than in making it, but that he requires more knowledge than skill to succeed outside. That this is the case in the old country is proved by the discussion which took place in England on the occasion of an address by the President of the Institute of Mechanical Engineers, when a leading technical journal criticised his advocacy of German methods of teaching manufacturing processes in specialised technical schools, saying, "Many engineers never see the inside of a works after they have left their apprenticeship, their lives being passed in erecting and running apparatus made by other people." This statement applies with greater force to the conditions prevailing with us. In taking this point of view, I am assuming that we shall during a great many years to come be users of imported machinery, but not to any great extent makers of it. Therefore our technical training should aim at teaching those matters which are incidental to the purchase and erection of machinery, its maintenance in good working order, and its profitable industrial use. It should also give our youth an opportunity of learning the amount of chemistry and general physics necessary for the carrying on of the chief industries of the country, giving a training of a more complete kind in those branches of industry which have, in this State, so far developed as to warrant final training to the point of imparting the skill of the finished tradesman. At the present time such a condition has been attained only in the mining and pastoral industries, and to a certain extent in the sugar and dairying industries, and all of these industries are specially catered for by the agricultural colleges and schools of mines.

Reverting to the more general problem of technical education as propounded, it will be seen that the function of the technical college in this State ought to be that of imparting to all its students a certain amount of manual skill and familiarity with materials; but to the student specially desirous of entering the mechanical industries it should be able to impart a more extended knowledge of general engineering matters, such as that of lubrication and the reasons underlying the wear and tear of machinery, a more exact knowledge of drawings and their meaning, so as to enable him to judge of the accessibility of the parts of a machine, and the provision for the taking up of wear, packing of glands, cleaning out of oil wells, against rusting, oil throwing, &c. The college should be able also to impart to him a knowledge of how to erect machinery, including the laying out of the work according to drawings, the building of foundations in concrete, brick, or timber, the erection of steam and exhaust piping so as to avoid water pockets and leaky joints, the setting of boilers, the choice of steam valves, water gauges, pumps, feed water heaters, and economisers. In fact, the college should primarily be prepared to teach its engineering students to intelligently purchase, erect, and use machinery and apparatus made by someone else. Only after providing for such teaching should the college apply its energies to satisfying the wants of the student who wishes to enter the field of manufacturing the machinery.

The field of technical education is so wide that in attempting to lay before you certain views on the subject I have confined myself to one branch of it, but even in such a partial exposition of the subject a few remarks on the influence of the primary school will not be out of place.

Most teachers at technical colleges have felt that the work of the primary school is of a character more particularly suited to the requirements of those engaged in literary or mercantile pursuits than industrial. This tendency, which exists in most countries, is particularly noticeable in the teaching of arithmetic in the higher classes. Two to three per cent. of the text-book work is devoted to calculations, covering mensuration and compound proportion, while 30 to 40 per cent. is devoted to banking and stock exchange work, which involves the inculcation of a special set of conceptions, covering such matters as bills of exchange, discounting of bills, and brokers' commission on sale of shares. In order to make the teaching of arithmetic more generally suited to the wants of the whole community, it is desirable that it be shorn of much of its mercantile tendencies, that any special reference to banking or stock exchange matters be minimised. It is also desirable that the practice of aiming at an absolute accuracy be modified in favour of a percentage accuracy, the percentage being dependent on the accuracy of the data and the accuracy really required in the result. At the same time pupils should be taught to calculate in rough approximations as a check on the production of absurdities, it being quite a common thing at present to meet lads who are proud of doing a sum with an accuracy of figures to six places of decimals.

It would be of great advantage to the future technical student if he were during his childhood to acquire the power of making and recording observations of his own, both in words and in rough pictures; if in learning drawing his energies were expended less in the direction of trying to produce pictures which were pleasant to the eye, and more in the direction of representing a well-known object in ground plan and in elevation, or even in section. He could then learn to make a record of his observations concerning the works of a clock, or a sewing machine. He could give an intelligible description of the streets in the immediate neighbourhood. It would also be to his advantage if the time now devoted to arithmetic of the banking type were devoted to rough experiments on weights and levers, with calculations appertaining thereto, all calculations being rough approximations (of an accuracy of 1 per cent. as in engineering problems). Algebra would be cut down to so much as is necessary to enable him to understand a formula such as is given in engineering pocket-books, all complicated problems such as those involving the solution of a quadratic equation being solved by the system of trial and error. Such an alteration in the present system of education would do much to inculcate that clearness of thought which can only be obtained by a departure from the worship of the infinitesimal and the recurring decimal, which drives men to state the National Debt with a "shilling and penny" exactitude. It would also lessen the tendency of the early training towards mercantile pursuits, a tendency which is responsible for much of the desire of the youth to settle in the cities and leave the land.

13.—THE PLACE OF RELIGION IN THE SYSTEM OF STATE EDUCATION IN NEW SOUTH WALES.

By ALEXANDER LOBBAN, Esq., Senior Inspector of Schools, New South Wales.

In order to form a correct conception of the characteristic features of the State system of education in New South Wales now, it is necessary to go back to the early years of colonial settlement to follow the process of evolution that has taken place. Very great difficulty was experienced in those days to obtain the most elementary instruction for the children, as neither teachers nor school buildings were available. Each of the early Governors took an interest in the children, and the old records show that a day school was opened in Sydney in 1803.

As settlement increased, and clergymen arrived in the colony, the establishment of elementary schools was left almost wholly in the hands of the ministers of religion, to whose zeal and energy at that time much of the subsequent success of education in the colony may be traced. Funds from the public Treasury were usually supplied to pay the salaries of the teachers; and the scholars met in the churches or other buildings that the promoters could obtain until schoolhouses were built. The first schools established were denominational.

Each denomination opened schools in connection with its own churches; and this led to what many considered an unjustifiable expenditure of public money. For as two, and sometimes three, schools were conducted in a district where there were barely enough children to support one, it followed that the amount paid for teachers' salaries was greater than the circumstances warranted. Moreover, bitterness was engendered by the rivalry to obtain pupils for these competing schools; and sectarian, and even personal, animosity was often created.

A large section of the public at length became dissatisfied with the existing arrangements, and urged that a change should be effected. Sir Richard Bourke, who was Governor of New South Wales at the time, gave the matter much consideration; and, in 1836, suggested to the Legislative Council the expediency of introducing a non-sectarian system of education which would be fair to all sections of the community, by affording sound secular education to all, and providing for general and special religious instruction also. He realised that New South Wales embraced a vast area of country, very thinly populated by people of various nationalities, professing different religious beliefs, so situated that they formed mixed communities, enjoying equal political rights and privileges; and, in all secular matters, working in the utmost harmony with one another; but in matters of education, divided into denominational sections which claimed separate schools for their children.

Sr Richard's object was to devise a scheme that would be agreeable to all, having due regard to efficiency on the one hand, and proper economy of the available funds on the other. He held that the Government was an embodiment of the will of the whole people, and derived its resources from all; and, therefore, could only legitimately apply State funds to school purposes of universal benefit, in which all the children should have a legal right to participate.

The proposal practically meant that the schools supported by the State under the supervision of the churches should be superseded by State non-sectarian national schools which would combine the principles of secular and general religious instruction by the teachers, and separate special religious instruction by clergymen, during school hours, to the children of their respective congregations.

This proposal was distasteful to the churches; and it was also strongly opposed by a section of the community which objected to the granting of any aid by the State to public education, arguing that the parents alone were personally responsible for this duty, and the State had no right to interfere in the matter. The Governor's statesman-like proposition was defeated, although the statistics proved that half of the children in the colony were receiving no education. The matter was reintroduced by the succeeding Governor, Sir George Gipps, three years later, and again rejected.

Meanwhile schools were being established by the Church of England, Roman Catholic, Presbyterian, and Wesleyan denominations, and the multiplication of small competing schools continued. The Legislative Council took the whole question into serious consideration in 1844, and appointed a committee of its members to investigate the case thoroughly. Mr. Robert Lowe (afterwards Lord Sherbrooke), was the chairman. The committee approved of Governor Bourke's suggestions, and recommended the introduction of a non-sectarian national system, similar to the one that had been satisfactorily brought into operation in Ireland in 1831. The Legislative Council adopted the committee's recommendation, and proceeded to take the necessary steps to appoint a board to organise the system.

The churches, anticipating that the new system would lead to the withdrawal of aid from the schools they had established, protested strongly against the movement, and so insistent was the opposition that no decided action was taken by the Government until 1848. Then two boards were appointed—a Denominational Board to supervise the work of education connected with the churches, and a National Board to organise and administer the new system of National Education.

From this period the education of the children became a portion of the State policy. The existence of the Denominational Board, proclaimed, with no uncertain sound, the influence of ministers of religion at that time, and further, the determination of a large section of the people to have their children taught at school the religious beliefs they entertained.

For a time the national system was very much misunderstood by the public, and the Commissioners met with great opposition in the prosecution of their duties. They had to proceed slowly. The first national school in Australia was opened in 1849, in the old Military Hospital in Fort street, Sydney; and in that building the board had its office also. Four national schools were opened in 1849, and the great work of inaugurating the first non-sectarian national school system in Australia was fairly commenced.

