REPORT

OF THE

FIRST MEETING

OF THE

AUSTRALASIAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

HELD AT

SYDNEY, NEW SOUTH WALES.

IN

AUGUST AND SEPTEMBER, 1888.

Edited by
A. LIVERSIDGE, M.A, F.R.S.
ROBT. ETHERIDGE, Junr.

Published by the Association.

PERMANENT OFFICE OF THE ASSOCIATION:
THE ROYAL SOCIETY'S HOUSE, 5 ELIZABETH STREET,
SYDNEY.

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146 Pitt Street.

1889.

NOTE.

THE Editors much regret that the Volume has not been published earlier, the delay, however, has been due to causes beyond their control; in the first instance much loss of time was due to the absence of sufficient funds to defray the cost of printing, the balance left over after paying the expenses of the Meeting having proved to be inadequate for that purpose. The expenditure attendant upon the formation and organization of the first Meeting was necessarily heavier than it is expected it will be for future Meetings, now that the Association is fully organized and has an assured Membership. The publication of the Volume was found by the Council to be possible only on the condition that certain Members should make themselves personally responsible for the expenses incurred, which was done by seven of them.

The delay has also been partly due to the fact that the Volume proved to be much larger than was at first anticipated, and to other causes which need not be specifically mentioned.

SYDNEY,
September, 1889.

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LIST AND EXPLANATION OF PLATES.

OBJECTS AND RULES OF THE ASSOCIATION.

OBJECTS.

The Association has been founded upon the same lines as the British Association, and its rules are practically the same. It should be particularly noticed that this Association also "contemplates no interference with the ground occupied by other institutions. Its objects are :—To give a stronger impulse and a more systematic direction to scientific enquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers; to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which may impede its progress."

RULES.

1. All persons who signify their intention of attending the first Meeting shall be entitled to become original Members of the Association, upon agreeing to conform to the Rules.

2 The Officers, Members of Council, Fellows, and Members of Literary and Philosophical Societies publishing Transactions or Journals in the British Empire, shall be entitled in like manner to become Members of the Association. Persons not belonging to such Institutions shall be elected by the General Committee, or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the payment of the prescribed Subscription, and the approval of a General Committee.

3. All Members who have paid their Subscriptions (£1 per Annum) shall be entitled to receive the Publications of the Association *gratis*.

4. The Association shall meet for one Week or longer. The place of meeting shall be appointed by the General Committee two years in advance.

5. There shall be a General Council, having the supreme control, to be composed of Delegates from the different Colonies or Colonial Scientific Societies. The number of Delegates from each Society or Colony shall be proportionate to the number of Members from the particular Colony or Society—Subscribing or otherwise—taking part in the proceedings (*i.e.* after the preliminary Meetings). Each Colony or Society shall be allowed to nominate a Delegate for each one hundred of its Members.

6. There shall be a GENERAL COMMITTEE consisting of Members of the Council, Presidents, Vice-Presidents and Secretaries of Sections, Contributors of Papers to the Association, and such others as may be elected.

7. A Local Committee shall be appointed at the place of meeting to make arrangements for the reception and entertainment of the visitors, and to make preparations for the Business of the General Meetings.

8. Sectional Committees shall be appointed for the following Subjects :—

SECTION A—Astronomy, Mathematics, Physics and Mechanics.
SECTION B—Chemistry and Mineralogy.
SECTION C—Geology and Palæontology.
SECTION D—Biology.
SECTION E—Geography.
SECTION F—Economic and Social Science and Statistics.
SECTION G—Anthropology.
SECTION H—Sanitary Science and Hygiene.
SECTION I—Literature and Fine Arts.
SECTION J—Architecture and Engineering.

9. Ladies are eligible for Membership.

10. The rights and privileges of Membership shall be in the main similar to those afforded by the British Association, subject to revision and alteration after the first Meeting of the AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

OFFICERS AND COUNCIL, 1888.

——:o:——

President:

H. C. Russell, B.A., F.R.S., F.R.A.S., &c., Government Astronomer, N. S. Wales.

Vice-Presidents:

The Hon. Dr. J. W. Agnew,—President of the Royal Society of Tasmania.
The Hon. Sir Frederick Darley, Knt.,—Chief Justice of N.S.W.
C. W. De Vis, M.A.,—President of the Royal Society of Queensland.
The Right Worshipful the Mayor of Sydney, Alderman John Harris.
Sir James Hector, K.C.M.G., M.D., F.R.S.,—Director of the New Zealand Institute and Geological Survey.
Hon. James Inglis,—Minister for Public Instruction, N. S. Wales.
Professor W. C. Kernot, M.A., C.E.,—President of the Royal Society of Victoria.
The Hon. Sir W. M. Manning, LL.D., M.L.C.,—Chancellor of the University of Sydney.
H. N. MacLaurin, M.A., M.D., LL.D.,—Vice-Chancellor of the University of Sydney.
Professor E. H. Rennie, M.A., D.Sc.,—President of the Royal Society of S. Australia.
Sir Alfred Roberts, M.R.C.S.,—President of the Royal Society of N. S. Wales.

(The President of the Royal Society, or its equivalent, in each colony is *ex officio* a Vice-President of the Association.)

President-Elect:

Baron Ferdinand Von Mueller, K.C.M.G., M.D., F.R.S., &c., Government Botanist, Melbourne.

Hon. Secretaries:

Professor Liversidge, M.A., F.R.S., &c.,—Royal Society of N. S. Wales, *Permanent Hon. Secretary.*

George Bennett, M.D., F.L.S., F.Z.S.,—Zoological Society of N. S. Wales.

Hon. Treasurer:

Sir Edward Strickland, K.C.B., F.R.G.S.,—President of the Royal Geographical Society of Australasia, N. S. Wales Branch.*

Secretary:

Edwin Quayle, F.C.S.†

* Died July, 1889.
† Resigned Oct., 1888.

Ordinary Members of Council:

J. R. Ashton,—President of the Art Society of N.S.W.
F. G. A. Barnard,—Field Naturalists' Club of Victoria.
James Barnard,—Royal Society of Tasmania.
Professor W. H. Bragg, B.A.,—Royal Society of S. Australia.
Captain E. E. Brett,—Royal Geographical Society of Australasia, N. S. Wales Branch.
Hon. Dr. A. Campbell, M.L.C.,—Royal Geographical Society of Australasia, South Australian Branch.
A. Collingridge,—Art Gallery of N.S. Wales.
W. J. Conder,—Victorian Institute of Surveyors.
J. C. Cox, M.D., C.M.Z.S., F.L.S.,—Field Naturalists' Club of Victoria.
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W. D. Cruickshank,—President of the Engineering Association of N. S. Wales.
R. L. J. Ellery, F.R.S., F.R.A.S.—Royal Society of Victoria.
J. J. Fletcher, M.A., B.Sc.,—Linnean Society of N. S. Wales.
W. A. Haswell, M.A., D.Sc.,—Otago Institute, New Zealand.
R. Hunt, C.M.G., F.G.S.,—Royal Society of Victoria.
G. A. Key,—Engineering Association of N. S. Wales.
Professor W. C. Kernot, M.A., C.E.,—Royal Society of Victoria, and Victorian Engineers' Association.
A. A. C. Le Souef, C.M.Z.S.,—Zool. and Acclim. Soc., Victoria.
R. T. Litton, F.G.S., F.Z.S., F.R.G.S.,—Historical Society of Australasia.
J. F. Mann,—Royal Geographical Society of Australasia, N. S. Wales Branch.
Hon. C. K. Mackellar, M.L.C., A.M., M.B., C.M.,—Royal Society of N. S. Wales.
C. Moore, F.L.S.,—Director of the Botanic Gardens, Sydney.—N. S. Wales Zoological Society.
J. A. Pond, F.C.S.,—Auckland Institute, New Zealand.
Thomas Rowe. F.R.I.B.A.,—President of the Institute of Architects, N. S. Wales.
A. O. Sachs,—Royal Geographical Society of Australasia, Victorian Branch.
The Rt. Rev. Daniel Fox Sandford, LL.D., Bishop of Tasmania,—Royal Society of Tasmania.
Professor Scott, M.A.,—Australian Economic Association.
James Smith,—Natural History Society of Rockhampton, Queensland.
S. Percy Smith, F.R.G.S.,—Auckland Institute, New Zealand.
Professor W. Baldwin Spencer, B.A.,—Royal Society of Victoria.
James Stirling, F.G.S., F.L.S.,—Geological Society of Australasia.
Professor W. J. Stephens, M.A.,—President of the Linnean Society of N. S. Wales.
Professor Anderson Stuart, M.D.,—Medical Society of Victoria.
R. Teece, F.I.A.,—President of the Australian Economic Association.
Professor A. P. Thomas, F.L.S.,—Auckland Institute, New Zealand.
J. P. Thompson, M.A., C.E.,—Royal Geographical Society of Australasia, Queensland Branch.
H. Tryon,—Royal Society of Queensland.
Hon. S. J. Way, Chief Justice of S. Australia,—Zoological and Acclimitisation Society of Adelaide.
Professor W. H. Warren, M.I.C.E.,—Royal Society of N. S. Wales.
C. S. Wilkinson, F.G.S., F.L.S.,—Royal Society of N. S. Wales.
Thomas Whitelegge,—Natural History Society of N. S. Wales.
Rev. J. E. Tenison Woods, F.G.S., F.L.S.,—Otago Institute, New Zealand.

Auditor:

Robert A. Dallen.

Publication Committee:

J. R. Ashton.
Dr. G. Bennett.
Captain E. E. Brett.
H. Deane, M.A., M.I.C.E.
R. Etheridge, Jr.
J. J. Fletcher, M.A., B.Sc.
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W. M. Hamlet, F.C.S., F.I.C.
Dr. W. A. Haswell.
F. B. Kyngdon.
Professor A. Liversidge, M.A., F.R.S.
J. H. Maiden, F.L.S., F.R.G.S.
E. L. Montefiore.
Gilbert Parker, B.A.
Professor W. J. Stephens.
Professor Anderson Stuart, M.D.
John Sulman. F.R.I.B.A.
Rev. J. E. Tenison Woods, F.L.S.
Professor R. Threlfall.
Dr. J. T. Wilson.
A. C. Wylie.

ARRANGEMENTS FOR THE FIRST MEETING.

——:o:——

The following circular was sent to all Members:—

Sir,

We beg to inform you that the First Meeting of the Australasian Association for the Advancement of Science will commence in Sydney on Tuesday, 28th August, 1888, and to request your attention to the following *Notices of Arrangements* for the Meeting.

The presentation of this letter on your arrival in Sydney at the Royal Society's House, 37 Elizabeth Street, will much facilitate the issue of Tickets or other arrangements.

The General Committee will meet on Monday, 27th August, at 4.15 p.m., at the Royal Society's House; and again on Tuesday, 4th September, at 4.15 p.m., at the University, for the purpose of making arrangements for the next Meeting.

The first General Meeting will be held in the Great Hall of the University on Tuesday, 28th August, at 8.30 p.m. when His Excellency the Governor will take the Chair, and the President will deliver an Address.

The Sectional Committees will assemble in the rooms set apart for their use, at the University, at 10.30 a.m. each day, until the conclusion of the Meeting.

The Sections will meet at the University at 11 a.m., for the reading and discussion of Papers.

The following Presidential Addresses will be delivered at 11 a.m. on Wednesday 29th August :—

Section A.—Astronomy, Mathematics, Physics, and Mechanics, by Mr. R. L. J. Ellery, F.R.S., F.R.A.S.

Section C.—Geology and Palæontology, by Mr. R. L. Jack, F.G.S.

Section D.—Biology, by Professor Tate, F.G.S., F.L.S.

Section F.—Economic and Social Science and Statistics, by Mr. H. H. Hayter, C.M.G.

The following Presidential Addresses will be delivered at 11 a.m. on Thursday, 30th August :—

Section B.—Chemistry and Mineralogy, by Professor Black, M.A., D.Sc.

Section E.—Geography, by Hon. John Forrest, C.M.G.

Section G.—Anthropology, by Dr. Carroll, M.A.

Section H.—Sanitary Science and Hygiene, by Dr. Bancroft.

Section I.—Literature and the Fine Arts, by Professor Boulger, M.A.

Section J.—Architecture and Engineering, by Professor Kernot, M.A., C.E.

The afternoons will be kept as free as possible for visits to places of interest, Public Institutions, Botanical, Dredging, and other Excursions.

The following Popular Scientific Lectures will be delivered in the Great Hall of the University :—

Thursday, 30th August, at 8 p.m., "On the Volcanic Eruptions in the Hot Lake District of New Zealand," by Sir James Hector, K.C.M.G., F.R.S.

Friday, 31st August, at 8 p.m., "On recent Discoveries on the Pineal Eye," by Professor Baldwin Spencer.

The Conversazione of the Royal Society of New South Wales, to which Members of the Association are invited, will be held in the Great Hall, University, at 8 p.m., on Wednesday, 5th September.

The Presidents and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

The hours and days of meeting for the Sections, etc., will be found in the accompanying Time-table.

The Authors of Papers are requested to prepare an abstract of their Papers to be sent in to the Publication Committee by 31st July.

On and after the date of Meeting (28th August) the issue of Tickets, Cards of Invitation, etc., will be made at the Reception Room, University, Glebe, between the hours of 9 and 1 am., and 2 and 5 p.m., where information as to Lodgings and the general arrangements for the Meeting can be obtained. Non-resident Members attending the Meeting are requested to register their addresses as soon as possible after their arrival in Sydney.

Members are requested to send in their names for any excursion or excursions they may decide to join, in order that arrangements may be made for their accommodation, etc.

Members are informed that upon their arrival in Sydney they can obtain copies of the Guide Book issued by the Association, and in it will be found articles on Meteorology, Botany, Physiography, and Geology, Marine and Land Fauna, Commerce and Industries, etc., together with particulars regarding a number of excursions, places of interest, etc. Full particulars will also be supplied in pamphlet form regarding the special excursions undertaken by the Association.

The Railway authorities of South Australia, Victoria, and New South Wales have agreed to issue return tickets at single fares to Members of the Association travelling by railway from other Colonies to attend the General Meeting.

It should be noted that the following Steamship Companies have undertaken to convey Members to Sydney and back at a reduction of 20 per cent. on the ordinary rates :—

A.U.S.N. Co.

Messrs. Wm. Howard Smith and Sons, Limited.