The competition between the schools under the two boards was marked. Strong opposition to the national system was manifested in many quarters. But when it became known that special attention was paid by the board to the character and qualifications of the teachers; and that thoroughly trained men were being obtained from the Home Countries to take charge of the principal schools; and, further, that the ordinary teaching embraced general religious instruction and the regular reading by the pupils of approved extracts from the Old and New Testaments, and that this *general* religious instruction was supplemented by *special* religious instruction given by clergymen to the children of their respective denominations, during school hours, public opinion began to soften.

To meet objections freely urged against the system, the board in one of its early reports said:—

"The object of the national system is to afford facilities to persons of every denomination for the efficient education of their children in the same school, without prejudice to the conscientious convictions of any. National schools, therefore, are open upon equal terms to all, and adequate provision is made for supplying the two parts, secular and religious, of which a complete education consists. In reference to the former, it may suffice to state, that all the ordinary branches of an English education are taught in every national school. The religious instruction is divided into *general* and *special*. The general religious instruction is given by the teacher to all the children whose parents do not object, and is of such a character that all Christians may receive it without offence. It is intended that the special religious instruction should be given by clergymen, or other approved religious teachers, to the children of their respective persuasions, and every necessary arrangement is made for the purpose."

The books used in the national schools were those prescribed by the National Board in Ireland, and they included a series of ordinary reading books, and a set of four scripture books. A "general lesson" was always suspended on the school wall as a moral chart for the guidance of the pupils. It was read by teacher and pupils immediately before the dismissal of the school on Wednesday and Friday afternoons.

The ordinary reading books contained many lessons of a distinctly religious character. In the First Book the youngest children read such sentences as:—

> "God loves us and sent His son to save us." . . . . "It was God that made me at first." . . . . "It was He who sent Christ to save me"—and others in the same strain.

In the Second Book, besides lessons of a general character, there was an epitome of Scripture History from the "Creation" to the "Destruction of Sodom and Gomorrah."

In the Third Book the Scripture narrative was resumed in a series of lessons from the Old Testament, beginning with the "Birth of Isaac" and ending with the "Delivery of the Law."

In the Fourth Book, which was the most advanced reader used in many schools, there was a consecutive history of the Jewish Nation from the "Departure out of Egypt" to the "Accession of King Rehoboam," finishing with a lesson on "Christian Salvation."

The Scripture lessons are arranged in four books:—

O.T. No. 1 contains the Book of Genesis.

O.T. No. 2 contains the historical portions of Exodus and Numbers, with exhortation of Moses as found in Leviticus and Deuteronomy.

N.T. No. 1 contains Luke's Gospel.

N.T. No. 2 contains the Acts of the Apostles, and extracts from the Epistle and Psalms.

The "General Lesson" was printed on a large sheet and read as follows:—

"Christians should endeavour, as the Apostle Paul commands them, to live peaceably with all men. Rom. xii., 8."

"Our Saviour Christ commanded His disciples to love one another. He taught them to love their enemies, to bless those that cursed them, and to pray for those that persecuted them. He, Himself, prayed for His murderers."

"Many men hold erroneous doctrines; but we ought not to hate or persecute them. We ought to seek for the truth, and to hold fast what we are convinced is the truth; but not to treat harshly those who are in error. Our Saviour did not intend His religion to be forced on men by violent means. He would not allow His disciples to fight for Him."

"If any persons treat us unkindly we must not do the same to them, for Christ and His apostles have taught us not to return evil for evil. If we would obey Christ, we must do to others, not as they do to us, but as we would wish them to do to us."

"Quarrelling with our neighbours and abusing them is not the way to convince them that we are in the right, and they in the wrong; it is more likely to convince them that we have not a Christian spirit."

"We ought to show ourselves followers of Christ, who when He was reviled, reviled not again. 1 Peter ii., 23."

These extracts are given thus fully to justify my statement that the non-sectarian system of State education in New South Wales from its inception in 1848 has always regarded religion as an essential part of school education, and made due provision for both general and special religious instruction.

For eighteen years the two school boards carried on their work practically in competition with each other, with funds granted by the State. Serious complaints of overlapping and inefficiency were sent to the Government from time to time, and abortive attempts were made by Sir Charles (then Mr.) Cowper, and Mr. William Forster, successively, to get measures through Parliament to remedy defects. Sir Henry (then Mr.) Parkes, succeeded in passing the "Public Schools Act" at the end of 1866, by which the two existing boards were abolished, and a Council of Education was created to administer both National and Denominational Education. The national schools were designated *Public Schools*, but the system of teaching was not changed, and the books used in the national schools were retained.

The council acted with discretion, tact, and prudence in welding the two hitherto opposing forces into a united body. The work of the Denominational schools was brought more in touch with that of the Public schools. The first hour each day in the Denominational schools was devoted to the special religious instruction prescribed by the several churches, under the direction of the teachers. The other four hours were to be devoted to secular study, as in the Public schools.

The value placed on moral training in the schools by the Council is indicated in the following extract from a circular sent to the teachers in 1867:—

"Of even greater importance than effective and enlarged instruction is the moral training of the youth of the Colony. The formation of habits of regularity, cleanliness, and orderly behaviour; the inculcation of regard for the rights of property (public and private); the growth of a spirit of obedience to the law, and respect for duly constituted authority; the correct practical appreciation of the value of time as an element of worldly success; the implanting of a love for patient and sustained exertion in some industrial pursuit; and the development of character for energy and self-reliance are all points of the highest value, both to individual chidren and to the community at large. Honesty, truthfulness, temperance, and other virtues may be cultivated by school discipline; reverence for sacred things may be fostered; and, without any violation of the strict neutrality required between conflicting creeds, a religious spirit may be educed by a teacher who exhibits in the performance of his own duty the promptings of religious influence.

The first pleasing result of the new departure was the passing away of the bitter feeling that positions with conflicting interests had created; and the *esprit de corps* among the teachers grew stronger year by year. Matters moved along pleasantly and successfully for several years. Then politicians began to speak of the Department as unwieldy, and claimed that it should be administered by a Minister of the Crown. The cry of "Secular, compulsory, and free" education was also vigorously raised in connection with a proposal to withdraw State aid from the Denominational schools. After a well fought political battle "*The Public Instruction Act of* 1880" was passed. It provided that the Department should be placed under the control of a Cabinet Minister, and that State aid to Denominational schools should cease in 1882. But instead of making the education system secular, it made definite provision for the imparting of both general and special religious instruction in the Public schools.

Clause 7 of the Act provided that: "In all schools under this Act the teaching shall be strictly non-sectarian, but the words 'Secular Instruction' shall be held to include general religious teaching as distinguished from dogmatical or polemical theology."

Clause 17, provided that:—

"In every Public school four hours during each school day shall be devoted to secular instruction exclusively, and a portion of each day, not more than one hour, shall be set apart when the children of any one religious persuasion may be instructed by the clergyman or other religious teacher of such persuasion; but, in all cases, the pupils receiving such religious instruction shall be separated from the other pupils of the school. And the hour during which such religious instruction may be given shall be fixed by mutual agreement between the Public School Board, in consultation with the teacher of such school and the clergyman of the district, or such other person as may be duly authorised to act in his stead, and any class-room of any Public school may be used for such religious instruction by like agreement: provided that if two or more clergymen of different persuasions desire to give religious instruction at any school the children of each such different persuasion shall be so instructed on different days. Provided also that the religious instruction to be so given shall in every case be the religious instruction authorised by the church to which the clergyman or other religious teacher may belong."

Clause 18 provided that:—

. . . . "No pupil in a Public school shall be required to receive any general or special religious instruction if the parents or guardians of such pupil object to such religious instruction being given."

No actual change in the character or method of imparting religious instruction in the schools took place in connexion with the administrative changes that occurred. The old National School Reading Books, and the "General Lesson" disappeared from the schools, but the Scripture Lesson Books were retained. The existing school readers contain many lessons on Scriptural subjects, including historical narratives from the Old and New Testaments, and extracts such as the "Sermon on the Mount" and the "23rd Psalm."

It has always been recognised by both the Department and teachers that the General and Special Religious teaching in the Public schools is as much a part of the school curriculum as reading, writing, and arithmetic. For convenience sake in large schools where there are several classrooms all the special religious instruction classes are taken at the same time—usually the first lesson in the morning—twice per week. As the ordinary school lessons occupy only three-quarters of an hour, the special religious teachers confine their lessons within the same limits. It is not uncommon to meet two, and even three, clergymen arriving at a Public school at the same time in the morning to take their classes. Their intercourse with the teachers is of the most friendly character, and in these meetings ministers of different denominations are brought into kindly communion with one another. No friction of any kind takes place, the very opposite is the case. This special work is often taken at great personal inconvenience, but a reward is felt in the good done to the children. The visits are stimulating to the pupils, helpful to the teachers in their great work of character-building, and gratifying to the parents. Nor is the general religious instruction given by the teachers fruitless. The high moral tone in the Public schools generally is widely recognised, and increasing interest is manifested both by teachers and ministers of the gospel in the religious education of the children.

The list of national schools numbered only four at the close of 1849; at the end of 1907 there were 3,131 schools in operation under the Department of Public Instruction. For the December quarter of that year there were 209,229 scholars enrolled—Church of England, 109,306; Roman Catholic, 31,436; Methodist, 28,954; Presbyterians, 24,453, and other denominations, 15,080. There were 5,745 teachers of all ranks in the service; and 46,473 visits were paid to the schools by clergymen (or recognised substitutes), to give special religious instruction—viz., Church of England, 25,661 visits; Roman Catholics, 1,100; Methodists, 7,654; Presbyterians, 7,292; and other denominations, 4,766.

14.—SECONDARY TEACHING AND THE STATE.

By P. F. ROWLAND, M.A., Grammar School, Townsville.

15.—AIMS AND DIFFICULTIES OF THE EDUCATION OF GIRLS.

By Miss HELEN WHITE, M.A., Grammar School, Ipswich.

16.—SCIENTIFIC TEACHING OF TEMPERANCE IN PUBLIC SCHOOLS.

By Rev. J. WILLIAMS, Brisbane.

17.—THE LACK OF CREATIVE SPIRIT.

By F. BENNETT, State School, Maryborough West.

18.—SOME DEFECTS IN QUEENSLAND'S SYSTEM OF PRIMARY EDUCATION.

By W. M. G. TOLMIE, Toowoomba.

ABSTRACT.

A system has no permanency, but must be varied to suit the changing conditions of a community. This has been the experience of other countries, and Queensland is no exception to the rule. "*The Education Act of* 1875," which established the system of primary education in Queensland, no doubt marked the advanced educational thought when it was framed. It sought to provide an opportunity for the instruments of culture—reading, writing, and arithmetic—to be acquired by the children of Queensland, as it was recognised that the form of Government in this State was democratic, and in order that this type of Government should produce the best results the education of the masses was very essential. In 1875 an intellectual education was all that was deemed to be necessary. The educational thought of to-day, which recognises that the aim of education is to secure the maximum of happiness, lays down the principle that happiness cannot be fully acquired without a religious, intellectual, and physical education; that "the people's school has more to do than merely teach the vehicles of culture—reading, writing, and arithmetic—that the chief aim is rather the preparation of citizens who can, and will, cheerfully serve their God, and their country as well as themselves.' Our primary system is defective inasmuch as it does not afford to the children who become the mass of the people a religious or moral training; it does not effectively teach them that as citizens they owe obligations to the State, and that the State is under obligations to them. It does not prepare the hundreds of children annually leaving school for the economic battle of life by instructing them in the reciprocal duties of employer, and employee. The child is thrown on the world's market quite unprepared with a knowledge of the duties of citizenship, and the result has been the cause of much social evil. Our primary system, whilst it succeeds in giving the child knowledge of the vehicles of culture, fails in supplying the kind of knowledge which increases his happiness, and his value as a citizen.

19.—CO-ORDINATION OF SCIENCE IN SCHOOLS.

By R. A. GRIEVE, B.A., Inspector of Schools, New South Wales.

ABSTRACT.

The national importance of science as a factor in the development of the resources of a country, and of the commercial activities and corporate efficiency of its people, is recognised by an ever-increasing number.

The development of science has been due not only to the workers in research laboratories, but to research methods of study.

In our own country co-ordination of science teaching needs adjustment so as to prevent waste of educational effort.

The impulse for science teaching is due to three motives—(1) Educational or cultural; (2) Industrial or vocational; (3) Sociological.

Sociological considerations require that science teaching should reach a greater number of people than it reaches at present. Since about 20 per cent. of the population are in the elementary schools,

and since only a small percentage of these now go beyond that stage in their school education, elementary science should be taught in the elementary schools in conformity with pedagogical laws.

The efficiency of "nature study" and of elementary science depends on the soundness of the principles of general method which govern educational effort. Demonstration is necessary, but not sufficient, heuristic methods must be supplemented and reinforced by didactic and literary methods. Training in scientific method is of more importance than the mere knowledge of facts. Every boy and girl attending the elementary school should acquire a taste for the scientific method of inquiry, and an interest in laboratory methods. The training of primary school teachers for elementary science teaching is an indispensable condition of its success.

The work begun in the elementary schools should be continued in the various types of secondary schools, or secondary school departments—Literary, commercial, and technological.

Differentiation in the type of school implies differentiation in the science curriculum. The secondary school, being a finishing school for life—in the case of the majority of its students—as well as a "fitting" school for higher professional or technological institutions, needs to adapt its science teaching and science curriculum to vocational as well as cultural needs.

Provisions must be made—(1) For those who leave the higher elementary school at 15; (2) for those who leave the secondary school at 16; (3) for those who leave the secondary school at 17 or 18.

Further provision must be made in day and evening continuation schools for those who, at fourteen years of age, take up the work of life either as unskilled workers or as apprentices. Legislation to make attendance obligatory upon both employer and employee is necessary. Science teaching in these schools would be combined with general education in English, mathematics, and manual work in the school workshop. Those whose education and ability qualify them to profit by the instruction would enter the lower technical schools where the education of most boys of this class would probably end. But a ladder should be provided for those whose ability and attainments are such as to enable them to profit by the instruction in the higher technological school which should be of university rank, but would deal more exclusively with what may be termed "industrial" science.

The university science courses would comprise pure science and professional courses. Where motives of economy render the simultaneous establishment of both a university and a higher technological school impracticable, the functions of both would be performed by a university of the type of the New Universities of England and America.

Both institutions, the university and the technological school, should have research laboratories mutually helpful, but each developing its own special functions in its own way.

Boston, Edinburgh, Manchester, and Leeds are compared as representing—(1) A separation of the two functions, and (2) a uniting of the two functions.

20.—THE PURPOSE OF EDUCATION.

By the Rev. D. J. GARLAND, late Archdeacon of North Queensland.

ABSTRACT.

The aim of true education is to secure the social efficiency of the future members of the State. The educational problem, therefore, will be settled not in sections, but by establishing a system organic to the whole life of the State. The kind of social individual who is turned out is the true test of any system of education. This is not fully recognised outside educational circles. A contrast in the growth of educational methods with half a century back; then unsuitable, overcrowded, insanitary buildings, severe discipline; to-day well lighted, ventilated, and sanitary buildings, discipline no longer a terror. The goal to-day to be aimed at is the training of the child in his whole nature, physical, economic, ethical. No one of these without the others is complete. Each co-related and interdependent. The word mind no longer limited to acts of memory. This faculty, call it what you please, must be trained as a necessary and integral part of the daily education. No casual or occasional method is sufficient, any more than for arithmetic or gymnastics. Differences of opinion exist as to methods of training the ethical side. These differences arise from causes for which educationalists are not responsible, but they must not wait till the churches can settle their squabbles. A solution must be found by which the child's ethical nature will be trained and developed, otherwise all our improvements in educational methods are thrown away. The churches are inadequate in their machinery, nor is it their exclusive function to provide the ethical training of future members of the State. Notwithstanding the great debt owed to the Church for its educational work for many centuries, the day has gone by for the Church to claim sole control of education, or to fail to work in harmony with the State on the subject. Australian thought is entirely against any return to any resemblance of education under ecclesiastical control, but still desires some kind of ethical training for the children. The problem has been solved to the satisfaction of the vast majority of persons in the States of New South Wales, Tasmania, and Western Australia. Progress of democracy has altered the relations of Church and education to the incalculable gain to education, by permeating the State with a sense of responsibility for the education of every child; but the State will fail quite as much as ecclesiasticism failed, and prove itself equally narrow, illiberal, and uninformed, if it is satisfied only with providing for physical, economic education, and shuns, because of difficulties which elsewhere have been overcome, any provision for ethical education without which the other parts are inadequate. Face to face with democratic powers and vaster democratic ideals, it is imperative if we are to place the true interest and government of the community beyond the reach of forces of dissolution and decay, that careful provision must be made for physical, economic, and ethical training of each individual in our community.

ADDENDUM

TO

CATALOGUE OF MARINE MOLLUSCA OF QUEENSLAND (pp. 343-371).

By C. Hedley.

While this volume was passing through the press, the Linnean Society of New South Wales published my article on the shells of Hope Islands. From this and other sources I can now add many names to the foregoing list, raising the total to 1,900 species of marine mollusca recorded from Queensland.

Pelecypoda.