Messrs. Huddart, Parker and Co.

Adelaide Steamship Co.

The Union S.S. Co. of N.Z. will carry Members at excursion rates.

We are, Sir,

Your obedient Servants,

A. LIVERSIDGE, M.A., F.R.S. }
G. BENNETT, M.D., F.L.S. } HON. SECS.

Royal Society's House,
37 Elizabeth-street, Sydney.

To ____________________

LIST OF EXCURSIONS,

WITH THE NAMES OF CONDUCTORS AS PROPOSED.

——:o:——

SERIES I.—*Thursday*, August 30th. Excursions for the day.

Conductors :—Mr. E. O. Moriarty, Professor Warren, Mr. J. J. Fletcher, Mr. Shellshear, Professor Liversidge, Mr. Darley, and Mr. Deane.

Excursion A.—Prospect Dam and Reservoir. Cost 15s.

„ B.—Trip round the Harbour and Parramatta River. Cost 7s. 6d.

„ C.—Fortifications at Middle Head. Cost 10s.

„ D.—Dredging and Fishing Excursion. Cost 10s.

SERIES II.—*Friday*, August 31st. Excursions for the day.

Conductors :—Mr. Oxley, Mr. Smail, Mr. Kyngdon, Mr. Angus Mackay, Professor Warren, Mr. Sulman, Mr. Dixon, and Mr. Deane.

Excursion E.—Sewage Farm at Cook's River.

„ F.—The Clyde Works at Granville.

„ G.—Railway Workshops at Eveleigh.

„ H.—New Gas Works at Mortlake. Cost 7s. 6d.

SERIES III.—*Friday*, August 31st. Excursion for four days.

Conductors : Mr. S. H. Cox, Dr. Helms, Professor Stephens, Dr. Haswell, Mr. Etheridge, Mr. David, Mr. Woollcott, Dr. Cox, Dr. Wilson, Dr. Thompson.

Excursion I.—Jenolan or Fish River Caves. Cost £5 12s. 6d.

„ J.—Bulli Pass, Woollongong, Kiama, Cambewarra, and Fitzroy Falls. Cost £6.

„ K.—The Hawkesbury, *viâ* Manly, Newport, and Sackville Reach. Cost £2.

SERIES IV.—*Saturday*, September 1st. Excursions for the day.

Conductors :—Dr. Cox, Hon. G. H. Cox, Mr. Moore, Professor Stuart, Dr. Bennett, Mr. Hunt.

Australasian Association for the Advancement of Science.

TIME TABLE.

DATE.	MORNING.	AFTERNOON.	EVENING.
MONDAY, AUGUST 27...			Meeting of General Committee at Royal Society's House, at 4.15 p.m.
TUESDAY, AUGUST 28		Mrs. RUSSELL'S Garden Party at the Observatory.	Presidential Address in Great Hall at University—8.30.
WEDNESDAY, AUGUST 29	Committees.—10.30. Presidential Addresses at 11, in Section A. C. D. F. Papers in all Sections to 1 o'clock.		Linnean Society's Meeting at 8. Reception by His Worship the Mayor at the Town Hall.
THURSDAY, AUGUST 30	Committees.—10.30. Presidential Addresses at 11, in Sections B. E. G. H. I. J. Papers in all Sections to 1 o'clock.	Excursions, Series I.—A., B., C., D. Dredging Excursion.	Popular Lecture by SIR JAMES HECTOR, "On the Volcanic Eruptions of the Hot Lake District of New Zealand."—8 p.m.
FRIDAY, AUGUST 31	Committees.—10.30. Papers in all Sections.—11 to 1.	Excursions, Series II.—E., F., G., H. ,, Series III.—I., J., K. Dredging Excursion.	Popular Lecture by PROFESSOR SPENCER, "On his recent Discoveries on the Pineal Eye.—8 p.m. Meeting of ASSOCIATION to make arrangements for next Meeting, &c., at 9.30 a.m. at the University.
SATURDAY, SEPTEMBER 1	Committees.—10.30. Papers in all Sections.—11 to 1.	Excursion Series IV.—L., M., N., O. ,, Series V.—P., Q., R.	
MONDAY, SEPTEMBER 3		Excursions, Series VI.—S.	
TUESDAY, SEPTEMBER 4			Meeting of General Committee at Royal Society's House.—4.15 p.m.
WEDNESDAY, SEPTEMBER 5 ...			Royal Society's Conversazione at the University.—8 p.m.

Excursion L.—The junction of the Warragamba and Nepean Rivers. Cost £1.

" M.—Spot were Cook first landed. Cost 12s. 6d.

" L.—Bondi, Coogee, and La Perouse. Cost 12s. 6d.

" G.—Newport *viâ* Manly and Pittwater. Cost 17s. 6d.

SERIES V.—*Saturday*, Sept. 1st, to *Monday*, Sept. 3rd.

Conductors:—Mr. John Mackenzie, Mr. T. W. Edgeworth David, Mr. Ashton, Mr. Pedley, Mr. Burge, Mr. Mann, Mr. Russell, Mr. Pittman, Mr. Twynam.

Excursion P.—The Blue Mountains, Wentworth Falls, and Govett's Leap. Cost £2 15s.

" Q.—The Hawkesbury. Cost £2 10s.

" R.—Newcastle Collieries. Cost £2 5s.

SERIES VI.—*Monday*, September 3rd. Two days' excursion.

Conductors:—Mr. Etheridge, Mr. Maiden, Mr. C. Cowper, Mr. Anderson, Mr. Moore.

Excursion S.—Clifton, Bulli Collieries, and Woollongong. Cost £1 14s.

TABLE, SHOWING THE PLACES AND TIMES OF MEETING OF THE AUSTRALASIAN ASSOCIATION, WITH PRESIDENTS, VICE-PRESIDENTS, AND LOCAL SECRETARIES, FROM ITS COMMENCEMENT.

PRESIDENT.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
H. C. RUSSELL, B.A., F.R.S., Government Astronomer, N.S.W., Sydney, Aug.-Sept. 1888.	HON. DR. J. W. AGNEW, President of the Royal Society of Tasmania. SIR FREDERICK DARLEY, Knt., Chief Justice of N.S. Wales. SIR JAMES HECTOR, K.C.M.G., M.D., F.R.S., Director New Zealand Institute. Prof. W. C. KERNOT, M.A., C.E., President of the Royal Society of Victoria. HON. JAMES INGLIS, Minister for Public Instruction. The HON. SIR W. M. MANNING, LL.D., M.L.C., Chancellor of the University of Sydney. H. N. MACLAURIN, M.A., M.D., LL.D., Vice-Chancellor of the University of Sydney. The Right Worshipful Alderman JOHN HARRIS, Mayor of Sydney. Prof. E. H. RENNIE, M.A., D.Sc., President of the Royal Society of S. Australia. Sir ALFRED ROBERTS, M.R.C.S.E., President of the Royal Society of N.S. Wales. C. W. de VIS, M.A., President of the Royal Society of Queensland.	PROF. A. LIVERSIDGE, M.A., F.R.S. GEORGE BENNETT, M.D., F.L.S., F.Z.S.

Presidents, Vice-Presidents, and Secretaries of the Sections of the Association.

Date and Place.	Presidents.	Vice-Presidents.	Secretaries.
Section A.—Astronomy, Physics, Mathematics, and Mechanics.			
1888. Sydney, N.S.W.	R. L. J. Ellery, F.R.S.		Prof. R. Threlfall, M.A.
Section B.—Chemistry and Mineralogy.			
1888. Sydney, N.S.W.	Prof. J. G. Black, D.Sc., M.A.	A. Leibius, Ph.D., M.A., &c. Prof. A. Liversidge, M.A., F.R.S. Prof. E. A. Rennie, M.A.	W. M. Hamlet, F.I.C., F.C.S.
Section C.—Geology and Palæontology.			
1888. Sydney, N.S.W.	Robert Logan Jack, F.R.G.S., F.G.S., Townsville.	T. W. Edgeworth David, B.A., F.G.S.	Robert Etheridge, junr.
Secton D.—Biology.			
1888. Sydney. N.S.W.	Prof. Ralph Tate, F.L.S., F.G.S., Adelaide.		W. A. Haswell, M.A., D.Sc.
Section E.—Geography.			
1888. Sydney, N.S.W.	Hon. John Forrest, C.M.G., F.R.G.S., Perth, W.A.	G. S. Griffiths, F.R.G.S., F.G.S.	J. H. Maiden, F.R.G.S., F.L.S., F.C.S.
Section F.—Economic and Social Science, and Statistics.			
1888. Sydney, N.S.W.	H. H. Hayter, C.M.G.		A. C. Wylie.
Section G.—Anthropology.			
1888. Sydney, N.S.W.	A. Carroll, M.A., M.D.		John Fraser, B.A., L.L.D.
Section H.—Sanitary Science and Hygiene.			
1888. Sydney, N.S.W.	J. Bancroft, M.D., Brisbane.		J. T. Wilson, M.B., C.M., and F. B. Kyngdon.
Section I.—Literature and the Fine Arts.			
1888. Sydney, N.S.W.	Prof. E. V. Boulger, M.A., D. Lit., South Australia.		Gilbert Parker, B.A., and E. L. Montefiore.
Section J.—Architecture and Engineering.			
1888. Sydney, N.S.W.	Prof. W. C. Kernot, M.A., C.E., Melbourne		John Sulman, F.R.I.B.A., and H. Deane, M.A., M.I.C.E.

LIST
OF
EVENING LECTURES.

Date and Place.	Lectures.	Subject of Discourse.
1888—Sydney.	Sir James Hector, F.R.S.	The Volcanic Eruptions in the Hot Lake District of New Zealand.
	Prof. W. Baldwin Spencer, B.A., &c.	Recent Discoveries on the Pineal Eye.

TABLE SHOWING THE NUMBER OF MEMBERS PRESENT, RECEIPTS TO, AND GRANTS MADE AT THE ANNUAL MEETINGS OF THE ASSOCIATION.

Date of Meeting.	Place of Meeting	Presidents.	ATTENDED BY							Amount Received up to and during Meeting.	Sums paid on Account of Grants for Scientific Purposes.
			Old Life Members.	New Life Members.	Annual Members.	New Annual Members.	Ladies.	Visitors.	Total.		
1888—Aug.-Sept.	Sydney.	H. C. RUSSELL, B.A., F.R.S.	—	—	805	—	45	—	850	£858 8s.	—

The Australasian Association for the Advancement of Science.

Dr. The Hon. Treasurer's Account of Receipts and Expenditure from April 1st to December 31st, 1888. Cr.

	£ s. d.	£ s. d.
To Subscriptions		850 0 0
,, Donations—T. W. Garlick	4 4 0	
John Harris	4 4 0	
		8 8 0
		£858 8 0

	£ s. d.	£ s. d.
By Salaries—Secretary	150 0 0	
,, ,, Clerical assistance and Attendants	48 11 6	
		198 11 6
,, Stationery and Printing		173 19 8
,, Advertising		74 7 6
,, Petty Cash and Postage		91 19 7
,, Exchanges on Country Cheques, &c.		5 2 11
,, Cablegram to British Association		7 3 0
,, Expenses in connection with popular lectures and diagrams		12 5 0
,, Deficiency on Excursions		1 17 0
,, Hire of Decorations		12 10 0
,, Furniture		7 0 0
,, Gas, &c.		3 15 0
,, Subsidy to Caterers, and for refreshments provided		8 2 9
,, Balance in Bank		261 14 1
		£858 8 0

Signed, Audited and found correct,
ROBERT A. DALLEN.

February 20th, 1889.

A. LIVERSIDGE,
Hon. Sec.

Ed. STRICKLAND,
Hon. Treas.

RESOLUTIONS PASSED

BY THE

GENERAL COMMITTEE.

———:o:———

GENERAL COMMITTEE MEETING, AUGUST 27TH, 1888.

RECOMMENDATION PASSED BY THE COUNCIL AND ADOPTED BY THE GENERAL COMMITTEE ON AUGUST 27TH, 1888.

Rules of the British Association Adopted.

Resolved—"That the rules of the British Association as printed be adopted by the Australasian Association for the Advancement of Science, and such other rules of the British Association be followed as may be necessary until the first meeting of the Australasian Association."

Presidents of Certain Societies to be Vice-Presidents.

Resolved—"That the Presidents of the Royal Societies of New South Wales, Victoria, South Australia, Queensland and Tasmania, and the Director of New Zealand Institute be elected Vice-Presidents for the year."

Presidents and Secretaries of Sections to attend Council Meetings.

Resolved—"That the Presidents and Secretaries of Sections be entitled to attend Council Meetings as visitors."

Authors to make Abstracts of their Papers.

Resolved—"That authors be requested to make abstracts of their papers."

Duties of Secretaries of Sections.

Resolved—"That the duties of the Secretary of each Section shall be :—

1. To conduct the Correspondence of the Section.
2. To attend the Meetings of the Section and to take Minutes of the Proceedings.
3. To cause due notice to be given of all Meetings of the Section.
4. To keep a list of Attendance.
5. To report progress to the Council at its meetings. The Secretary to refer unsuitable Papers to the Sectional Committee."

Change of Title of Section H. to Sanitary Science and Hygiene.

Resolved—"That the Council recommend to the Association that the title Section H. be altered so as to read 'Sanitary Science and Hygiene.'"

Vice-Presidents of Sections to be elected by the Sections.

Resolved—"That the question of electing Vice-Presidents of Sections be left to the discretion of the respective Sections."

Publication of Papers.

Resolved—"That the Papers be published in full or in abstract at the discretion of the Publication Committee, and according to the funds at the disposal of the Association."

Constitution of Sectional Committees.

Resolved—"That the President, Secretary, Authors of Papers, together with such other persons as might hereafter be nominated, shall form a Committee for each Section.

Papers by Non-Members to be Communicated by a Member.

Resolved—"That Authors of Papers who are not members of the Association be permitted to send their Papers, but that such Papers shall be communciated by a member of the Association.

Introduction of Visitors to Meetings.

Resolved—"That members of the Association have the privilege of introducing one person at the Meeting of Sections, Inaugural Meeting, the Popular Science Lectures, and the Excursions, and that a second ticket for the Lectures be issued to members if the accommodation permit of this being done."

Resolved—"That the privilege of introducing a friend does not extend to the Garden Parties, Receptions, and the Conversazione given by the Royal Society of New South Wales."

MEETING OF THE GENERAL COMMITTEE, FRIDAY, AUGUST 31, 1888.

Extracts from the Minutes.

Present—Mr. H. C. Russell, B.A., F.R.S., in the chair; Professor Liversidge, M.A., F.R.S.; Dr. Bennett, F.L.S.; Sir James Hector, K.C.M.G., F.R.S.; Mr. Pond; Mr. S. Percy Smith, F.C.S.; Mr. Charles Moore, F.L.S.; Dr. J. C. Cox, F.L.S.; Mr. S. H. Cox, F.G.S.; Professor Kernot; Professor Anderson Stuart; Hon. John Forrest, C.M.G.; Mr. J. Sulman; Mr. R. Etheridge; Mr. W. M. Hamlet, F.C.S.; Mr. Mingaye, F.C.S.; Mr. C. A. Smith, F.C.S.; Professor Rennie, D.Sc.; Professor Bragg; Mr. F. Wright; Mr. W. A. Dixon, F.C.S.; Mr. Maiden, F.L.S.; Mr. J. J. Fletcher, B.Sc.; Dr. Ashburton Thompson; Mr. R. L. Jack, F.G.S.; Mr. J. F. Mann; Dr. J. Fraser, B.A.; Mr. A. C. Wylie; Dr. J. T. Wilson; Mr. H. H. Hayter, C.M.G.; Dr. A. Campbell, M.L.C.; Mr. J. R. Ashton; Sir W. M. Manning, LL.D.; Dr. H. A. MacLaurin, LL.D.; Mr. R. Teece: Captain E. E. Brett; Mr. H. Deane; Mr. H. Tryon; Dr. W. A. Haswell, M.A.; Professor W. H. Warren, Mr. W. J. Condor.

Arrangements for First General Meeting.

The President having briefly referred to the arrangements made by the Council for the First General Meeting, it was

Resolved,—"That the action of the Council be approved of, and the various arrangements made for the meeting, be adopted."

Visit to Hobart and Dunedin.

The President announced that invitations had been received for the Association to visit Hobart and Dunedin next year.

Invitations to visit the Observatory, Botanic Gardens, &c., &c.,

It was also announced that invitations had been received to visit the Observatory, Botanic Gardens, Australian Museum, the Mining and Geological Museum of the Department of Mines, the Royal Mint, the Fortifications, Government Printing Office, Post and Telegraph Offices, Model Schools, &c.

Vote of thanks to Professor Liversidge.

Mr. JAMES STIRLING moved a cordial vote of thanks to Professor LIVERSIDGE for his action in initiating the movement which had resulted in the formation of the Australasian Association for the Advancement of Science.

The President having spoken in support, the motion was carried by acclamation.

Professor Liversidge thanked the members present, and referred to the cordial manner in which his efforts towards the formation of the Association had been seconded by the President, Council, Secretaries of Sections, and the Secretary.

Next meeting to be held in Melbourne.

Resolved,—On the proposal of Mr. R. L. J. ELLERY, supported by Professor KERNOT and Mr. K. L. MURRAY, "That the next meeting be held in Melbourne."

Resolved,—"That the date of meeting for 1889 be left to the Local Committee in Melbourne."*

Place of meeting in 1890.

Sir JAMES HECTOR, on behalf of the New Zealand delegates, cordially invited the Association to meet in New Zealand in 1890, and suggested that the place of meeting should be left to the decision of a Conference of representatives of New Zealand Societies. Mr. S. H. Cox seconded the invitation.

Professor TATE invited the Association to make Adelaide their place of meeting in 1890, and Professor RENNIE seconded the invitation.

Professor BRAGG and the Hon. Dr. CAMPBELL warmly supported the invitation to hold the meeting in Adelaide in 1890.

Mr. JAMES BARNARD moved that the 1890 meeting be held in Tasmania.

Professor BLACK, Mr. POND, and Mr. S. PERCY SMITH cordially supported Sir J. HECTOR's invitation to visit New Zealand.

The motion to visit Hobart in 1890 was put and lost.

The motion to visit Adelaide in 1890 was put and lost.

The motion to visit New Zealand was put and carried.

Resolved,—"That the third meeting be held in New Zealand."

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*The Melbourne Committee have arranged for the Meeting to be held Jan. 7th, 1890.

President for 1889.

Resolved,—"That BARON VON MUELLER be elected President for the year 1889."

Permanent Headquarters.

Resolved,—On the motion of Sir JAMES HECTOR, "That Sydney be the permanent headquarters of the Association, and that the Royal Society of New South Wales be thanked for their liberality in granting the use of their house for the meeting and office work of the Association, with a request that they will kindly continue the privilege."

Permanent Hon. Secretary.

Resolved,—On the motion of Sir JAMES HECTOR, "That Professor LIVERSIDGE be permanent Hon. Secretary, and that he be authorised to employ such clerical assistance as may be required to enable him to fulfil the duties."

Limited Number of Vice-Presidents.

Resolved,—"That the number of Vice-Presidents of the Association be limited to the President of the Royal Society or its equivalent in each colony."

Local Committee for 1889.

Resolved,—"That the delegates from Victoria be charged with the formation of the Local Committee for the 1889 meeting."

Finances.

The President announced that after the expenses attendant upon the formation of the Association, and the carrying out of the present meeting had been met, there would remain a credit balance of £200, or thereabouts, to go towards the publication of the volume.

Government Support.

Mr. R. L. J. ELLERY suggested that the Government of the different colonies should be asked for support, and the President announced that application had already been made for a £1 for £1 subsidy to the Government of New South Wales.

Mutual Co-operation of Medical Congress.

Resolved,—"That the Council of this Association forward a communication to the Council of the Australian Medical Congress, about to assemble in Melbourne, inviting the Medical Congress to mutual co-operation in the cause of science, and suggesting that either the Medical Congress should hold its future meetings at the same time and place as the Association, or that it should unite with the Association as one organisation."

Resolved,—"That the permanent Hon. Secretary be requested to communicate with the Hon. Secretary of the Intercolonial Medical Congress, inviting the co-operation of the Congress in the cause of science, and suggesting that if possible the meetings of the two Associations should be held at the same place and at the same time."

Greeting to British Association at Bath.

Resolved,—"That a telegram to the following effect be forwarded to the President of the British Association at Bath:—'Australasian greets parent Association; successful meeting; 820 members; 110 papers.'"

The Alteration of Rules without previous Notice.

Resolved,—On the motion of Mr. ELLERY—"That no alteration of the Rules shall be made without notice being given at one General Meeting, and the proposed alteration or alterations carried at the next following General Meeting."

Thanks tendered to the Senate of the Sydney University.

Resolved,—On the motion of Mr. ELLERY—"That the Senate of the Sydney University be thanked for their kindness in granting the use of the University Buildings for the first General Meeting of the Association."

Delegates to form Local Committees.

Resolved,—On the motion of Professor LIVERSIDGE—"That the delegates appointed for the Sydney meeting of the Association be requested to form Local Committees in their respective colonies, upon the lines of the Local Committees of the British Association."

MEETING OF THE COUNCIL, TUESDAY, OCTOBER 9, 1888.

EXTRACTS FROM THE MINUTES.

The Royal Society's Rooms.

A letter was received from the Royal Society of New South Wales, granting to the Association the continued use of their Rooms.

Resolved,—"That the Royal Society be thanked."

British Association.

The following Telegram to Professor Liversidge was read:—

"The President and General Committee of the British Association, heartily congratulate you upon the great success of the inaugural meeting."

Entrance Fee—New Members.

Resolved,—"That new Members are eligible for election by the Local Council upon payment of an Entrance Fee of £1, and an Annual Subscription of £1."

MEETING OF THE COUNCIL, WEDNESDAY, OCTOBER 17, 1888.

EXTRACTS FROM THE MINUTES.

The Financial Year.

Resolved,—"That the Financial Year end on the 30th June, and that this decision be conveyed as a recommendation to the General Committee in Melbourne."

Annual Subscriptions, &c.

Resolved,—"That a recommendation be sent to the General Committee, at its next meeting, to the effect that all Entrance Fees and Compoundings be funded."

SYNOPSIS OF GRANTS OF MONEY APPROPRIATED TO SCIENTIFIC PURPOSES BY THE GENERAL COMMITTEE AT THE MEETING IN 189 .

The names of the members who are entitled to call on the Treasurer for the respective grants are prefixed.

[None.]

THE ANNUAL MEETING FOR 1889.

The meeting at Melbourne has been postponed by the Melbourne Committee to January 7th, 1890.

PLACE OF MEETING FOR 1890.

The third Annual Meeting of the Association will be held in New Zealand at a date to be arranged.

GENERAL STATEMENT OF SUMS WHICH HAVE BEEN PAID ON ACCOUNT OF GRANTS FOR SCIENTIFIC PURPOSES,

[None.]

COMMITTEES OF INVESTIGATION APPOINTED AT THE GENERAL COMMITTEE OF THE SYDNEY MEETING, AUGUST 31st, 1888.

No. 1.—Conditions of Labour Committee.

On the Motion of Mr. Hayter,—"That the following be appointed a Committee to inquire into the question of the Conditions of Labour, with special reference to strikes, and to make suggestions for their remedy: Professor Elkington, Mr. W. Garlick, Major Goldstein, Mr. H. H. Hayter, Professor Kernot, Mr. H. K. Rusden, Mr. H. C. Russell, and Mr. A. C. Wylie."

Secretary—*Major Goldstein, Melbourne.*

No. 2.—Australasian Meteorology Committee.

On the motion of Mr. Ellery—"That the following Committee be appointed to enquire into the present state of Meteorology in the Australian Colonies: Mr. R. L. J. Ellery, Mr. H. C. Russell. Mr. W. Sutherland, and Professor R. Threlfall."

Secretary—*Mr. H. C. Russell, Sydney.*

No. 3—Australasian Biological Station Committee.

On the motion of Dr. HASWELL,—" That the following be appointed a Committee to consider the Establishment and Endowment of a Biological Station for Australasia : Mr. A. DENDY, Mr. J. J. FLETCHER, Dr. W. A. HASWELL, Mr. A. H. S. LUCAS, Mr. MACGILLIVRAY, Professor BALDWIN SPENCER, and Professor R. TATE.

Secretary—*Dr. W. A. Haswell, Sydney.*

No. 4—Australasian Biological Biographical Committee.

On the motion of Professor BALDWIN SPENCER,—" That the following Committee be appointed to draw up a List of Works and Papers bearing on Biological Science, with special reference to Australian Forms : Mr. A. DENDY, Mr. J. J. FLETCHER, Dr. W. A. HASWELL, Mr. A. H. S. LUCAS. Professor F. J. PARKER, Professor SPENCER, Professor R. TATE, Professor THOMAS, Mr. C. A. TOPP, Mr. H. TRYON, Mr. T. WHITELEGGE, and Dr. J. T. WILSON."

Secretary—*Mr. J. J. Fletcher, Sydney.*

No. 5—Protection of Native Birds and Mammals Committee.

On the motion of Professor SPENCER,—" That the following be appointed a Committee to consider and investigate the question of the Protection of Native Birds and Mammals : Mr. A. J. CAMPBELL, Dr. W. A. HASWELL, Mr. R. M. JOHNSON, Professor BALDWIN SPENCER, Professor STEPHENS, Professor R. TATE, and Mr. H. TRYON."

Secretary—*Mr. R. Etheridge, Sydney.*

No. 6—Sydney Hygienic Committee.

On the motion of Dr. WILSON,—" That the following Committee be appointed to consider certain points in the Construction and Hygienic Requirements of Places of Amusement in Sydney :—Mr. W. E. ROTH, Mr. SULMAN, Dr. ASHBURTON THOMPSON, Professor WARREN, and Dr. J. T. WILSON."

Secretary—*Mr. J. Sulman, Sydney.*

No. 7—Australasian Mineral Census Committee.

On the motion of Professor LIVERSIDGE,—" That the following Committee be appointed to prepare a Census of Australasian Minerals :—Mr. R. L. JACK, Sir JAMES HECTOR, Professor A. LIVERSIDGE, Professor MASSON, Mr. W. SKEY, Mr. C. S. WILKINSON." The following have since been added :—Mr. E. B. LINDON, Mr. A. W. CLARKE and Mr. RULE.

Secretary—*Professor A. Liversidge, Sydney.*

No. 8—Australasian Glacial Evidence Committee.

On the motion of Professor LIVERSIDGE,—" That the following Committee be appointed to investigate and report on Glacial Evidence in Australasia :—Mr. H. Y. L. BROWN, Mr. S. H. COX, Sir JAMES HECTOR, Mr. R. L. JACK, Mr. W. H. RANDS, Mr. JAMES STIRLING, Professor R. TATE, and Mr. C. S. WILKINSON."

Secretary—*Professor Ralph Tate, Adelaide.*

No. 9—Town Sanitation Committee.

On the motion of Professor LIVERSIDGE,—" That the following Committee be appointed to enquire into and report on Town Sanitation:—Dr. BANCROFT, Hon. Dr. ALLAN CAMPBELL, M.L C., Mr. W. M. HAMLET, Sir JAMES HECTOR, Professor LIVERSIDGE, Professor THOMAS, Professor R. THRELFALL, and Professor WARREN."

Secretary—*Hon. Dr. Allan Campbell, M.L.C., Adelaide.*

No. 10—Australasian Seismological Committee.

On the motion of Professor LIVERSIDGE,—" That the following Committee be appointed to investigate and report upon the Seismological Phenomena in Australasia :—Mr. A. BIGGS, Mr. R. L. J. ELLERY, Sir JAMES HECTOR, Mr. H. C. RUSSELL, Professor R. THRELFALL, and Mr. C. TODD."

Secretary—*Sir James Hector, K.C.M.G., &c., New Zealand.*

No. 11—Australasian and Polynesian Races Bibliography Committee.

On the motion of Professor LIVERSIDGE,—" That the following be appointed to draw up a Bibliography of the Australasian and Polynesian Races, with special references to Philology :—Hon. Dr. AGNEW, Rev. J. COPELAND, Rev. S. ELLA, Rev. W. WYATT GILL, Sir JAMES HECTOR, Mr. A. W. HOWITT, Dr. J. FRASER, and Mr. J. F. MANN."

Secretary—*Dr. John Fraser, Sydney.*

No. 12—Antarctic Exploration Committee.