Lissarca picta, Hedley, 1899: *Austrosarepta*
Glycymeris australis, Quoy and Gaimard, 1835; *Pectunculus*
hanleyi, Angas, 1879; *Axinæa*
G. pectunculus, L., *should be* G. amboinensis, Gmelin, 1791; *Cardium*
Ostrea hyotis, Linne, 1758
Pecten pyxidatus, Born, 1778; *Ostrea*
Chlamys radula, Linne, 1758; *Ostrea*
spectabilis, Reeve, 1853; *Pecten*
corymbiatus, Hedley, 1909
Amusium japonicum, Gmelin, 1791; *Ostrea*
Placuna sella, Gmelin, 1791; *Anomia*
papyracea, Lamk, 1819
Modiola vagina, Lamarck, 1819
Mytilus ater, Zelebor, 1866
Modiolaria subtorta, Dunker, 1857; *Modiolarca*
splendida, Dunker, 1857; *Volsella*
Anatina anatina, Linne, 1758; *Solen*
Myadora pandoriformis, Stutchbury, 1830; *Anatina*
Hemicardium donaciforme, Schroeter, 1786; *Cardium*
Cuna capillacea, Hedley, 1909
praecalva, Hedley, 1909
Codakia simplex, Reeve, 1850; *Lucina*
Phacoides rugosus, Hedley, 1909
sperabilis, Hedley, 1909
Sportella jubata, Hedley, 1909
sperabilis, Hedley, 1909
Rochefortia viastellata, Hedley, 1909
Cardium setosum, Redfield, 1846
Dosinia mira, Smith, 1885
scalaris, Menke, 1843
Gafrarium catillus, Hedley, 1909
Chione nitida, Quoy and Gaimard, 1835; *Venus*
paucilamellata, Dunker, 1858; *Mercenaria*
scandularis, Hedley, 1909
Petricola pseudolima, Souverbie, 1862
Tellina etesiaca, Hedley, 1909
T. donaciformis, Desh., *should be* T. lilium, Hanley, 1844
Arcopagia dapsilis, Hedley, 1909
Semele isosceles, Hedley, 1909
Theora nasuta, Hedley, 1909
Mactra rufescens, Lamarck, 1818.

Gasteropoda.

Gibbula dacostana, Preston, 1909
tenuilirata, Preston, 1909
Monilea cinerea, Preston, 1909
Cyclostrema anxium, Hedley, 1909

Liotia anxia, Hedley, 1909
tribulationis, Hedley, 1909
Leptothyra crassilirata, Preston, 1909
Neritina crepidularia, Lamarck, 1822
oualaniensis, Lesson, 1830
Obtortio vulnerata, Hedley, 1909
Ergæa walshii, Reeve, 1856
Capulus violaceus, Angas, 1867
Cerithiopsis pinea, Hedley, 1909
telegraphica, Hedley, 1909
tribulationis, Hedley, 1909
westianum, Hedley, 1909
Triphora tribulationis, Hedley, 1909
Crossea concinna, Angas, 1867
Vermicularia deposita, Hedley, 1909
Epitonium koskinum, Hedley, 1909
Odostomia abjecta, Hedley, 1909
adipata, Hedley, 1909
anxia, Hedley, 1909
articulata, Hedley, 1909
chorea, Hedley, 1909
gumia, Hedley, 1909
laquearia, Hedley, 1909
maccullochi, Hedley, 1909
migma, Hedley, 1909
sperabilis, Hedley, 1909
tribulationis, Hedley, 1909
Turbonilla gabrieli, Hedley, 1909
perscalata, Hedley, 1909
taylori, Hedley, 1909
tenuissima, Hedley, 1909
tribulationis, Hedley, 1909
Eulima conaminis, Hedley, 1909
piperita, Hedley, 1909
Architectonica maxima, Philippi, 1848; *Solarium*
Gyrineum rubicola, Perry, *should be* Bursa granularis, Bolten, 1798; *Tritonium*
Trivia scabriuscula, Gray, *should be* T. oryza, Lamarck, 1810
Trivia grando, Gaskoin, *should be* T. edgari, Shaw, 1909
Marginella anxia, Hedley, 1909
Glyphostoma ocellatum, Jousseaume, 1884
Mangilia anxia, Hedley, 1909
calcata, Hedley, 1909
infulata, Hedley, 1909
naufraga, Hedley, 1909
perissa, Hedley, 1909
rigorata, Hedley, 1909
Drillia livida, Gmelin, 1791; *Strombus*
Nassaria mordica, Hedley, 1909
Arcularia candens, Hinds, 1844; *Nassa*
Pyrene albina, Kiener, 1841; *Columbella*
Thais tritoniformis, Blainville, 1833; *Purpura*
Drupa anaxares, Duclos, 1832; *Purpura*
Pythia chrysostoma, Tapp.-Canefri, 1883
Retusa impasta, Hedley, 1909
pharetra, Hedley, 1909
Cylichna collyra, Melvill, 1906

LIST OF MEMBERS

OF THE

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE FOR THE YEAR ENDING JUNE, 1909.

Armati, Percy, Pharmaceutical Chemist, Mackay
Agnew, Miss M., Girls and Infants' State School, Woolloongabba
Ayscough, A. L., Cork Station, Winton
Aitcheson, H., Pharmaceutical Chemist, Charters Towers
Allen, F. C., Pharmaceutical Chemist, Ipswich
Andrews, G., State School, Barolin
Allom, S. R. F., Edward street, Brisbane
Allan, James, care of Messrs. Allan and Stark, Queen street
Abbott, W. E., Wingen, N.S.W.
Adams, G. H. M., Broughton Cottage, Waverley, N.S.W.
Armitage, R. W., Continuation School, Melbourne, V.
Ashton, Rev. J. W., Rectory, St. Andrews, South Brisbane
Allan, Mrs., Messrs. Allan and Stark
Adcock, G. H., Rutherglen, Victoria
Anderson, Dr. C., Australian Museum, N.S.W.

Brünnich, J. C., F.I.C., F.C.S., Chemist, Department of Agriculture
Badger, J. S., General Manager, Brisbane Tramway Company, Countess street
Bousfield, F. S. N., M.A., Boys' Grammar School, Brisbane
Beet, J. F., State School, Coorparoo
Bevington, W. J., State School, Sandgate
Bell, D. J., Central State School, Brisbane
Bancroft, Peter, M.B., and Ch. M., Ann street, Brisbane
Bell, N. M., Assoc. M. Inst. C.E., Consulting Engineer, 356 Queen street, Brisbane; and Sydenham, Wickham terrace
Bourne, Miss C. E., Girls' Grammar School, Maryborough
Bannerman, Adam, State School, Wilsonton, Toowoomba
Bell, Norris G., M. Inst. C. E., Deputy Chief Engineer of Railways, Central Station
Board, Peter, M.A., U.S. and Director, Department of Public Instruction, Sydney
Bleek, Wm. A., Electrician, Adelaide street
Byram, W. J., care Messrs. Byram and Hawthorn, Solicitors, 303 Queen street
Briggs, J., State School, South Brisbane
Blair, J. W., M.L.A., Lutwyche Chambers, Adelaide street
Broe, Miss Helena, Girls' Central School, Charters Towers
Bourne, Eleanor, M. B., Wickham terrace, Brisbane
Ball, L. C., B.E., Assistant Government Geologist, Mines Department
Bennett, Fred, State School, Maryborough West
Baldwin, D., State School, Red Hill, Mount Morgan
Beattie, Miss E. J., Gowrie House, Wickham terrace
Batty, Rev. F. de Witt, M.A., Bishopbourne, Rosalie
Bernays, C. E., 45 Adelaide street, Brisbane
Breen, Rev. Father, Presbytery, Kangaroo Point
Brunnich, Karl F. C., Daheim, Taringa
Brunnich, Mrs. J. C., Daheim, Taringa
Bailey, Miss Margaret A., Hume street, Toowoomba
Beer, Wm., State School, Clifton
Brydon, Mrs., Principal, Technical College, South Brisbane
Brydon, Miss, care of Principal, Technical College, South Brisbane
Badger, Mrs. J. S., Toowong
Barton, Miss F.

Blake, C. E., Pharmacy College, Elizabeth street, Brisbane
Bennett, G. W., 127 Queen street
Belfield, A. H., Dumaresq, N.S.W.
Barlow, Hon. A. H., M.L.C., Toowong
Bailey, J. F., Director, Botanic Gardens, Brisbane
Bage, Miss F., M.Sc. University, Melbourne
Barkley, H., 9 Denham street, Hawthorn, V.
Bundey, Miss Ellen M., Mus. Bac., 148 Molesworth street, North Adelaide
Benson, W. N., B.Sc., University, Adelaide
Brown, Professor W. Jethro, LL.D., University, Adelaide
Bragg, Professor W. H., M.A., F.R.S., University, Adelaide
Budd, Thomas, Albion
Bowes, Rev. J., Bayview terrace, Wooloowin
Barnett, L. E., F.R.C.S., L.R.C.P., M.B., C.M., 83 Stafford street, Dunedin
Bernays, Mrs. C. E., 45 Adelaide street
Bundock, C. W., Cooralbyn, Beaudesert
Bundock, Mrs. C. W., Cooralbyn, Beaudesert
Barrett, Rev. Bro. J. J., Nudgee College
Bailey, A. R., Malvern, Victoria
Barton, E. C., M.L.A., Electric Supply Company, Ann street
Bancroft, Mrs. P., Ann street
Bevington, Mrs., Sandgate
Beit, Mrs. L. S., Toowoomba
Billbrough, Ernest, State School, Aspley
Bridges, F. T., A.M.P. Society, Queen street
Bragg, H. O., Adelaide, S.A.
Bragg, R. C., Adelaide, S.A.
Beet, Mrs. J. F., Coorparoo, Brisbane
Berry, Professor Richard, M.D., University, Melbourne
Bell, Hon. J. T., M.L.A., Speaker, Legislative Assembly, Brisbane.
Burne, Dr. W. S., Ann street