On the motion of Hon. JOHN FORREST,—" That the following Committee be appointed to consider the question of Antarctic Exploration :—Mr. JAMES BARNARD, Mr. R. L J. ELLERY, Hon. JOHN FORREST, Mr. G. S. GRIFFITHS, Baron F. VON MUELLER, Professor BALDWIN SPENCER, and Professor STEPHENS."

Secretary—*Mr. Ellery, Melbourne.*

No. 13—Australasian Geological Record Committee.

On the motion of Mr. R. L. JACK,—" That the following be appointed a Committee for Geological Record during the year:—Mr. R. ETHERIDGE, Professor F. W. HUTTON, Mr. R. L. JACK, Mr. R. M. JOHNSON, Mr. JAMES STIRLING, and Professor R. TATE."

Secretary—*Mr. R. Etheridge, Sydney.*

No. 14—Australasian Chemical Science Committee.

On the motion of Professor BLACK,—" That the following Committee be appointed to consider and report upon the State and Progress of Chemical Science in Australasia during the year, with Special Reference to Gold and Silver Saving Appliances used in these colonies and elsewhere :—Professor BLACK, Mr. S. H. COX, Professor KERNOT, Dr. LEIBIUS, Professor A. LIVERSIDGE, Professor MASSON, and Professor RENNIE."

Secretary—*Mr. S. Herbert Cox, Sydney.*

ERRATA ET CORRIGENDA.

[*The lines are inclusive of the heading to each page.*]

Page 11, line 32—*after* Warren *delete* comma.
Page 45, line 18—*for* 3 *read* 1.
Page 125, line 27—*for* addre:ss *read* address.
Page 125, last line—*for* acquired *read* required.
Page 126, line 3—*for* acquired *read* required.
Page 127, line 39—*for* irregularly *read* irregular.
Page 128, line 27—*for* acetelene *read* acetylene.
Page 128, line 29—*for* napthalene *read* naphthalene.
Page 129, line 28—*for* cokeing *read* coking.
Page 129, line 35—*for* crystalizes *read* crystallizes.
Page 130, line 3—*for* poliminized acetelenes *read* polymerized acetylenes.
Page 131, line 9—*for* celulose *read* cellulose.
Page 131, line 16—*for* herbivorea *read* herbivora.
Page 133, line 22—*for* lense- *read* lens-.
Page 134, line 20—*for* Volatile hydrocarbon *read* Volatile hydrocarbons.
Page 134, last line—*for* adipo-celluloses *read* adipo-cellulose.
Page 134, line 10—*for* latter *read* former.
Page 135, line 11—*for* ash *read* cork.
Page 137, line 19—*for* menstruæ *read* menstrua.
Page 140, line 5—*for* are *read* is.
Page 140, line 43—*for* hydrchloric *read* hydrochloric.
Page 141, line 5—*delete* vapour.
Page 141, line 6—*for* water *read* vapour.
Page 141, line 32—*for* tho *read* the.
Page 142, line 21—*for* ·4121 *read* ·4424.
Page 142, line 32—*for* 28·454 *read* 28·451.
Page 145, line 30—*for* second NH_3 *read* HNO_3.
Page 149, line 21—*for* ·068 *read* ·065.
Page 149, line 28—*for* 3·135 *read* 5·135.
Page 167, line 39—*for* hydrochlorine *read* hydrochloric.
Page 179, line 23—*for* xvii. *read* xvi.
Page 185, line 18—*for phillipinensis* read *philippinensis.*
Page 244, line 29—*for* Diamentina *read* Diamantina.
Page 244, line 35—*for* Diamentina *read* Diamantina.
Page 262, line 31—*for* chracteristically *read* characteristically.
Page 338, line 6—*for* F. Jeffrey Parker *read* T. Jeffrey Parker.
Page 338, line 30—*for* Geologists *read* Zoologists.
Page 339, line 22—*for* connections *read* connection.
Page 339, line 42—*for* onetagenesis *read* metagenesis.
Page 340, line 16—*for* usually *read* probably.
Page 341, line 16—*for* larger *read* large.
Page 341, line 19—*for* action *read* active.
Page 342, line 11—*for* Zygote *read* Oosperm.
Page 342, line 14—*for Cryptoganes* read *Cryptogames.*
Page 342, line 27—*for* reception *read* receptive.
Page 421, line 4—*for* limits. When *read* limits, when the census was taken ;.

Page 421, line 6—*for* Island, *read* Island ;
Page 422, line 6—*for* professing *read* possessing.
Page 422, line 11—*for* the uniformity *read* that uniformity.
Page 424, line 21—*for* other's *read* others.
Page 424, line 34—*for* are *read* is.
Page 432, line 20—*for* Mr. Giffin *read* Mr. Giffen.
Page 478, line 34—*for* M.L.C. *read* M.E.C.
Page 478, line 40—*for* Flinder's *read* Flinders.
Page 479, line 17—*for* beneficial *read* benificent.
Page 479, line 23—*for* ubraided *read* upbraided.
Page 479, line 43—*for* Aborgine *read* Aborigine.
Page 479, line 46—*for* humerous, *read* humorous.
Page 479, line 47—*for* "Convict Once," and other poems *read* "Convict Once and Other Poems."
Page 480, line 11—*for* herione *read* heroine.
Page 480, line 21—*for* affected *read* effected.
Page 480, line 32—*for* wallably *read* wallaby.
Page 484, line 2—*for* 3 *read* 4.
Page 489, line 24—*for* incion *read* incision.
Page 573, line 13—*for* extention *read* extension.
Page 599, line 10—*for* Anstralian *read* Australian.
Page 637, line 23—*for* Lacrozea *read* Lacrozia.

PRESIDENT'S ADDRESS

BY

H. C. RUSSELL, B.A., F.R.S., F.R.A.S., F.R.M.S.,

A VICE-PRESIDENT OF THE ROYAL SOCIETY, N.S.W.,

GOVERNMENT ASTRONOMER, N.S.W.,

At the First Meeting of the Australasian Association for the Advancement of Science.

IT was not without serious misgiving as to my fitness for the office that I accepted, in the early days of this Association, the honorable position to which you elected me; and could I have foreseen that your choice would call me to preside at such a great and representative gathering as this, held in the great hall of our University, within which all the associations are so enobling, I must have declined the honor which your kindness has conferred upon me. I can only assure you that I am deeply sensible of the importance of the duties you have asked me to fulfil, and that it is my earnest desire to do everything I can to further the object for which we are met together. I must ask you to look kindly on the many short-comings which I know will mark my efforts. In July, 1831, just 57 years ago, Mr. (afterwards Sir) David Brewster, wrote to the Secretary of the Yorkshire Philosophical Society, and proposed that the Society should call a meeting of all the scientific men in the United Kingdom, with a view to the formation of an Association for the Advancement of Science. The proposal was approved and encouraged by the Society, and received the most zealous and effective support from Sir John Herschel and Sir Roderick Murchison in London, and from Mr. Robison, Mr. Forbes, and Mr. Johnstone of Edinburgh. A committee was appointed to consider how it should be done, and they reported: "That they were of opinion that the invitations for the first meeting, which was to be held in York, should be co-extensive with whatever desire there might be throughout the country to promote science." Invitations were accordingly sent out in the form of a circular letter, dated July 12, 1831, to the Presidents and Secretaries of all the Scientific Institutions in the United Kingdom and known to the Committee, asking them to give a general invitation to all the members of the Societies to join the Association and attend the first meeting at York. At this time there were 39 Scientific Societies, 13 in London and 26 in other parts of the Kingdom. As indicating how very comprehensive was the invitation issued by the promoters of the Association, I quote its last paragraph, which reads :—"All persons interested in scientific pursuits are admissable to the meeting." The meeting was accordingly held in the hall of the Philosophical Society of Yorkshire on Tuesday, September 27, 1831. Three hundred and fifty-three persons attended, including most of the scientific men of the United Kingdom, and it was thereupon decided to form an association, and that it should be called "The British Association for the Advancement of Science," the objects of which shall be 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 British Empire with one another, and with foreign philosophers ; and to obtain a greater degree of national attention to the objects of science, and a removal of any disadvantages of a public nature which impede its progress. Such was the first stage in the history of the British Association ; the foundation had been laid, and it was broad enough to support the imperishable structure that has been raised upon it. It was a conception worthy of Sir David Brewster, and has done more for the advancement of pure and applied science than any other institution in the United Kingdom. It has won the confidence of Governments, who have adopted and acted upon the recommendations of the Association, and regularly placed in its keeping sums of money for the promotion of science. How the work has been carried out, and what has been done, I cannot pretend to tell you now. It is the story of the advance of science in all the sciences during the last 57 years, and would occupy at least the rest of this week. I regret my inability to condense the story into the limits of this address, for I can conceive of no stronger incentive to the formation of a similar Association here than the history of what has been done for science by the disinterested labours of those who from time to time have formed the working members of the British Association. If one turns over the back volumes published by them, they are full of invaluable reports upon almost every subject. The mere list of titles makes a volume. Is there any scientific subject that needs investigation by a number of persons ; a committee is at once formed, men found willing to take a share in the work that in some cases lasts for years ; they have but to ask and hundreds of men all over the kingdom will give willing help. For instance, underground drainage is a subject that requires for its investigation the united labours of hundreds of people, who will patiently gauge their wells all over the country and report the result; without hesitation a committee of the British Association took up the work and carried it on for years to a successful report. Is it desirable to investigate the phenomena of shooting stars; a committee again takes up the subject, works out all the results, tells us a mass of invaluable facts bearing upon their phenomena. Is it necessary to form a grand star catalogue out of all the labours that have gone before; the Association at once appoints a committee and grants the money for the publication of their invaluable catalogue. Is the theory of ship-building in a state of chaos; a committee of scientific and practical men collects the results of experience, reduces them to order, to the improvement of ship-building. And so on. Hundreds of subjects, scientific and practical, have been thoroughly investigated, and the information brought up to date by the voluntary labours of the members who have made the British Association true to its charter. It has advanced the sciences all round—mathematical, chemical, physical, mechanical, physiological, and botanical. It found thousands of fellow-workers in science separated by distance and different associations, and it abolished distance by itself going about the country, and made a common ground upon which all could meet and work for the promotion of their common object without losing their individuality as workers in their own sphere. It brought as it were to a focus the science of England; made it possible to see at glance what had been done; opened up the vista of a grand scientific progress, and marshalled the men who were to move forward; the best men in each subject were called to work side by side with their equals or betters, and necessarily when each subject came to be treated in this special way, there was a great advance; but it is not a thing of the past, it is a living principle of to-day. Last year the meeting at Manchester included 5000 members. Not all workers it is true, but all learners, and the most humble contributing something towards the publication of the labours of those who are leaders in the van of workers. Its influence has come across the ocean, and brought us here to-night, and we hope before the end of this week we shall have a number of preliminary reports upon scientific labours in these colonies in the past. At the very time that Sir David Brewster was using his pen and his influence to stir up the scientific men of England to greater effort in the cause of science, and to the formation of the British Association for the Advancement of Science, the British Government were sending to Sydney one of the most energetic scientific men that ever sat foot upon Australian soil, (James Dunlop, the Astronomer), with a view of keeping alive the dying embers of the first attempt to plant science in this part of the world. And I think it most fitting that, at this first meeting of the Australasian Association for the Advancement of Science, we should remember that first effort to promote science in a country so remote from the home of science. It is difficult now to form any idea of the condition of society in Australia when Sir Thomas Brisbane landed, and nothing but the habit of disregarding difficulties, which a long military experience had taught him, would have made it possible in his mind to form a scientific society under such circumstances. But he had been so accustomed to go into strange places and make his own surroundings that it appeared to him possible to do the same here. He landed in the end of November, entered upon his official duties on December 1, 1821, and by January 2 following he had found out the only scientific men in the colony, formed them into the Philosophical Society of Australia, and had the first paper read. He never seems to have anticipated any difficulty in managing this handful of civilians, who, however, soon got beyond his control. His own enthusiasm for science was very remarkable. In the midst of the harassing marches and all the perils of the great continental war in which he bore a part, even when he had to sleep six nights in the snow with nothing but his overcoat to cover him, and found himself frozen to the ground each morning, and once with 900 men frozen to death around him, he always had his astronomical instruments in his baggage, and brought them into use whenever there was half a chance. It was this intense love for science, coupled with his military ideas, which made him so anxious to get all the scientific men around him in a duly organised society, each to do his duty rigidly or suffer the consequences. But with all his enthusiasm he soon found that a small army of scientific workers was not so manageable as the armies he had been accustomed to. The members of this first Australian Society, according to Judge Field, were:—Alexander Berry, Henry Grattan Douglas, M.D., Baron Field (Judge), Major Goulburn (Colonial Secretary), Captain Irwin (Bengal N.I.), Captain P. P. King, John Oxley (Surveyor-General), Charles Stargard Rumker (Astronomer), Edward Wolstencraft, His Excellency Sir Thomas Brisbane, K.C.B., F.R.S., president. I find no record of the rules of this society, excepting one, and that was if a member failed to read a paper when his turn came he forfeited £10. They met at each other's houses in turn, and the only refreshment allowed was a cup of coffee and a biscuit. It seems that the society was more of a mutual friendly association or scientific club than a formal society. At that time there was no public library, and but one bookseller for the whole of Australia; so the members catalogued their books and lent them to one another. With such a strong incentive to write papers, there can be no doubt that meetings seldom lapsed for want of a paper, but they were not published in proceedings, and the only existing record is given by Judge