Chater, A. B., care of Messrs. Thomason and Chater, Manufacturing Chemists, 69 Queen street and Woolloongabba
Curd, E. J., State School, Dunellan
Collins, W. J., State School, Breakfast Creek
Cummings, James, State School, Wynnum
Cleminson, James, State School, North Rockhampton
Colledge, W. R., Friendly Societies' Dispensary, 344 Queen street
Caldersmith, G., State School, Townsville Central
Cameron, J. A., M.D. and B.S., Ipswich
Considine, F. J., Friendly Societies' Dispensary, 344 Queen street
Crofts, Alfred, Pharmaceutical Chemist, Nambour
Carvosso, A. B., M.B., Ch.M., George st., Brisbane
Crellin, James, State School, Bulimba
Chelmsford, His Excellency Lord, Government House, Brisbane
Chelmsford, Lady, Government House, Brisbane
Carter, H. J., Ascham, Darling Point, Sydney
Cameron, Walter, B.A., Assistant Government Geologist, Mines Department
Cameron, Mrs. Walter, care of Assistant Government Geologist, Mines Department
Corrie, L. G., F.L.S., F.Q.I.A., Bowen terrace
Crase, Alderman John, Warren street, Valley
Cribb, Miss Estelle M. B., Gooloowan, Ipswich
Cleland, W. Lennox, M.D., C.M., Parkside, S. Australia
Cooper, Mrs. Lena, Provisional School, Carrara, Nerang
Cottell, R. J., junr., M.L.A., 282 Queen street, Brisbane
Carter, Hon. A. J., M.L.C., 444 Queen street, Brisbane
Costin, C. W., Clerk, Legislative Council, Brisbane
Crosser, Miss A. E., Wienholt street, Auchenflower
Cargeeg, Miss Say, Girls' High School, Ivanhoe, Toowoomba
Cargeeg, Miss Ida, Girls' High School, Ivanhoe, Toowoomba
Carson, Miss, Grammar School, Brisbane
Connellan, J. D., Pharmaceutical Chemist, Red Hill
Case, J. W., J.P., Pharmaceutical Chemist, Wickham street
Clarke, D. J., care of Messrs. Thomason and Chater, Queen street
Cribb, J. George, Milton

Carvosso, Mrs. W. H.
Cribb, Mrs. J. George, Milton
Card, G. W., Geological Survey, Mines Department
Cox, A. F., Messrs. D. and W. Murray, Creek street, Brisbane
Carment, David, A.M.P. Society, Pitt street, Sydney, N.S.W.
Carment, Mrs. D., A.M.P. Society, Pitt street, Sydney, N.S.W.
Carment, Miss, A.M.P. Society, Pitt street, Sydney, N.S.W.
Cambage, R. M., Department of Mines, N.S.W.
Chapman, Dr. H. G., The University, Sydney
Cook, W. E., M. Inst., C.E., Carlow street, North Sydney
Colley, D. J. K., Royal Mint, Sydney
Crago, Dr. W. H., 16 College street
Cooper, His Honour Sir Pope, K.C.M.G., Bowen terrace, Brisbane
Chambers, John, Motopeka, Hastings, Napier, N.Z. (Life Member)
Cornish, G. P., Second Avenue, East Adelaide
Chapman, Professor R. W., M.A., B.C.E., University, Adelaide
Cooke, W. T., D.Sc., University, Adelaide
Clark, Miss Caroline, Knightsbridge, S.A.
Clark, Miss E., Knightsbridge, S.A.
Chambers, Miss N., Prospect, S.A.
Cox, Miss Katherine H., Wakefield street, Adelaide
Coughlin, P. M., care of Thomason, Chater, and Co., Queen street
Cowell, Sidney W., care of W. A. McGuffie and Co., Queen street
Cowley, R. C., Director, College of Pharmacy
Chilton, Charles, M.A., D.Sc., F.L.S., Professor of Biology, Canterbury College, Christchurch
Clarke, Ede C., Geological Survey, Wellington
Clewett, Hon. F., M.L.C., Riverview terrace, Hamilton
Clewett, Miss, Riverview terrace, Hamilton
Collins, William, Nindooimbah, Beaudesert
Connah, F. E., Government Analyst's Department
Carroll, C. J., Manly, Sydney
Connellan, Mrs. J. D., New Farm
Connellan, Miss, New Farm
Colledge, Miss, Swan's Road, Taringa
Cosgrove, Jos., Ipswich road
Collins, Miss, Mundoolan
Collins, George, Mundoolan
Copeland, Rev. L. T., Grove street, Toowong
Cooper, Miss, Bowen terrace, Brisbane
Carroll, C. J., President, Pharmaceutical Society, N.S.W.
Cumpston, J. H. L., M.D., D.P.H., Central Board of Health, Perth
Costin, W. J., Ph.C., Wickham street

Dempsey, J. J., State School, Junction Park
D'Weske, E. R., Pharmaceutical Chemist, East street, Rockhampton
Davidson, J., Pharmaceutical Chemist, Bundaberg
Dixon, Rev. Horace H., M.A., High School, Southport
Desmond, J., Government Veterinary Surgeon, Adelaide, S.A.
Dempsey, Mrs. J. J., State School, Junction Park
Dunstan, Benjamin, Government Geologist, Mines Department
Duffield, W. Geoffrey, D.Sc., Sea Wall, Glenelg, S.A.
Donaldson, His Grace St. Clair, D.D., Archbishop of Brisbane, Bishopbourne, Milton
Doak, W. J., B.E., Assistant Engineer, Chief Engineer's Office, Central Station, Brisbane
Dean, Hon. John, M.L.C., Parliament House, Brisbane
Davidson, Wm., Clevedon, Oxley
Davey, Hon. A. A., M.L.C., Auchenflower
Davey, Mrs. A. A., Auchenflower
Davey, Master A. H., Auchenflower
Denham, Hon. D. F., M.L.A., Logan road, Junction Park
Deane, Henry, Equitable Buildings, George st., Sydney
Dixson, Hugh, 100 The Strand, Sydney
Dixson, Dr. Thos., 157 Macquarie street, Sydney
Docker, Judge, Eltham, Woolahra, Sydney
Dun, W. S., Department of Mines, Sydney

Deacon, Miss Mary, Girls and Infants' State School, Bundaberg Central
Danks, A. T., 391 Burke st., Melbourne
Daley, C., Buckland's Avenue, Geelong, V.
Donaldson, J. E., Wickham street, Valley
Donaldson, Master, Wickham street, Valley
Downes, Mrs., Charters Towers
Dinning, Rev. H., Coorparoo, Brisbane
Dennis, Jas., M.A., Flood street, Bondi
Dixson, Miss A. S., care of Dr. T. S. Dixson, 157 Macquarie street, Sydney
Darcy, Miss, West End

Edwards, E. E., Bryntirion, Wickham terrace
Exley, Arthur, State School, Ithaca Creek
Edwards, M. M., care Messrs. Nicol Robinson, Fox, and Edwards, 272 Queen street
Enys, J. D., F.G.S., Enys Castle, Penrhyn, Cornwall, England (Life Member)
Easterfield, T. M., M.A., Ph.D., F.I.C., F.C.S., Professor of Chemistry, Victoria College, Wellington
Exley, Mrs. A., Bardon, Paddington

Freeman, J. B., State School, Eagle Junction
Franklin, Charles George, State School, Capella
Foxton, J. G., M.H.R., care of Messrs. Foxton, Hobbs, and McNish, Albert street
Forbes, Alexander, Pharmaceutical Chemist, Stanley street, South Brisbane
Falkner, Edgar A., M.B., L.R.C.P., F.R.C.S., Toowoomba
Flint, C. A., M.A., Technical College, Ipswich
Fisher, T. G., State School, Kangaroo Point
Firkin, A. J., care of Messrs. Allan and Hanbury, Sydney
Flint, A. C., Kendall street, Ipswich
Fortescue, Miss, Girls' State School, Kangaroo Point
Fennelly, R., C.E., Kilmore, Victoria
Forsythe, Miss Harriette, Imperial Hotel, Gatton
Ferguson, Miss Eleanor, Central Post Office, Brisbane
Forsyth, P. H., State School, Glenvale, Toowoomba
Fraser, C. S., care of Messrs. Flavelle and Sankey, Queen street
Fowles, J. K., State School, Gatton
Forrest, John, Bowen terrace, Brisbane
Fox, George, M.L.A., Parliament House, Brisbane
Forsyth, Mrs. P. H., State School, Glenvale, Toowoomba
Foreman, Dr. Joseph, 141 Macquarie street, Sydney
Fryar, Wm., Coorparoo
Fowler, T. Walker, M.C.E., M. Inst., C.E., 421 Collins street, Melbourne, Victoria
Ferguson, Andrew, B.Sc., School of Mines, Adelaide
Farr, Coleridge C., D.Sc., A.M.I.C.E., Canterbury College, Christchurch
Fewtrell, John, State School, Townsville West
Ferguson, J., care of Messrs. Watson, Ferguson, and Co.
Forster, A., Pharmacy Board, Sydney
Frackelton, Rev. Dr., Ann street Brisbane
Frackelton, Mrs, Ann street, Brisbane
Forster, A., Pharmaceutical Society, N.S.W.
Freeman, W., New South Head road, Double Bay, Sydney
Freeman, D. S., New South Head road, Double Bay, Sydney
Fletcher, J. J., M.A., B.Sc., Linn. Soc., N.S.W.
Gailey, Richard, Architect, Courier Buildings
Guinane, James, State School, Millchester, Charters Towers
Gibson, A. J., M.A., Ph.D., Bingera, Bundaberg
Grimes, R. F., Valley Corner (Dentist)
Gurney, E. H., Vulture street West, near Hampstead road, South Brisbane
Gordon, Alexander M., Friendly Societies' Dispensary Company, Gill st., Charters Towers
Gibson, Dr. J. Lockhart, M.D., Wickham terrace
George, John, B.A., State School, Indooroopilly
Gordon, J. P. J., Pharmaceutical Chemist, Rockhampton
Graham, C. S., B.A., Technical College, Brisbane

Gross, George, Grammar School, Brisbane
Gullett, Hon. Henry, M.L.C., Wahroonga, N.S.W.
Gray, Wm. Thos., State School, Gowrie Little Plain, Toowoomba
Guthrie, F.B., F.I.C., F.C.S., Chemist, Department of Agriculture, Sydney
Gryst, E. F., Semaphore road, Exeter, S.A.
Greenfield, W. H., Geological Survey Office, Mines Department, Brisbane
Griffith, H. H., 61 Hurtle Square, Adelaide
Gard, Henry J., Brisbane Hospital
Gaydon, Thomas, Pharmaceutical Chemist, Childers
Gray, Hon. G. W., M.L.C., Hamilton
Goldsmith, A. J., Moray street, New Farm
Goddard, E. J., The University, Sydney
Goodlet, J. M., Canterbury House, Ashfield, N.S.W.
Graham, George, Redan street, Mosman, Sydney
Greig-Smith, Dr. R., Linnean Society, Elizabeth Bay, Sydney
George, Mrs. John, State School, Indooroopilly
Gibson, Mrs. Lockhart, Wickham terrace
Grey, F. J., State School, Gowrie Creek
Greene, Miss A., Wynnum
Garland, Rev. David, Holy Trinity, Woolloongabba, Brisbane
Grieve, R. M., B.A., Penkivil street, Bondi, Sydney
Gregory, Professor J. W., D.Sc., F.R.S., care of Messrs. Courtney and Dunn, Melbourne
Groom, Hon. L. E., Toowoomba

Henderson, J. B., F.I.C., F.C.S., Government Analyst, Executive Buildings, William street
Hunter, R. D., State School, North Pine
Hogbin, Miss Annie, Girls' State School, Central Ipswich
Halford, A. C. F., M.D., Turrawan, Clayfield
Hirst, Miss L., Girls' Central School, Gympie
Holland, C. W., Lands Department, Executive Buildings
Hall, Robert, F.L.S.., C.M.Z.S., Museum, Hobart
Hunt, G. W., Ph.M.P., Post Office, Southport
Holdaway, Edwin, State School, Kolan South
Hamilton, D. C., Central State School, Rockhampton
Hurley, Timothy, Boys' State School, Mackay
Holdaway, E. W., State School, Kolan South
Hunt, Miss Fanny E., Girton College, Toowoomba
Hardy, Miss C. E., Girls' State School, Mount Morgan
Hunter, Robert, Mines Department, Gympie
Hirschfeld, Eugen, M.D., Wickham terrace, Brisbane
Hicks, John, River terrace, Milton
Hicks, Mrs. John, River terrace, Milton
Hicks, Master Victor, River terrace, Milton
Hooper, Loftus, Laidley
Hooper, Miss M., State School, Milton
Hooper, Miss, Barrington road, Baroona Hill, Milton
Hardgrove, Miss A., Ridley street, Auchenflower
Hall, Hon. T. M., M.L.C., Corinda
Hughes, E. F., Gladstone road, South Brisbane
Hughes, Mrs. E. F., Gladstone road, South Brisbane
Harrison, G. R., Beecroft
Henderson, J., City Bank, Sydney
Helms, R., 136 George street, Sydney
Haswell, Professor, The University, Sydney
Halligan, G. M., Public Works Department, Sydney
Hedley, C. M., Australian Museum, Sydney
Hodder, Samuel, Menevia, Balmain, Sydney
Heron, J. S., Pennant Hills, Sydney
Hamlet, W. M., Department of Public Health, Sydney, N.S.W.
Hamlet, Mrs., Department of Public Health, Sydney, N.S.W.
Hamlet, Miss, Department of Public Health, Sydney, N.S.W.
Ham, Dr. Burnett, M.D., M.R.C.S., Director, Health Department, Brisbane
Harwood, S. J., State School, Warwick East
Hall, T. S., M.A., D.Sc., University, Melbourne
Howchin, Walter, F.G.S., University, Adelaide

Hamilton, Augustus, Dominion Museum, Wellington
Hogg, Evelyn G., M.A., Christ's College, Christchurch
Hewitt, Mrs. care of J. S. Badger, Toowong
Hurworth, E., State School, Rocklea
Henderson, Mrs. J. B., care of Government Analyst
Hopkins, Dr., North Quay
Hurworth, Dr. C. W., Edward street, Brisbane
Hewitt, T. C., Gowrie House, Wickham terrace; or Grammar School, Toowoomba
Hussey, G. F., Currie street, Adelaide

Illidge, Rowland, Union Insurance Company, Eagle street
Ingram, Alexander, Hamilton, V.
Iredale, T., care of Charles Hedley
Iredale, Mrs., care of Charles Hedley
Irving, Colonel, Ann street, Brisbane

Jackson, S. T., State School, Mount Gravatt
James, R., Pharmaceutical Chemist, Gatton
Jubb, E. St. V., Pharmaceutical Chemist, Ruthven street, Toowoomba
Johnston, James, State School, Kangaroo Point
Jack, R. L., LL.D., Consulting Mining Geologist, Norwich Chambers, Hunter street, Sydney
Jack, Mrs. R. L., Norwich Chambers, Hunter street, Sydney
Jones, Mrs. A. R., Darthula, Cordelia street, South Brisbane
Jones, Miss M., Darthula, Cordelia street, South Brisbane
Jones, Percy W., A.I.C., Technical College, Rockhampton
Jones, Mrs. Percy W., Rockhampton
Johnston, Mrs. Jas., Neereeadah, Kangaroo Point
Jackson, Alfred G., 65 Ann st., Brisbane
Jensen, Hon. Marcus, M.L.C., care of Messrs. Ruthning and Jensen, George street, Brisbane
Just, Wm., Pharmaceutical Chemist, Clifton
Johnson, Hon. T. A., M.L.C., Warwick
Jacobs, A. T., Prospect, N.S.W.
Josephson, J. P., 81 Elizabeth street, Sydney
Jensen, H. I., D.Sc., Plunkett street, Drummoyne
Johnson, E. Angas, M.D., Adelaide
Jensen, Miss Clio, Valhalla, Caboolture
Johnston, T. H., Bureau of Microbiology, Board of Health, Sydney.
Jackson, Mrs. C. T. V.

Kidd, Thomas, State School, Stafford-on-Kedron
Keys, James, State School, Norman Park
Kerr, J. S., Ardgare, Gregory terrace, Brisbane
Kemp, Charles, Central State School, Maryborough
Kerr, Mrs. J. S., Ardgare, Gregory terrace, Brisbane
Kerby, T. G., State School, Wellington Point
Kemp, Mrs. Chas., Central State School, Maryborough
Kidston, Hon. W., M.L.A., Parliament House, Brisbane
Knox, E. W., 5 O'Connell street, Sydney
Knibbs, G. H., F.S.S., F.R.A.S., Commonwealth Statistician, Melbourne, V.
Kerby, Mrs. T. G., State School, Wellington Point
Kerby, Miss Veda, State School, Wellington Point

Large, Miss E. P., Girls' State School, Brisbane Central
Lunn, John, Pharmaceutical Chemist, Sandgate
Lucas, T. P., L.S.A., R.C.P., Wakefield's Buildings, Adelaide street, Brisbane
Le Fanu, Archdeacon H. T., M.A., Diocesan Registry, Ann street
Long, Benjamin, State School, Leichhardt Ward, Rockhampton
Lethem, C. B., Urrbrae, Clayfield
Longworth, M. A., Central State School, Rockhampton
Lloyd, W. F., Ganges street, West End
Lamont, A. J., Union Trustees Company, George and Queen street
Lenehan, R., Clarence Pharmacy, Stanley street, South Brisbane
Laurence, C. A., Albert road, Strathfield

Littlejohn, Dr. E. S., Young street, Croydon
Liversidge, Professor, United Universities' Club, Suffolk street, Pall Mall, L.
Lucas, A. H. S., Grammar School, Sydney
Lucas, Mrs., Grammar School, Sydney
Leadbeater, J., Grammar School, Rockhampton
Lambert, C. A., Bank of N.S. Wales, Warwick
Love, E. F. J., M.A., D.Sc., F.R.A.S., University, Melbourne
Little, Rev. W., Sherwood
Laverack, Dr. (Muriel), Kangaroo Point, East Brisbane
Loney, T S., William street, Sydney
Love, Dr. Wilton, Wickham terrace
Love, Mrs., Wickham terrace
Larcombe, Mr. C. O. G., Kalgoorlie School of Mines
Lusby, Sydney Gordon, Stanmore road, Stanmore, Sydney
Legge, Colonel W. O., F.R.G.S., Cullenwood House, Cullenwood, Tas.
Lord, F., Marathon, Oriel road, Albion