Field, who published four of them in his "Geographical Memoirs";—No. 1. "On the Aborigines of New Holland and Van Dieman's Land"—read January 2, 1822. 2. "On the Geology of part of the coast of New South Wales, from Hunter River to the Clyde" read in the same year by Alexander Berry. 3. "On the Astronomy of the Southern Hemisphere," by Dr. Rumker—read March 13, 1822. 4. "On the Maritime Geography of Australia," by Captain P. P. King, R.N.—read October 2, 1822. Mr. Oxley also read a paper, and Major Goulburn some notes on meteorological observations; and lastly, Sir Thomas Brisbane communicated meteorological observations. We have evidence, therefore, that seven at least of the twelve were workers. Allan Cunningham (botanist) also contributed papers to Judge Field's memoirs—one describing his travels from Bathurst to Liverpool Plains in 1823, and the second on the botany of the Blue Mountains, as observed in November and December 1822. Judge Field does not say that these papers were read to the Society, so that he may not have been a member, but without doubt all the members did good service in the colony. The Society which was thus commenced with such flattering promise of usefulness was destined to but a brief period of existence. A question arose between the Government and some of the members as to the value of the dollar—the coin then current—which led to estrangement and the breaking up of the little band of workers who cultivated science. It appears that this was caused by the decree that the dollar, after the centre had been punched out to make a small coin equal in value to sixpence and known as a "bit," should still pass for its original value, the effect of which was severely felt by business people, because it raised the value of the pound sterling 25 per cent. But the great work which Sir Thomas did in Australia, and what I am disposed to think induced him to accept the position of Governor in the distant colony, was his astronomical work. He had applied before taking the appointment for the consent of the Government to start an observatory when he got to Sydney, but that being refused, on the ground that they were then making arrangements to establish an observatory at the Cape, and did not think it necessary to have two southern observatories, he at once determined to take the whole cost and responsibility upon himself, purchased a complement of instruments, and selected two assistants, Dr. Rumker, as a first-class astronomer and mathematician, and Mr. Dunlop, for his great natural ability and enthusiasm in the pursuit of astronomy. He brought the whole with him, astronomers and instruments landing in Sydney in November, 1821. The observatory was at once marked out, within one hundred yards of Government House, Parramatta, so that he could at any convenient time take a share in the work; but he could not wait for the building. I find, from the observations, that he observed the sun's solstice in

December, and he so hurried on the building that it was completed and ready for use by the end of April. He, with both assistants, worked at high-pressure observing until June 16, 1823, when Mr. Rumker, owing to some difference in opinion between himself and Sir Thomas, left the Observatory. Dunlop at the time was not a trained Astronomer, but he was a ready learner, and a little training from Sir Thomas made him master of the instruments, and then he began that well-known feat of observing which probably has never been equalled. By the end of February 1826, or in two years and eight months, he made 40,000 Observations, and so catalogued 7385 stars. He then left the Observatory, and in 16 months at his own house in Parramatta he catalogued 621 nebulæ and clusters of stars, made drawings of the Milky Way nebeculæ, major and minor, and many nebulæ, catalogued and measured 253 double stars. For this he got the gold medal of the Royal Astronomical Society, and afterwards gold medals from the Royal Institute of France and from the King of the Belgians. Meantime Rumker had returned to the observatory and agreed to carry out a work that was recommended by Sir Humphry Davy as President of the Royal Society, viz., the measurement of an arc of the meridian in New South Wales (that arc is not measured yet.) Sir Humphry Davy urged that "the measurement of an arc of the meridian in New South Wales would not only be of importance to astronomy in affording data for determining correctly the figure of the earth, a matter of great interest to navigation, but would likewise be useful in laying the foundation for a correct survey of our colonies in that great and unexplored country" (dated 20th October, 1823.) Five years later, in 1828, things had made some progress, Mr. Rumker had agreed to measure the arc, and he ordered the apparatus ; but in January of the following year, 1829, he again left the observatory, and that for the time was an end of the arc of the meridian proposal. Dunlop was reappointed in 1831, and the observatory lingered on without publishing until 1847, when it was dismantled. One cannot look back at the history of that Observatory without pain, owing to the misfortunes which seemed to upset every effort to make it useful. Sir Thomas was evidently a first-class observer with the sextant, but knew nothing of fixed instruments ; hence he bought a lot of instruments second-hand, and wholly unfit for the work they were intended to do, and Rumker, who was, without doubt, an able astronomer, had some bee in his bonnet that became very troublesome in the atmosphere of Parramatta. Sir Thomas Brisbane had the command of men and means in abundance, the will and the ability to direct, and so all but the two little ifs was ready for the measurement of an arc of the meridian—a work too long left undone, and one which I hope this Association will take up, not with its funds, but with its influence, and urge on to completion. It is a work of the greatest scientific and practical importance. The four great colonies interested in this question have each done a part of the work which will be allotted to them when the arc, which must extend from the south to the north of the continent, is finally measured; and if this Association rightly uses its influence the work will be done. At present our surveys are quietly going on upon the assumption that the earth is a regular spheroid, when it is more than probable, from the arrangement of land and water, that it is nothing of the sort at this particular part of its surface. Sir Thomas Brisbane evidently contemplated this when he left England, for he took with him the pendulum apparatus to determine the figure of the earth, and left his friends in England to bring the necessary pressure to bear upon the Government to get the arc measured under his administration. I have introduced the subject here as one in every way suitable to occupy the attention of the Association, or at least one section of it; and I thought the early history of the conception would be new to most of us. And its author is in every respect well worthy of remembrance at our first meeting. He was the first man who can fairly be called a patron of science in Australia, having spent, in furnishing the Observatory alone, without salaries, more than £1,600. He was the first to form an association of scientific men in Australia, with a view of advancing science, and Sir John Herschel justly said of him, when presenting the gold medal of the Royal Astronomical Society for the Parramatta catalogue, "It will be to you a source of honest pride as long as you live to reflect that the most brilliant trait of Australian history marks the era of your government, and that your name will be identified with the future glories of that great colony in ages yet to come, as the founder of her science. It it a distinction worthy of a British governor. Our first triumphs in those fair climes have been the peaceful ones of science, and the treasures they have transmitted to us are imperishable records of useful knowledge, speedily to be returned with interest to the improvement of their condition, and their elevation in the scale of nations." Amongst the eleven men who formed the first scientific society in Australia there was far more than an average amount of ability. The great weakness of the society, and that which made it impossible for it to exist except under the fostering care of the Governor, was its want of numbers; and unfortunately in many branches of science the same difficulty exists to-day, and makes it always difficult, and in some sciences impossible, to keep alive societies for their promotion only. Even in those societies which include a number of subjects, and thereby add to their numbers the workers in each, it is often difficult to find enough original work, and perhaps I ought to say enthusiasm, to keep a healthy amount of vitality at its meetings. I am sure there are many here present who have to do the work of scientific societies who must have felt this, and who have often wished, as I have, for something to put a little additional vitality into the members, and for something also, which would bring together a greater number of workers in each branch of science, so that ideas might be interchanged, and a little healthy emulation aroused. Not something to withdraw members from their own societies and steady work, but something to make us feel that it won't do to go to sleep; because our fellow-workers in the other colonies are very wide awake. The Australian Association for the advancement of science, seems to me to meet our case exactly. Its meetings only last for one week in each year, and therefore cannot take members from their local societies, and by assembling the workers in each branch of science from all the colonies, by asking them to form committees and work side by side for a time, it promotes the exchange of ideas upon the same subject, and the pleasure which that affords. There can be no more fitting time to explain the steps which have led up to our association for the advancement of science than this, our first meeting, when I hope all the members are present. I have no doubt that to very many the information will be new, and under any circumstances we must leave for those who come after us an account of the origin of an effort in the cause of science, which I am sure will have an important and lasting influence on the scientific progress of Australia. The first step was taken by Professor Liversidge, who is himself an institution for the advancement of science, and knows no fatigue in that service. Round him everything has revolved in perfect order to the complete preparation for this meeting. On September 16, 1884, in a letter to the *Herald**, which was afterwards reproduced by most of the colonial and some of the home papers, he pointed out that the interest created in Australia by the announcement at the British Association meeting in Montreal of Mr. Caldwell's discovery of the oviparous nature of the platypus and porcupine had led to the suggestion that they should meet some day in Australia; but that he thought this was improbable at present, owing to the time it would take and the cost, and he suggested that we should make preparations for the realisation of the proposal by bringing about a federation or union of the members of the scientific societies of Australia, Tasmania, and New Zealand into an association on the lines of the British Association, and that the first meeting should be in 1888, as one of the features of the Centennial year. He had previously, viz., in 1879, mentioned the proposal to a few, but thinking matters were hardly ripe to press it he had not gone further. Nearly two years then elapsed and no one took up the suggestion, so in his address as President of the Royal Society in May, 1886, he said, "I am still of opinion that arrangements should be made for holding a meeting

* See Appendix for this and other particulars.

of those who wish to form an Australasian Association in 1888, and I shall be glad if those who are in favour of it will kindly send me their names." "If the proposed Australasian Association for the advancement of science should really become an accomplished fact, as I hope it will, the first meeting should I think, be held in 1888," and he then sketched an outline of the rules for it, based on those of the British Association. On June 30, 1886, came the first support to his proposal; the council of the Royal Society of New South Wales resolved to take a part in furthering these views, then promises of support came in from the other colonies. Thereupon in July, 1886, he sent a circular to the presidents of the various Australasian Societies, telling them that his proposal had been favourably received, and requesting them to appoint members of their council or delegates to represent them at a meeting of such delegates from various societies as soon as possible. The number of representatives or delegates from each society was to be one for each 100 members. On July 28, 1886, the Royal Society of New South Wales appointed five delegates; 34 other Societies agreed to join, and 28 appointed delegates for the meeting, which was called for 10th November, 1886. At the meeting 16 delegates were present—7 from New South Wales, 2 from New Zealand, 2 from Queensland, 5 from Victoria. They framed and adopted the provisional rules which we now have, and which are the British Association rules altered to suit our circumstances. It was resolved that the President, Hon. Secretaries, and Hon. Treasurer should be elected by ballot from the representatives of the colony in which the meeting is to be held, and the Presidents of sections from members in the other colonies, and that the first election shall be held in Sydney in March, 1888; and further, that the first meeting should be held in the beginning of September, 1888, in Sydney. Special appeal was then made in the daily press to all who intended to join the Society to send in their names, so that they might be eligible for election to the official positions, officers for which had to be elected by ballot, and the elections were delayed as long as possible to give everyone time to join. The delegates were called together, and met on March 7, 1888, and they elected—H. C. Russell, B.A., F.R.S., President; Prof. Liversidge, M.A. F.R.S., and Dr. George Bennett, F.L.S., Hon. Secretaries; and Sir Edward Strickland, K.C.B., Hon. Treasurer. Since then the Council, composed of the delegates from the various Societies taking part in the work, have held 13 meetings, and have found plenty to do in arranging the details for the meeting, electing Vice-Presidents, Presidents, and Secretaries of sections, collecting papers to be read, &c., for this meeting, and have caused to be sent out 6000 circulars to members of Scientific Societies in Australia; they have, in fact, been sent to every member whose address was known to them, and thinking it possible that there were many others who would join an Association with such a wide basis, they have appealed to the public through the daily papers of all the colonies, very frequently by advertisement and paragraph, and the result is that to-day our numbers are 750*, which, I think, is very satisfactory and encouraging. I cannot pass from this reference to the Council without expressing on behalf of the Association our recognition and warmest thanks, for the hard and continuous work which has been done by the Secretaries of Sections, in working up those Sections, writing countless letters, guide, handbooks, etc., and to all the Members of the Council for their cheerful hard work to further the end in view. I may mention that in Australasia there are only 38 Scientific Societies known to the officers of this movement. All these were appealed to by letter; 34 expressed their intention of taking part in it, and of these 28 sent representatives to the meetings—this out of a population which may be roughly stated at 4½ millions. In 1831 when the parent Society was formed the population of the United Kingdom was 23 millions, and there were in existence 39 Scientific Societies.

I have endeavoured thus briefly to sketch the history of the movement which has resulted in the present Association. Like the British Association, our basis is broad enough to take in "whatever desire there may be in the country to promote science," and those who have joined hope that no man will stand aloof who has any desire to help in the advancement of science. After the experience gathered by a similar institution in the old country I have no fear for the future of this movement. I do not expect the Association to emerge from the shell of its first meeting perfect; that would be unreasonable; but I believe that we have accepted a constitution and acquired an impulse which in the course of time will lead us on to the realisation of our purpose. The scientific man works very much alone, isolated from those around him by his peculiar manner of life, and from his fellow-workers by distance, because so far the world expects each scientific man to be a world in himself, to be able to do all it wants of that science, and is not disposed to keep several where one can be made to do. The call of the British Association, therefore, to meet once a year those who are like-minded, appeals to his social instincts in a very effective way. Hence the opportunity of going to the meeting to see and talk with his fellow-workers is not to be lost. It is a real pleasure to have a talk with kindred spirits, and a very effective motive for application all through the year, for no man would choose under such circumstances to neglect his self-culture, and feel at the meeting that he was far behind his fellows. Then these meetings naturally led to the formation of

*820 At the close of the Meeting.

committees, who must work up all those subjects which the individual cannot manage. One of our first duties will be to work up all the facts known in every branch of Australasian science, if you will allow me to use the term. I mean all those branches of science which are more immediately connected with the material advancement of the colonies. This I hope will not take long, and then we shall be in a position to advance in these subjects. Every worker knows how necessary it is to have all facts in clear and orderly arrangement, as a preliminary and necessary step to any safe advance. It may seem to some that I am asking too much—that we are all hard-worked men, and but few in numbers, and have no time for such work—but exactly the same may be, and has been said, of the men who are the workers in the British Association, yet they are not the men of leisure, but the busy men of science, who do the work, and it is very instructive to watch how they respond to the call of the association; it comes like a call to arms that must be responded to, and is responded to often at great personal sacrifice, and with no other motive than loyalty to the cause they serve. But the parent Association has just the same power over hardworked professional and business men; in thousands of cases it has taken from such a man a week of ill-spared time during which he attended the meetings, and by so doing has succeeded in setting him to work for a year, thinking how he can advance the cause of science. As like produces like, so these meetings of workers make many new workers; and as we read down the list of names of those who have been drawn into the great army of workers we find the name of every distinguished man in the United Kingdom—men with a practice or business in which they had no spare moments; Stephenson, Scott Russell, Brunel, Bessemer, Nasmyth, Armstrong, Warren, de la Rue, Spottiswoode, Whiteworth, Siemens, and so on, through all that grand muster-roll of which any nation would be proud. Now, I do not for one moment suppose that we with four millions can make the same display of talented workers that the United Kingdom can from thirty-seven millions; but we can find some, and I am quite sure that our association will be the means of bringing to the front many men amongst us now scattered through the country who have ability and genius, and who are willing to take up some of the subjects which require investigation and work them out; men whose daily work is of another kind, but who have nevertheless a keen love for science and investigation and the spare time to take up a limited subject and fill up the whole detail. I am convinced that there are many such who require no other stimulus than that of being invited to render services of the highest order. They want to work, but do not know where to begin; while, on the other hand, a crowd of suggestions meet the busy scientific worker at every turn. Ideas that want realising are continually floating in his thoughts.