Morris, John, State School, Beenleigh
Marshall, C. W., State School, Nerang
Morton, C. R., State School, Jones Hill, Gympie
Minnis, J. A., Pharmaceutical Chemist, Mount Morgan
Morgan, Sir Arthur, K.C.M.G., M.L.C., Warwick
Marshall, Mrs. Elvina, Nerang
Muir, Andrew, State School, Mundingburrah, Townsville
Marshall, Miss Charlotte, Stratton House, Commercial road, Brisbane
Mackie, R. Cliffe, Wieanbien, Hamilton
Munro, James, Hamilton road, Hamilton
Munro, Mrs. James, Hamilton road, Hamilton
Marks, Hon. C. F., M.D., M.L.C., Wickham terrace, Brisbane
Murphy, Hon. P., M.L.C., Hamilton
Marshall, G. W., Pharmaceutical Chemist, Valley
Monteith, H., Queen street
Mingaye, G. C. H., Department of Mines, Sydney
Miles, E. H., Wentworth road, Burwood
Matthews, R. H., Hassall street, Parramatta
Maiden, J. H., Botanic Gardens, Sydney
Mackie, Mrs. R. Cliffe, Riverview terrace, Hamilton
Mowbray, Mrs. James, Tekowai, Vulture street, South Brisbane
Matheson, Geo. C., 272 Queen street
Masters, Rev. F. G., M.A., Holy Trinity Vicarage, Balaclava, V.
Morgan, P. G., M.A., A.O.S.M., Geological Survey, Wellington
Marshall, Ptk., M.A., D.Sc., F.G.S., Professor of Geology, Otago University
Mitford, W. W., 45 Queen street
Mackay, Miss Emily, Riverview terrace, Hamilton
Malaher, Dr. A. E., Nambour
Moseley, Miss, Brookes street, Bowen Hills
Morison, Miss M., Dauphin terrace, Dornoch terrace, South Brisbane
Mackie, A., M.A., 157 Macquarie street, Sydney
Marks, E. O., B.A., Assistant Government Geologist, Brisbane
Muir, Alexander, Queen street, Brisbane
Mitchell, John, Technical College, Newcastle
Macdonald, John, Moray street, New Farm

McConnel, J. H., B.A., Cressbrook Station, *viâ* Toogoolawah
McNamee, Thos., State School, Hendon
McCullough, D. B., His Worship the Mayor of South Brisbane, Stanley street, South Brisbane
McIlwraith, Will, "Bulletin" Office, Rockhampton
McQueen, Rev. Sweyn, St. Andrew's Church, Creek street
McGregor, J. G., care of Messrs. Atthow and McGregor, Edward street
McGregor, Mrs. J. G., Boundary street, South Brisbane
McLeod, J. A., State School, One-mile, Gympie
McConnel, D. R., M.A., Technical College, Brisbane
McConnel, Mrs. D. R., Technical College, Brisbane
McGrath, P. J., State School, Engelsburg

McCullough, Mrs. D. B., Melbourne street, South Brisbane
McCall, Thos., Government Analyst's Department, Executive Buildings
MacLaurin, Sir Normand, 155 Macquarie street, Sydney
McDonnell, A. Eneas, M.D., Rathdonnell, Toowoomba
McAlpine, D., Government Vegetable Pathologist, Melbourne, V.
McGuffie, W. A., Queen street
McCloy, Miss, Sandgate
McConnel, Mrs. J. H., Cressbrook, *viâ* Toogoolawah
Mackay, G. J., 206 Queen street, Brisbane
McMillan, Miss, State School, Taringa
McDougall, Miss, Bowen terrace, Brisbane
McLay, C., Treasury Buildings

Norton, Hon. Albert, M.L.C., care of Union Trustees, George and Queen street
Nicoll, J. R., M.A., M.B., and Ch.M., Willowburn Asylum, Toowoomba
Neville, R. S., Tobacco Expert, Department of Agriculture
Nevill, Mrs. K. B., Brighton road, South Brisbane
Nevill, Miss Kate, Franklin Villa, South Brisbane
Norton, Mrs. A., Rosalie
Nieschke, F. W., M.D., C.M., Malvern House, Wakefield street, Adelaide

Orr, Andrew W., B.A., M.D., Wickham terrace
Ogg, Miss M. A., Brunswick street, New Farm
O'Sullivan, Hon. Thos., M.L.C., Celtic Chambers, George street
O'Connor, Daniel, Duporth, Oxley
Ogilby, J. Douglas, Amateur Fisherman's Association, Courier Building

Power, G. W., M.A., Moray street, New Farm
Pascoe, W. J. R., State School, Belmont
Potts, H. W., F.C.S., F.L.S., Hawkesbury Agricultural College (Principal), Richmond
Papi, H. C., Ph.D., State School, Woolloongabba
Parker, W. R., Dentist, Edward street
Poole, Wm., B.E., F.G.S., Director, Charters Towers School of Mines
Pimlott, W. H., State School, Hatton Vale, Laidley
Pulleine, R. H., M.B., Bank of N.S.W. Chambers, North terrace, Adelaide, S.A.
Pearce, Wm., Stone's Corner, Coorparoo
Page, Geo. J., Pharmaceutical Chemist, Mount Morgan
Page, Mrs. Geo. J., Mount Morgan
Plant, Hon. E. F. H., M.L.C., Parliament House, Brisbane
Paterson, H., 197 Liverpool street, Sydney
Pollock, Professor, The University, Sydney
Piper, W. G., Hink's Buildings, Elizabeth street, Melbourne, V.
Paterson, Hugh, 197 Liverpool street, Hyde Park, Sydney (*Life Member*)
Poole, Miss Ethel, Prospect, S.A.
Pagan, Wm., Chief Engineer of Railways, Central Station
Patterson, Union Bank, Queen street
Pound, C. J., Government Biologist, Brisbane
Pollock, Miss, care of Professor Pollock
Peacock, R. W., Experimental Farm, Bathurst
Phillips, George, C.E., Telegraph Chambers, Queen street

Roe, Reginald H., M.A., Boys' Grammar School
Ross, R. N., Inspector of Schools, Cutbush's Hotel, George street
Richards, S. J., Pharmaceutical Chemist, Mount Morgan
Rutledge, Sir Arthur, K.C.M.G., His Honour, Supreme Court, Brisbane
Rose, R. B. G., Pharmaceutical Chemist, Gympie
Rose, Mrs. R. B. G., Pharmaceutical Chemist, Gympie
Rands, W. H., F.G.S., 373 Queen street, Brisbane
Riley, E. A., Narrabri, N.S.W.
Rudd, A. W., M.A., LL.B., Clayfield College
Roach, B. S., Education Department, Adelaide
Rothwell, T. J., Capemba, Taringa

Ridgley, C., Pharmaceutical Chemist, Red Hill
Rothwell, Miss, 48 Perkin street, Newcastle, N.S.W.
Roth, Dr. Reuter, 52 College street, Sydney
Roth, Mrs., 52 College street, Sydney
Ross, W. G. Clunies, B.Sc., Technical College, Ultimo
Rutherford, P. C., State School, Gladstone
Rennie, Professor E. H., M.A., D.Sc., University, Adelaide
Roe, Miss Mollie, Albion
Roe, Mrs. R. H., Arwin Tel, Eildon Hill, Albion
Rutter, T. D., Queen street, Brisbane
Ryan, Miss M., State School, Jones Hill, Gympie
Rich, S. W. G., care of Messrs. Thomason, Chater, Co.
Russell, P. O'C., Elizabeth street
Riddell, R. McL., Inspector of Technical Colleges, Brisbane
Riddell, Mrs. R. McL.
Rowland, P. F., M.A., Grammar School, Toowoomba
Rowland, Mrs. P. F., Grammar School, Toowoomba