Now it is some promising line of investigation, some experiments that only want making to put the finishing touch to a long line of reasoning, and establish some new scientific fact or some new law of nature. Now it is a new view of an old and well-fought difficulty, some new vantage ground that promises success; but he cannot leave the pressing duties of the present hour to work out the promising future. And for him to meet those who have time and ability to work is like hope in the wilderness, and if our association can bring them together it will have done much to promote science. It has been said that amateurs at science do little in the more difficult subjects of investigation; but those who say so overlook the fact that, when a man does do difficult work, they cease to call him an amateur, and class him with professional men. It is a well-known fact that some of the greatest honours in scientific work have been won, and are being won, by men who would be properly classed as amateurs—men who have stolen from leisure and from sleep the hours necessary for their favourite study. It is a mistake to class all amateurs as alike. As well say that all business men are alike. Science seems ever to point forward. The question answered to-day suggests two for to-morrow. There may be no halting place, and none is desired. Obedience to the law of service develops into a service of love, and the search for truth is the pleasure of existence. And if we are true to our colours we will see that truth is not stored away in dusty papers, but published to the world, so that everyone may see what and how it is. The British Association has put the best men to do this, and to publish the known facts in every science to the world, and has found this the best method of helping that great majority who are ready and willing to help if taken up to the front and shown clearly the boundary between what is known and what is unknown. It is this noble example that we wish to follow. The Australasian Association is for the advancement of science, and if it fails in that, it will fall to pieces. But it is not the hobby of a few individuals, or of one colony; it takes in all who wish to advance science in all the colonies; it meets here this year, in Melbourne, probably, next year; going to another colony every year, gathering up the enthusiasm of each colony in turn, and will come back to us when we are very glad to receive it. By its charter the association is bound to promote the intercourse of scientific men and lovers of science; to give a stronger impulse and a more systematic direction to scientific inquiry; to obtain a public recognition for the claims of science, and to endeavour by every means in its power to promote scientific inquiry; to grapple with the scientific questions that effect the material advancement of this portion of the British dominions—questions in chemistry, physics, and geology; in mining, mineralogy, and engineering; in meteorology, water conservation, and irrigation; and every other subject that may promote our national advancement. I hope you will not think my subject is running away with me, for the experience of the British Association fully justifies us in believing that we may expect all this and much more from our association. We are often told of the influence of science upon material advancement; but there is another thing that I should like to dwell upon, but that I fear to keep you too long. We hear too little about the influence that scientific work has upon a man's character. There is a science culture as well as a classical culture, and it would be worth while tracing its influence upon those who get it, and through them upon society. And we hear far too little about the influence which science is having upon the young, by exercising their powers of observation and reason on the phenomena of nature around them. Scientific education is spreading through all classes of the community, and slowly but surely, like the advance of every great truth, the world has learned to recognise the fact that science is the great lever in the material advancement of the people; nay, more, that we cannot have material advancement without a previous advance in science. If we are to have new processes in the arts, new applications of the laws of nature for the wellbeing of mankind, we must first have the study of nature and the laws which govern its operations before we can hope to employ them for our advantage. In a new country like this, with all its local variations in the laws of nature, its uncultivated forest fruits and flowers, its unknown vegetable and mineral wealth, the fact is forced upon us in a thousand ways that we must know or we must suffer. And we use the word science in its comprehensive sense. There have been those who said that the proper study of mankind is man, and who, while strenuously denying to this study the dignity of a science, have thought no other science worthy of culture. And there have been others who have asserted that man's only study was nature in the things around him, neglecting altogether the science of man. But man and nature are correlative, and, therefore, true science must embrace both studies. And even in the things around us we must not take the vulgar view, which only sees the necessity for cultivating those branches of science that are direct producers of gold and minerals. As a well-known politician in another colony once said to me when I asked him to spend a few pounds on pure science, "Will it affect the price of beef and mutton? If not, I won't spend a shilling on it." Unfortunately he is not alone in his opinion; there are many whose only measure for scientific value is a coin of the realm. If there is to be a true advance of science it will not come from one-sided efforts. Each branch must be pushed forward in its own special direction, and in—what is just as important—its relation to all other branches of science. Science stands or falls as a whole; if we limit it to certain purposes or persons, it ceases to be science, and becomes mere empiricism. This Association stands as a protest against the short-sighted and utilitarian policy of those who would cultivate only what they characteristically call the bread and butter sciences. Our purpose is the advancement of all the sciences, believing, as we do, that the true advance of one is inseparably connected with that of all the others, and by the advance we do do not simply mean the increase in knowledge of its laws, but also in the application of it to the wants of mankind. Too often in the past the advance of science has been checked for generations by those who said they knew that the earth stood still, and who did their best to make it do so, and our protest is against the views of men of the same stamp in the present day who think they know everything and select what is useful. Is that dreamy astronomer to be banished because he sits in some darkened dome peering through his telescope at some distant star, and wanting to know where it is. What has that got to do with the material advancement of the people, says the Utilitarian. Nay, that very quest turned into a demand for better mechanical contrivances, better glass, and better workmen, led Fraunhofer to strain every nerve to meet it. He will examine light in its passage through lenses most minutely, and thus learn to correct the previous errors in his telescopes, and while he did that he found those definite lines in the spectrum that will for ever be known by his name. He recognised their exact coincidence with those given by well-known terrestrial substances, and so gave the world the spectroscope, that most wonderful instrument working out through the most abstract science, the quickest, most perfect—aye, even the cheapest way of answering a thousand pressing questions in the money-making arts. Has chemistry served its purpose when it analyses our soils and our minerals ; when it makes a mixture to take gold from quartz, and money out of everything. Is it not to go into our schools and colleges and universities, and teach those who will never use its solvents—those wonderful affinities in nature, those laws of combination and dissolution, of solution and crytallisation—the laws which formed the water, built up the solid rock, the earth, the flowers? Is the study of pure mathematic to be banished because it cannot find an equation for the locality of a big nugget, when it has found and is finding thousands of equations which are mines of untold wealth in the material advancement of humanity. No, certainly not; for 'tis fitting that man, dwelling in that infinitely complicated organism, his body, which responds on its ten thousand strings to every breath of nature, should study not one or two, but all the laws which govern it for weal or woe, and learn to place himself in harmony with all.

APPENDIX TO ADDRESS.

On September 16, 1884, Professor Liversidge wrote the following letter, which appeared in the Sydney papers that date, was afterwards reproduced by most of the other Colonial and some of the Home papers:—

THE BRITISH ASSOCIATION.

To the Editor.

Sir,—During the past fortnight we have received several telegrams from London, respecting the late meeting of the British Association, at Montreal, and in some of them references are made to suggestions that a future meeting should be held in Australia.

As far as one can judge, the idea seems to have been thrown out when Professor Moseley, F.R.S., announced Mr. Caldwell's discovery of the oviparous nature of the platypus and Australian porcupine*. The news seems to have created or rather re-awakened interest in the peculiarities of Australian Natural History, and on the spur of the moment some of the more enthusiastic members appear to have proposed that a subsequent meeting of the British Association should be held in Australia.

The Victorian Premier, with commendable promptitude, at once telegraphed the necessary invitation for the Association to visit Melbourne next year; an invitation might also have gone from Sydney, and especially under the circumstances. Without such invitation the meeting is not likely to take place here, for the Association only visits towns to which it is invited, and generally there is more or less competition amongst the principal towns to secure the acceptance of their invitations, and to bring this about the competing towns offer as many attractions as possible.

For the Montreal Session, all the great English Steamship Companies between England and America, and the Canadian and United States Railway Companies reduced their fares to members and their families; the Government Railways were, of course, made free to them, and the Telegraph Companies also granted free use of their lines all over Canada and the United States. Numerons free excursions were arranged to places of interest, some extending over a period of twelve or fourteen days, the members and their families merely paying for their meals and sleeping-berths at quite nominal rates.

In addition to the reductions made by the Steamship Companies, the Canadian Committee voted $14,000 for the purpose of still further reducing the cost of members' (and of their relatives) passages to Canada. The Australian Colonies would of course gladly help in the same way; but, taking the much greater expense and time of voyage into account, the amount to be raised here would have to be many times as much.

I am, however, very much afraid that, although Australia, New Zealand, and the Islands offer great attractions to many of the members (I know of one eminent scientific man who is returning to England, via Australia from the Montreal meeting), yet, but comparatively few could afford the time and money to come out here.

The visit to Montreal, and the excursions through Canada and the United States could all be managed in a month or six weeks, and at a comparatively small expense—in fact, most of those who went to Canada made the trip do duty for the annual autumn holiday or visit to the sea-side; but out of the 2,000 to 3,000 members and associates (2,714 attended

* Sent from Sydney by cable.

the Southport meeting in 1883) only a comparatively small number could arrange to visit Australia. The round voyage could scarcely be squeezed into the long vacation of those fortunate enough to have one, and the necessary travelling expenses would considerably exceed the whole year's income of many—for the pursuit of science is not a lucrative one, and as a rule its followers are poor.

Hence, taking all things into account I do not think we could expect more than fifty members, if so many. And unless some 400 or 500 attended (between 800 and 900 entered their names for the Montreal session), the gathering could scarcely be considered as a meeting of the British Association. Therefore, instead of looking for a near visit from the Association, I would suggest that we should rather be, preparing the way for issuing an invitation later on, when we have made suitable provision to entertain our intended scientific guests, and as a preliminary step I would venture to suggest as a member of the parent Association, that we might try to bring about a federation or union of the members of the various Scientific Societies in Australia, Tasmania, and New Zealand, into an Australasian Association for the Advancement of Science on the lines of the British Association, with a view to hold the first general meeting in Sydney, on the hundredth anniversary of the Colony, when there will probably be an International Exhibition to celebrate that event. With the combined attractions we might hope to gather together a very fair number of scientific visitors to take part in the proceedings.

I mooted the question during the last Exhibition in Sydney, in 1879, but matters seemed hardly ripe for it ; but now, perhaps, with the greater advancement in numbers and in wealth, something might come of it in 1888.

The details for an Association suited to the scattered Australasian Colonies necessarily offer some difficulties, but they can all be more or less readily overcome, and I hope to be able shortly to communicate with the different Societies to discuss the necessary arrangements

After the first meeting the gatherings could take place annually, or every two or three years, in one of the principal towns of Australasia, as agreed upon by the members.

I am sure that such an Association—which must come sooner or later if we are to hold our own—would not only do a great deal for the advancement of science in the Colonies, but would also favour their progress in other ways.

Trusting that this letter may bring about expressien of opinion upon the matter,

I am, &c ,
A. LIVERSIDGE.

The University, September 16, 1884.

In his President's address delivered to the Royal Society of N.S.W., 5th May, 1886, Professor Liversidge returns to the subject and says—

"I am still of opinion that arrangements should be made for holding such a meeting in 1888, and for founding the proposed Australasian Association for the Advancement of Science, and I shall be glad if those who are in favour of it will kindly send me their names as intending members, so that the necessary preliminary steps can be taken.

. . . .

"If the proposed Australian Association for the Advancement of Science should really become an accomplished fact, as I hope it will—for progress in material affairs cannot well be expected, and certainly will not be made unless a corresponding advancement be first made in science—we should not necessarily be compelled to hold yearly meetings at first. The headquarters of the Association, however, could not be conveniently shifted every year; but so that each colony should have an equal share in its affairs, the offices might be moved at stated intervals from capital to capital."

He then sketched an outline of the proposed Association on the lines of the British Association. You will observe that nearly two years after the proposal he still had to say "if the proposed Australian Association should really become an accomplished fact," obviously the idea had not yet asserted itself amongst the various Societies; this was in May, 1886; on June 30, 1886, at a meeting of the Council of the Royal Society of N.S.W., Professor Liversidge moved that steps be taken to form an Australian Association for the Advancement of Science, and undertake its initiation on the lines laid down in his Presidential address; and it was resolved that the Council will take part in the furtherence of Professor Liversidge's proposal. On the 27th of July, he sent out the following letter and circular:—

The University,
Sydney, July, 1886.

To the President and Council of the * * * *

Gentlemen,—

The proposal that a meeting of the Scientific Societies of Australasia should be held in Sydney during the year 1888 (the Hundredth Anniversary of the Foundation of these Colonies), having been very favourably received in this and the other Colonies,* I have the honour to request that you will kindly take the matter into consideration, and if disposed to take part in the matter that you will be pleased to appoint members of your Council to meet representatives of the Council of the Royal Society of New South Wales, and of other Societies, for the purpose of making arrangements for the proposed meeting in 1888, and of forming an Australasian Association for the Advancement of Science, on the lines of the British Association.

It is suggested that in the first instance one representative should be deputed from the Council of each Society for every 100 members on its roll.

Should you not be able to send members from your own body or Society it is open to you to appoint delegates from amongst your corresponding members, or others, to represent your Society at the forthcoming preliminary meetings to be held in Sydney. An early answer is respectfully requested to allow the first meeting to be held with as little delay as possible.

A copy of some suggested rules are forwarded by book post.

I am, Gentlemen,
Yours truly,
A. LIVERSIDGE.

PRELIMINARY CIRCULAR.

Australasian Association for the Advancement of Science.

It is proposed to hold a meeting of the various Scientific Societies in Australia and New Zealand in 1888 (the One Hundredth Anniversary of the Foundation of these Colonies), upon the lines of the British Association meetings, and to form an Australasian Association for the Advancement of Science, with similar aims and objects.

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* In the public Press.

OBJECTS OF THE ASSOCIATION.

The objects of the British Association are set forth as follows: and the proposed Australasian Association would probably do well to try to follow the same lines :—

"The Association contemplates no interference with the ground occupied by other Institutions. Its objects are—to give a stronger impulse, and a more systematic direction to scientific enquiry—to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another, and with Foreign Philosophers—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress."

(Here followed Proposed Rules.)

On the 28th July, 1886, the Royal Society, New South Wales, in response to this circular, resolved that the following gentlemen be selected as representatives of the Royal Society of New South Wales at the proposed Australasian Association for the Advancement of Science, viz., C. Rolleston, C.M.G., President; H. C. Russell, B.A., F.R.S.; Professor Liversidge, F.R.S,; C. S. Wilkinson, F.G.S., F.L.S., and the Honorable Dr. C. K. Mackellar, M.L.C. In August the following letter was sent :—

THE UNIVERSITY,
Sydney, August, 1886.