Shirley, John, B.Sc., Colarmie, Brunswick street, New Farm
Spenceley, Thos., State School, Newtown, Ipswich
Simmonds, F. W., Pharmaceutical Chemist, Toowong
Sutton, Alfred, M.R.C.S., L.S.A., North Quay
Skelton, A. G., State School, Allenstown, Rockhampton
Swanwick, K. ff., B.A., LL.B., Barrister, Celtic Chambers, George street, Brisbane
Scott, E. W. Kerr, M.B., Ch.M., Brunswick street, New Farm
Spowers, Allan A., Surveyor-General, Survey Office, Brisbane
Stewart, Rev. R., River terrace, South Brisbane
Shea, Michael, State School, Coomera
Smith, James, State School, Flagstone Creek, *viâ* Helidon
Statham, E. J., Nerrida, Parramatta, N.S.W.
Saunders, J. H., M.B., M.R.C.S., Box 142, G.P.O., Perth, W.A.
Spiers, James, State School, Toowoomba East
Scott, W. J., Under Secretary, Lands Department
Shea, P. J., State School, Aramac
Shea, H. C., Ambulance, Gill street, Charters Towers
Sheldon, Miss Annie, Hudson's road, Albion
Sheldon, Miss Kate, Hudson's road, Albion
Smith, W. H., B.A., State School, Monkland
Story, J. D., Under Secretary, Department of Public Instruction, Brisbane
Sutton, Geo. L., Experimental Farm, Cowra, N.S.W.
Stark, Robt. B., care of Messrs. Allan and Stark, Queen street
Scott, Herbert W., Queen street, Brisbane
Skertchly, Professor S. B. J., Corinda
Slade, W. B., River terrace, Milton
Slade, Mrs. W. B., River terrace, Milton
Slade, Miss, River terrace, Milton
Symons, F. N., Pharmaceutical Chemist, Rockhampton
Saunders, Geo. J., School of Mines, Charters Towers
Sutton, J. W., Bowen terrace, Brisbane
Sutton, Mrs. J. W., Bowen terrace, Brisbane
Saunders, H. H., Pharmaceutical Chemist, Roma
Smith, Wm. Ramsay, M.B., M.S., Winchester street, East Adelaide
Süssmilch, C. A., 38 Bland street, Ashfield, N.S.W.
Sulman, John, Wynyard Square, Sydney
Shellshear, Walter, Existing Lines Office, Sydney
Spencer, Dr. Walter, Edgeware road, Enmore, N.S.W.
Smith, J. McGarvie, Woollahra, Sydney
Shorter, John, 193 Clarence street, Sydney
Stephen, Sir Henry, Bellevue Hill, Sydney
Steane, S. A., Hay, N.S.W.
Swanwick, F. ff., Norman Park
Swanwick, Mrs. F. ff., Norman Park
Swanwick, Miss, Norman Park
Skeats, Professor E. W., D.Sc., A.R.C.S., University, Melbourne
Sweet, G., F.G.S., The Close, Wilson st., Brunswick, V

Sweet, Miss Georgina, D.Sc., University, Melbourne, V.
Simpson, A. M., Adelaide, S.A. (*Life Member*)
Simson, Augustus, Launceston, Tas.
Stirling, Professor E. C., C.M.G., M.A., M.D., F.R.S., University, Adelaide
Sampson, A. Stanfield, Ph.C., Longreach
Smith, Mrs. A. Parr, care of J. G. McGregor, Edward street
Speight, R., M.A., B.Sc., F.G.S., Canterbury College, Christchurch
Scriven, E. G. E., Under Secretary, Department of Agriculture
Smith, Fredk. W., State School, Walkerston
Shirley, Mrs. John, Colarmie, New Farm
Shirley, Miss Edith, Colarmie, New Farm
Sutherland, W., Ph.C., Edward street, Brisbane
Spiers, Mrs., Toowoomba
Scott, Mrs. H. W., care of H. W. Scott, Esquire, Tennyson
Swain, Miss Alice E., 112 Leichhardt street
Schofield, Professor J. A., The University, Sydney
Schofield, Mrs., care of Professor Schofield
Stewart, Miss Lily, River terrace

Thompson, Samuel, Binstead, Brookes street, Bowen Hills
Townsend, C. J., Brilliant Extended Cyanide Company, Charters Towers
Taylor, E., care of Messrs. Taylor and Colledge, Charlotte street
Tomlin, Canon L. W. S., M.A., Theological College, Nundah
Thomason, H. W., Pharmaceutical Chemist, Stanley street, South Brisbane
Tomkys, H., Boys' Central School, Rockhampton
Thomson, John, M.B., Ch.M., Inchcolm, Wickham terrace
Teece, Richard, F.I.A., F.F.A., F.S.S., A.M.P. Society, Sydney
Turner, A. J., M.D, Wickham terrace
Turner, Mrs A. J., Sherwood
Tardent, Henry, Wynnum
Timbury, F. J., Pharmaceutical Chemist, Petrie's Bight
Taylor, Hon. W. H., M.D., M.L.C., Bankesea, Wharf street
Trout, R., Given terrace, Paddington
Thomson, Hon. D., Milson's Point, Sydney
Taylor, James, Blaen-Crai, Dundas
Tietkins, W. H., Department of Lands, Sydney
Tillyard, R. J., Grammar School, Sydney
Thomas, William, Armidale
Touche, J. Edward, 15 Copthall avenue, London
Trivett, J. B., Bureau of Statistics
Taylor, I., B.Sc., B.E., F.C.S., A.R.S.M., Blaen-Crai, Dundas, Sydney (*Life Member*)
Thompson, Robert, M.B., M.R.C.S., Bunya Bunya, Wickham terrace
Thomson, G. M., M.P., F.L.S., F.C.S., 129 Moray place, Dunedin
Tyas, Wilson, Book Depôt, Queen street
Thompson, Rev. W., Bishopsbourne
Tilley, A. L., 7 to 8 Hay street, Perth, W.A.
Tryon, H., Entomologist, Department Agriculture
Taylor, E. R., Hydraulic Engineer's Office, Treasury Buildings
Timbury, Mrs. A. L., Kentmore, Manly
Thomson, Miss E. L., Nudgee road, Hendra
Thom, C. H. W., Geological Survey Office, Brisbane
Thorpe, A., Windsor Town Council, Albion

Vowles, George, State School, Petrie terrace
Van Cooten, W. J. F., Albert School, Maryborough
Verco, J. C., M.D., F.R.C.S., North terrace, Adelaide
Vowles, Mrs. G., Merivale street, South Brisbane
Vonwiller, O. U., The University, Sydney

Watkins, George, care of Watkins and Mackay, Pharmaceutical Chemists, 206 Queen street
Warren, D. S., State School, Leichhardt street
Wedd, Joseph, State School, Newmarket
Warren, Miss Agnes, Girls' State School, North Ipswich

Weedon, Thornhill, F.S.S., Registrar-General, Treasury Buildings
Wilkinson, Miss, Girls' Grammar School, Brisbane
Wilson, Miss Annie E. W. N., Girls and Infants' State School, Kelvin Grove road
Wearne, R. A., B.A., Director, Technical College, Ipswich
Waddle, Isaac, State School, Biggenden
Weedon, Warren, Selby House, Wickham terrace
Woodward, B. H., Museum, Perth, W.A.
Watson, Professor Archibald, M.D., F.R.C.S.E., L.S.A., University, Adelaide
White, Miss Helen, Girls' Grammar School, Ipswich
Whiting, F. C., Relieving Teacher, Department of Public Instruction
Wilkinson, J., Pharmaceutical Chemist, Valley
Walters, Samuel, Engineer-in-Chief's Office, Adelaide, S.A.
Weston, Robert, Outridge Printing Company, Queen street, Brisbane
Wassell, J. W., Teneriffe, Brisbane
Weedon, Mrs. Thornhill, Church Hill, Woolloongabba
Wark, William, Kurrajong Heights, N.S.W.
Walton, T. W., 56 Connell street, Sydney
Wilson, Professor, The University, Sydney
Walker, J. T., 109 Pitt street, Sydney
Wills-Allen, T. P., Gunnedah, N.S.W.
Welch, William, Boyle street, Mosman, N.S.W.
Welch, Mrs., Boyle street, Mosman, N.S.W.
Walkom, A. B., Chandos street, Ashfield, N.S.W.
Woolnough, Dr. W. G., The University, Sydney
Weston, Percy L., Norman Chambers, Creek street, Brisbane
Williams, Rev. James, 99 Harcourt street, New Farm
White, E. J., F.R.A.S., Observatory, Melbourne, V.
Wilkinson, W. Percy, Commonwealth Analyst, Melbourne, V.
Walker, J. T., 109 Pitt street, Sydney (*Life Member*)
Watkins, Mrs. G., Toowong
Waite, Edgar, Canterbury Museum, Christchurch
Ward, J. W., Pharmaceutical Chemist, Queen street
Ward, G. W., Pharmaceutical Chemist, Queen street
Wasteneys, Hardolph, Laboratory, Waterworks, *viâ* Red Hill
Wilson, M. N., Thorne street, Bowen Bridge road, Albion
Wright, Mrs. Lilie A., Warwick
Williams, Mrs. James, 99 Harcourt street, New Farm
Woodroffe, F. W., H.M. Customs, Brisbane
Wadsworth, A., North Sydney
Warren, Mrs. D. S., Langshaw street, New Farm
Wilson, A. B., Eldon Chambers, Queen street
Watkins, Master W. G., Maroomba, Toowong
Watkins, Miss E. E., Maroomba, Toowong
Weedon, Dr. C. T., care of Thornhill Weedon, Esquire, Registrar-General
Wadsworth, A., V.P., Phar. Society, N.S.W.
Wiley, J. S., Queen street

Youngman, Rev. Dr., Menuchah, Toowong
Young, J. H., Hutt street, Adelaide, S.A.
Yardley, Miss Florence E., Girls and Infants' State School, North Toowoomba

Zerner, W. A., State School, Albany Creek

BRISBANE:
ANTHONY JAMES CUMMING, GOVERNMENT PRINTER, WILLIAM STREET.
1910.