TO THE HONORABLE SIR P. A. JENNINGS, K.C.M.G. &c., &c.
Premier of New South Wales.

SIR,—I have the honor to draw your attention to the enclosed printed documents, in which it is suggested that the Hundredth Anniversary of the Foundation of the Australian Colonies should be commemorated by holding a meeting of all the Scientific Societies during the year 1888, and to request that you will be pleased to consider whether you would be able to recommend your Government to afford the proposed Association any pecuniary aid to promote the advancement of Science, as is done elsewhere. Should you wish to see me respecting the matter, I shall be very happy to wait upon you at any time you may appoint.

(Signed) A. LIVERSIDGE.

On 8th October, 1886, he wrote again from the University to the Secretaries of the various Societies as follows :—

SIR,—I have the honor to inform you that a meeting of the Committee appointed to make preliminary arrangements for the proposed Australian Association for the Advancement of Science will be held at the house of the Royal Society of New South Wales, Sydney, on Wednesday, 10th November, at 3 p.m., at which the attendance of the representative of your Society is requested.

The business for the consideration of the Committee is as follows :—

1. To frame Provisional Rules.
2. To appoint a date in 1888 for the first meeting of the proposed Association; copies of previous circulars enclosed.

(Signed) A. LIVERSIDGE.

In all, six thousand circulars have been sent out to members of Scientific Societies in Australia, Tasmania, and New Zealand, that is, to every member whose name and address was known; and to those who take an interest in the Association, but who are outside the Societies, appeal has been frequently made by advertisements and notices in all the leading papers of the various Colonies.

On the 10th November the meeting thus called duly met, there were present the following delegates :—

NEW SOUTH WALES.

Geographical Society of Australasia (N. S. W. Branch), Sir Edward Strickland, K.C.B.
Linnean Society of N.S.W., Professor W. J. Stephens, M.A., and J. J. Fletcher, M.A., D. Sc.
N.S.W. Zoological Society, Dr. A. T. Holroyd, F.L.S.
Royal Society of N.S.W., H. C. Russell, B.A., F.R.S. ; Professor Liversidge, F.R.S. ; C. S. Wilkinson, F.G.S., F.L.S.

NEW ZEALAND.

Nelson Philosophical Society, S. Herbert Cox, F.C.S., F.G.S.
Philosophical Institute of Canterbury, S. Herbert Cox, F.C.S., F.G.S.

QUEENSLAND.

Geographical Society of Australasia (Queensland Branch), J. P. Thomson M.A., C.E.
Royal Society of Queensland, Henry Tryon.

VICTORIA.

Geological Society of Australasia, R. T. Litton, F.Z.S.
Historical Society of Australasia, R. T. Litton, F.Z.S.
Royal Society of Victoria. Professor Kernot. M.A., and K. L. Murray.
Victorian Institute of Surveyors, W. J. Conder, and W. H. Nash.
Victorian Engineers' Association, Professor Kernot, M.A., and K. L. Murray.

In the absence of Mr. C. Rolleston, C.M.G., President of the Royal Society of New South Wales, Mr. H. C. Russell, B.A., F.R.S., was unanimously voted to the Chair.

At the request of the Chairman, Professor Liversidge informed the meeting of the steps which had hitherto been taken towards the formation of the proposed Association, and stated that the business for the consideration of the Committee was as follows :—

1. To frame Provisional Rules.
2. To appoint a date in 1888 for the first meeting of the proposed Association.

WEDNESDAY, 10th NOVEMBER, 1886.

PRELIMINARY MEETING OF THE AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, HELD AT THE ROYAL SOCIETY'S HOUSE, No. 37 ELIZABETH STREET NORTH, SYDNEY, AT 3 P.M.

Professor Liversidge placed on the table, letters from the principal Australasian Societies, agreeing to the proposal to form an Australasian Association for the Advancement of Science and appointing the following delegates, viz. :—

NEW SOUTH WALES.

1. Engineering Association of N.S.W., A. C. Mountain and Geo. A. Key.
2. Geographical Society of Australasia (N.S.W. Branch), Sir Edward Strickland, K.C.B.
3. Institute of Architects of N.S.W., Thomas Rowe, F.R.I. B.A.
4. Linnean Society of N.S.W., Professor W. J. Stephens, M.A., and J. J. Fletcher, M.A., B.Sc.
5. N.S.W. Institute of Surveyors, no reply received.
6. N.S.W. Zoological Society, Dr. A. T. Holroyd, F.L.S., and Dr. George Bennett, F.L.S.
7. Royal Society of N.S.W., C. Rolleston, C.M.G.; H. C. Russell, B.A., F.R.S.; Prof. Liversidge, F.R.S.; C. S. Wilkinson, F.G.S.; Hon. C. R. Mackellar, M.B., M.L.C.

NEW ZEALAND.

8. Auckland Institute, no delegate appointed.
9. Hawke's Bay Philosophical Institute, no reply received.
10. Nelson Philosophical Society, S. Herbert Cox, F.C.S., F.G.S.
11. New Zealand Institute, no reply received.
12. Otago Institute, Rev. J. E. Tenison-Woods, F.G.S., F.L.S.
13. Philosophical Institute of Canterbury, S. Herbert Cox, F.C.S., F.G.S.
14. Southland Institute, no reply received.
15. Wellington Philosophical Society, no delegate appointed.
16. Westland Institute, no delegate appointed.
17. Westland Naturalist and Acclimatisation Society, no reply received.

QUEENSLAND.

18. Geographical Society of Australia (Queensland Branch), J. B. Thomson, M.A., C.E.
19. Royal Society of Queensland, Henry Tryon.

SOUTH AUSTRALIA.

20. Royal Society of South Australia, no delegate appointed.
21. South Australian Institute of Surveyors, no delegate appointed.
22. Zoological Society, no reply received.

TASMANIA.

23. Royal Society of Tasmania, The Right Rev. The Bishop of Tasmania, and James Barnard.

VICTORIA.

24. Field Naturalists Club of Victoria, Rev. W. Woolls, Ph. D., F.L.S.
25. Geographical Society of Australasia (Victorian Branch), no delegate appointed.
26. Geological Society of Australasia, R. T. Litton, F.Z.S.
27. Historical Society of Australasia, R. T. Litton, F.Z.S.
28. Institute of Architects, no reply received.
29. Microscopical Society of Victoria, no delegate appointed.
30. Royal Society of Victoria, Robert Hunt, F.G.S. ; and Prof. Kernot, M.A.
31. Victorian Engineers' Association, Prof. Kernot, M.A., and K. L. Murray.
32. Victorian Institute of Surveyors, W. J. Conder, and W. H. Nash.
33. Zoological Acclimatisation Society, Albert A. C. Le Souef.

PROCEEDINGS OF THE SECTIONS.

PROCEEDINGS OF THE SECTIONS.

Section A.

ASTRONOMY, PHYSICS, MATHEMATICS, AND MECHANICS.

President of the Section: R. L. J. ELLERY, F.R.S., *&c., Government Astronomer of Victoria.*

The First Meeting of the Committee of the Section was held in the Lecture Room of the Physical Laboratory of the University on Wednesday, August 29th, 1888. Amongst the Members present were the following :—

R. L. J. Ellery, M.A., F.R.S., President of the Section; H. C. Russell, B.A., F.R.S., President of the Association; Professor R. Threlfall, M.A., Secretary of the Section; W. Sutherland, M.A.; J. F. Adair, M.A.; H. A. Lenehan, A. Pollock, N. A. Graydon.

It was decided that the following order should be observed in the reading of the Papers ;—

For Wednesday, August 29—

1. The President's Address.
2. Two Papers by W. Sutherland, M.A., one on "The Law of Molecular Force," and one on "Molecular Refraction."

For Thursday, August 30—

1. A Paper by H. C. Russell, F.R.S., on "The Early History of Astronomy in Australia."
2. A Communication by Professor Arthur Rücker, requesting information as to Magnetic Irregularitles, supposing any to occur in Australia.
3. A Paper by N. A. Graydon, on "Variations of Atmospheric Pressure and Wind."

For Friday, August 31—

A Communication by H. C. Russell, F.R.S., on "A Proposed Means of Estimating Variations of the Vertical and recording the same continuously."

The following Papers by Professor Threlfall, M.A.:—

1. On "The Physical Laboratory at the University."

2. On "The Measurement of High Resistances and on Galvanometers suitable for the purpose."

3. On "The Clark Cell as a means of obtaining a Standard of Current, and on its application in the Construction of a Graded Galvanometer for the use of the Prince Alfred Hospital." This last in conjunction with Mr. Pollock.

MEETING OF SECTION A, HELD ON WEDNESDAY, AUGUST 29TH.

The President, Mr. R. L. J. Ellery, F.R.S., in the Chair.

The President delivered the following Address:—

ON THE PRESENT POSITION OF ASTRONOMICAL KNOWLEDGE;

LADIES AND GENTLEMEN,—The Australasian Association for the Advancement of Science, just organised, having done me the honour of electing me President of Section A, embracing Astronomy, Mathematics, Physics, and Mechanics, I propose to open the proceedings with a brief address on "The Present Position of Astronomical Knowledge," but in doing so I must content myself with a very superficial review of the most prominent and interesting features in recent progress of knowledge concerning the tenants of space, the most generally received views upon various theories and hypotheses relating to their constitution, and an indication of the stage at which we have arrived in the perfection of our instruments and methods of research, and the difficulties besetting further advance.

If we look back to the time this great city was founded, about a hundred years ago, we find that our greatest advance since then has been in the direction of Physical Astronomy. In Mathematical Astronomy the world's knowledge was so much enriched during the century following Newton's great work, that now, near the end of the 19th century, our position is not remarkably beyond what it was when Herschell first pointed his just finished forty-feet telescope to the planet Saturn and discovered two new satellites, now about one hundred years ago. In physical astronomy, however, the additions to our knowledge during the period referred to, and more particularly during the last quarter of a century, may be regarded as little short of marvellous.

Progress in Astronomy now depends in no small degree on progress in its sister sciences, in optics, in electricity, especially in photography, chemistry, and physics generally; and as a new departure is made in any of these branches of knowledge, some new implement or some new power is furnished with which to attack afresh many of the numerous and baffling problems of the universe which come within the province of the Astronomer. Thus we find that the revelations of the spectroscope in the laboratory at once made possible the solution of a host of difficult questions and the testing of numerous hypotheses on the chemistry of the universe; while the dawning of the different stages in our knowledge of dynamics, heat and light, and their inter-relations, were quickly followed by corresponding advances in physical astronomy, which have thrown new light upon the great question of the history and present constitution of the heavenly bodies, and afford grounds upon which to base new theories and hypotheses.

I think we may take for granted that the great questions of physical astronomy now may be briefly summed up as follows:—

What is the present constitution of the visible universe; is it unchangeable, or is it in a state of change?

What has been its previous history, and to what is it all tending?

The objects for study to which we look for most help in the solution of these questions are of two classes; first, those tenants of space in our immediate neighbourhood whose distance from us can be counted in millions of miles—the numbers of the solar system—and, second, those bodies which are so far removed from the solar group that light cannot span the intervening space in less than three years.

The history of the solar group has been hypothetically sketched in the nebular theories of Kant and Laplace, the former imagining in the beginning a cloud-like mass of dissociated elements with a nucleus or condensed centre, occupying the space now filled by our solar system, and that formation of separate bodies out of this matter took place by mutual gravitation of parts.

Laplace was led to very similiar conclusions, his assumption being that the planetary space was occupied by the sun, surrounded by an immense fiery atmosphere, endowed with a rapid rotatory motion, which eventually broke the hot vaporous matter into rings, these in turn condensing into planets with their appropriate orbital motions.

This grand conception, despite certain difficulties which present themselves in view of more modern knowledge, is up to the present time the accepted theory of the early evolution of our system, and while advance in knowledge has suggested objections to the full acceptation of the hypothesis, it has, on the other hand, furnished strong evidence of its general correctness.

There is plenty of evidence that the matter of which the several bodies consist is generally speaking the same. The same constituents are known to exist in all, but under different conditions, due to different grades of heat, condensation, and motion.

Generally speaking the accepted idea is that all the planets are in different stages, not so much of age as of condensation and temperature. Some, we know, are of very low density compared with others. Saturn would float in water, while the earth is six times as dense. Some are at much higher temperatures than others, while one, and perhaps two, are at the stages of their existence which, so far as human knowledge goes, is the only one favourable to animal or vegetable life. The stages of a planet's existence are generally supposed to begin after actual condensation into a spherical mass, with one of great surface heat, and very low density—hot plastic masses, hardly coherent enough to resist disruption by centrifugal force; then a stage where cooling has brought about a recombination of dissociated elements; then a farther cooling and formation of a solid crust to the sphere, which later on arrives at the stage of our earth. When, by further cooling, water becomes eternally solid, except in equatorial regions, it arrives at a later stage when all appears dead and unchangeable as seems to be the case with our moon.

We will now, briefly review our present knowledge of the several bodies included in Laplace's famous nebular hypotheses, the sun and planets.

As regards the sun, the chief mathematical questions are his distance and dimensions; the former has now been ascertained within the narrow limits (astronomically speaking) of about 1,000,000 miles, that is, all recent determinations place it between 92,000,000 and 93,000,000 of miles, and with our present method and means of observation, this almost appears to be the limit of accuracy attainable. Up till about thirty-four years since, the sun's distance had been accepted as 95,000,000 of miles. The sun's real diameter is a point that cannot be spoken of with certainty owing to the vaporous condition of its surface. The most recent assumption gives a diameter of 867,000 miles.

With respect to the physical constitution and condition of the sun, I can but take a brief glance at the astounding results which observation and investigation have revealed by means of the spectroscope. Summing up our knowledge, we find this body in all probability to consist of a vaporous mass of a very low density, which, as Professor Young suggests, appears to be of a consistence analogous to tar or honey. The vapour consists of gases at a temperature at which dissociation of elements takes place. The visible surface or photosphere is probably somewhat cooler than the underlying vapours, and the spectroscope reveals therein absorption lines, indicating the presence of most of the elements known on the earth excepting the metalloids. Outside the photosphere is an envelope of incandescent gases called the chromosphere, invisible except by aid of the spectroscope, but which is still at an extremely high temperature. Enormous eruptions of incandescent hydrogen pierce the photospheric and chromospheric envelopes, and are belched forth in fountains to hundreds of thousands of miles beyond the sun's surface; these jets are often seen by aid of the spectroscope in the neighbourhood of sun spots when near the edge of the sun's disc, and are the cause of the red protuberances seen around the edge of the dark moon during a total eclipse, on which occasions, so long as totality lasts, a beautiful phenomenon known as the corona is also seen, which it is generally supposed is composed of matter in a comparatively cool state, either in the process of being ejected from or falling back upon the sun's surface.

The red protuberances, as the jets of hot hydrogen seen during total eclipses were named, used to be considered phenomena only to be seen during total eclipses until it was shown by Jansen and Lockyer at the Indian eclipses of 1872 that they could be seen at any time when present by means of a properly arranged spectroscope. The possibility of seeing the corona also at times other than that of total eclipse or, in fact, almost at any time, has more recently suggested itself to some astronomers, and Dr. Huggins has by a photographic method obtained results that are very important, and seem to show that the faint light from the heated matter which produces the phenomenon of the corona seen during total eclipses of the sun, is capable of acting on the sensitive silver film and giving a picture.

Dr. Huggins found that by "stopping off" or filtering the bright glare from the sun itself that a photographic impression could be obtained of the surrounding region, and in almost every plate a faint picture, apparently of a corona, was obtained. A good deal of doubt was expressed as to the pictures being real impressions of the corona, but a photograph secured at nearly the same time that a total eclipse was observed in another part of the world afforded an opportunity for comparison, and it was found that the photograph corresponded very closely with drawings and photographs taken during the progress of the total eclipse.

Of Mercury and Venus—the two planets nearest the sun—we know little that was not known a hundred years ago, and although statements have from time to time appeared of discoveries of markings, signs of mountains, and so forth, they have not been such as could be accepted by astronomers. It is generally considered they both possess somewhat dense atmospheres, but their rotation periods even are, as yet, a mystery.

No heavenly body has been so thoroughly watched and scrutinised as our satellite the moon, its geography, or rather selenography, has been most minutely examined and beautiful maps constructed. Now and then we have heard of certain minute changes in the surface having been observed, or of appearances as of an active volcano, or jets of steam, but I think it is now generally conceded that the lunar surface is in a stage of unchangeableness, if one may use such a word.

The more fruitful investigations concerning our satellite relate chiefly to questions of temperatures, existence of atmosphere, etc. Although it seems impossible at present to arrive at any certainty about lunar temperatures it appears probable from the most recent investigations that the lunar surface under a vertical sun is hotter than boiling water, and that under lunar night the temperature gets much below any ever known on the earth, and perhaps 200 or 300 below zero. All investigations with respect to the existence of a lunar atmosphere have tended to a negative result.

Concerning our own planet, astronomers and physicists have given us the results of some important investigations as regards its density, its true figure, and the effects of secular change in the ellipticity of its orbit. The earth is generally regarded by geologists as a sphere of molten matter, surrounded by a comparatively thin solid crust; mathematicians and physicists, however, demand a much greater rigidity of the general mass than this would admit. To resist the tide-producing action of the sun and moon as the mass of the earth apparently does, would require a rigidity equal to that of steel. The theories of the geologist and mathematicians are therefore widely at variance with respect to the condition of the earth's mass.

While the figure of our planet is regarded as an ellipsoid of revolution, there has always been some doubt as to the exact regularity of its figure, as well as of the precise ratio of the polar and equatorial diameters. Accurate goedetic measures of its surface have been made only in comparatively a very few places, and although the results have revealed no great departure from the figure of the ellipsoid, they are insufficient to give us certainty on the point. The most recent investigations by Colonel Clarke, however, point to it being an "ellipsoid of three unequal axes," for he states he finds from an examination of all geodetic measures available that different meridians have different radii of curvature. But, having personal experience of the great difficulties and uncertainties of measures of this kind with our most modern instruments and methods I should regard this part of the question as still unsettled. The ellipticity of the earth's figure given by Colonel Clarke as between 1-293 and 1-294 is now I believe generally accepted as correct.

A very interesting point has been discussed by Dr. Croll with a view of accounting for the secular climatic change indicated by geological facts, tropical deposits in polar regions, and *vice versa.* The earth revolves round the sun in an elliptical orbit, whose eccentricity is now about at a minimum, yet we are nearer that body in January than in July by about 3,000,000 miles—the amount of eccentricity changes, and Dr. Croll says that 850,000 years ago this difference was 12,000,000 instead of 3,000,000 miles. Under such circumstances the hemisphere, whose winter occurred at aphelion, or at the greatest distance of the sun, must have been subjected to greatly prolonged cold, and under the rule of excessively low temperature, while the opposite hemisphere, with its long summer and short winter, must have been in a condition favorable to most luxuriant vegetation and the support of animal life of different form than now existing. This view at all events is based upon mathematic reasoning, and may perhaps account for the geological facts referred to, and the occurrence of successive glacial epochs whose traces are found in comparatively low latitudes. The latest glacial epoch is estimated by Dr. Croll to have taken place 200,000 years, but the maximum 840,000 years ago. A question here suggests itself, namely, whether epochs of greater or less sun heat, owing to the increase of or diminution of the absorptive influence of the sun's photosphere, as suggested by Professor Langley, may not be also accepted as a probable cause of glacial periods.

Owing to the nearness to which the planet Mars often approaches us and the earth-like character of its telescope appearance, it naturally presents a most interesting study to the astronomer. It is seen to be marked out as if into continents and seas, the marking often appearing as if obscured by clouds. Very considerable change in the features have been observed from time to time, and recently appearances as of narrow channels or canals have been seen, which have changed and split and been joined by cross channels. These observations have been dilated upon by popular scientific writers, who have suggested that the canals and channels are the work of martial inhabitants for irrigation or other great engineering purposes. The writers must imagine stupendous works by stupendous beings, when canals and irrigation channels are as wide as the Mediterranean Sea. The mapping of Mars has been pushed to a minuteness that many astronomers cannot follow, but the soaring imagination of our popular writer brooks no bounds, and where we have canals and artificial channels this year we may discover barges and steamboats next. My own experience leads me to regard many of the drawings and speculations concerning the martial surface as being a little in advance of ascertained facts. It is undoubtedly very earth-like in character, and is very probably nearer the same stage (as regards cooling) of our planet than any other, it also appears to be endowed with an atmosphere often cloud-laden, obscuring the features of the planet's surface. We wait for increased powers of observation at the future near approaches of this planet for further developments. The most interesting fact in connection with this planet is the comparatively recent discovery by Hall in 1877 in America of his two satellites, whose existence had not hitherto been ever suspected. The remarkable features of these bodies are their nearness to the parent planet, their smallness, and their rapid motion. They have been named

Deimos and Phobos ("fear and panic"). Phobos is only 3,760 miles and Deimos 12,500 miles from Mars' surface. The former goes round the planet in a little over $7\frac{1}{2}$ hours, and the latter in about $30\frac{1}{4}$ hours. The actual dimensions can only be estimated from light measures, which give diameters of about nine and eleven miles.

Outside the orbit of Mars we come to that region of solar dominion tenanted by the planetoids. You will remember that at the beginning of this century no body was actually known between the orbits of Mars and Jupiter, although it was already suspected that some body or bodies did exist there. In 1801 Piazzi discovered the first of the minor planets, Vesta, and now we have 277 on the list, the whole mass of which, it is computed, would only form a body equal to 1·3,000th part of the earth's volume. Pickering, from photometric measures, estimates the diameter of the largest, Vesta, at 319 miles, while the smallest have diameters probably not exceeding 10 miles.

Jupiter, or as he is now often called, the giant planet, is a favorite study for both the practical and physical astronomer. His immense size, his systems of satellites, and the peculiar and changing appearance of his surface tend to make this planet one of the most attractive of the solar group. Probably the chief interest is now centred on observational evidence of the physical condition of the planet's surface. It has long been suspected that some of the light we see on Jupiter is intrinsic or not reflected sunlight, but recent investigation seems to show that while the surface of the planet is apparently at a comparatively high temperature, very little, if any, native light is emitted from him. His visible surface is evidently vaporous and disturbed by equatorial storms giving rise to the ragged and rippled edges of the belts. His vapoury envelope appears to have a rotation period differing from that of the solid body, for the periods obtained by observing the successive passages of some markings or spots are different from those given by other spots. Moreover, the comparatively recent phenomenon of the red cloud or spot afforded excellent opportunities for testing this question. This remarkable appearance of an immense cloud-like mass of a distinct brick red colour, which, I fancy, was first actually drawn on paper by our esteemed President, Mr. H. C. Russell, in 1876, continued to be visible on the planet's surface until 1885. By consecutive observation of this red cloud in Jupiter's atmosphere, it was found to complete its circuit in 9 hours 55 minutes and 36 seconds, while a white spot or cloud near it took some $5\frac{1}{2}$ minutes less, showing a relative motion one from another of nearly 260 miles an hour. Jupiter's actual rotation is assumed to be about 9 hours and 55 minutes. It seems then almost certain that whatever may be the constitution of the Jovian surface, it is unstable and subject to a relative motion in itself. These observed facts, combined with the comparatively low density of its mass, which is only a third more than that of water, while the density of our earth is nearly six times greater, lead us to the conclusion that this planet is in a comparatively early stage of its history, perhaps in a semi-fluid state, destined in ages to come by cooling and increasing density to a condition approaching that of our earth.

The most beautiful and wonderful of the planets is Saturn, with its mysterious ring and its following of eight satellites. Its immense distance, however, has so far presented an insurmountable obstacle to anything more than conjecture as to physical condition or constitution. The mathematical questions as to dimensions, distances, and motions of the several parts of this group are now pretty well established within small limits, but the constitution of that wonderful appendage the ring or of the planet itself remains an unsolved problem. The density of Saturn is extremely small, being only three-quarters that of water, and would float in that medium only three-quarters immersed; this being the case, we can scarcely conceive its being a solid body. The rotation period, from observations in 1876 of a bright equatorial spot by Asaph Hall at Washington, appears to be about ten hours and a quarter, but if the visible surface of the planet be in the same or perhaps in an earlier condition than that of Jupiter, the actual rotation of the planet may be somewhat different. Definite markings on the body of the planet or on the ring, by which the axial period may be measured, are of rare occurrence, so that even on this point our knowledge is not very definite. The ring is seen to be divided up into three principal annuli, the two outer bright and solid looking, the inner darker, with a guaze-like structure; hence it is called the *crape ring.* The constitution of this appendage has always been a puzzle to astronomers, but, from dynamical and other physical considerations, the most acceptable hypothesis appears to be that it is composed of an aggregation of minute particles of matter circulating about the central body in orbits proportioned to their distances from it, and that the particles composing the inner ring must, to account for what is seen, be of different constitution to those of the outer or brighter rings, The spectroscope gives evidence of aqueous vapour in Saturn.

Distance, that helps to keep Saturn's condition enshrouded in mystery, casts a more impenetrable veil over our two outer planets, Uranus and Neptune, concerning which recent astronomical research has added little to what was known a quarter of a century ago.

Sometimes lately, faint markings have been seen on Uranus, which have given a rough approximation to its period of rotation as about ten hours. On favourable occasions the little green disc has given decided indications of an equatorial bulging, as if its plasticity were such that axial rotation was putting a great strain on its cohesion. There is one remarkable feature the result of recent observations of this body, namely, that the orbits of the satellites appear to be in a plane coincident with the bulging, but that bands apparently equatorial are seen to exist in a plane differing from that of the satellites by over 40 degrees.

The spectrum of this planet shows the presence of free hydrogen on its surface, from which we may conclude its present condition is more nearly the solar one than any member of the group, except, perhaps, Neptune, whose spectrum appears very analogous to that of Uranus. We can see very little of Neptune, and do not even yet know its rotation period. This question, as well as that of the existence of other planets outside of him, form problems for the future.

The spectroscope has helped us to a knowledge of the nature of the fixed stars and nebulæ that was formerly little dreamt of. On account of the immense distance of the nearest of these bodies, seen through our largest telescopes, they appear simply as points of light, but analyse this light by the spectroscope and a flood of knowledge comes to the observer.

Most of the stars show a spectrum of lines, either bright from a glowing gas, or dark from the absorption effects of overlying vapour, in many cases marvellously like our sun. Indubitable evidence is presented to us of the presence of metals, gases, and other substances familiar to us on the earth and in the vapours of the sun, and indeed of their being in all probability suns in themselves. We find, however, that there are several varieties of spectra among the stars, yet not so numerous but they can be grouped into half a dozen classes or so. One group exhibits a spectrum almost identical in character with the solar one, others exhibit a few bright lines only, some again have both bright and dark lines, many show the fluted spectrum characteristic of certain elements at comparatively low temperatures, while others exhibit a continuous spectrum, or a spectrum partly continuous and partly broken by lines or flutings. The appearances tell us plainly of the existence of matter at high but different temperatures, from that of a Bunsen burner, perhaps up to that of the cauldron of glowing Bessemer steel, and onwards to that of the solar surface itself. The conclusions we have come to with regard to most of the principal fixed stars is that they are bodies very analogous to our sun, and probably consisting of the same matter, but from their different conditions revealing to us the presence only of such elements as are vapourised, or rendered incandescent, at the temperature which is at present maintained on their surface. We account for the occasional sudden increase in the brightness of a star—indeed, all variability of stars—by sudden or gradual alterations of this temperature from causes which cannot, so far, be explained, except upon an hypothesis recently advanced by Mr. Lockyer. As regards the nebula and nebulous stars, so far as we can yet speak, they seem to consist of some kind of cosmical matter in a more or less heated state, for I think we may take for granted that at the distances of the fixed stars and nebula, no matter, even in large masses, would be visible unless at a very high temperature. It may, therefore, be that the objects we see are but a portion of the matter actually existing. I think we may reasonably believe that in many of the nebulæ evolutionary changes are in progress, and we can scarcely look at some of the planetary and disc-like nebula with bright centres without imagining a condition of things such as Laplace had in his mind when he devised his theory of the genesis of the solar system. Although any statements of observed change in the nebulæ have hitherto been regarded with considerable doubt, the recent condensation in the Andromeda nebula and the undoubted change that has taken place in the nebula of Eta Argus since Sir J. Herschell's drawings up to the present time, forces us to an admission that changes do take place, and are seen readily enough to satisfy the most stubborn sceptic. The relations existing between comets and meteroids, or those meteors which move in regular orbits around the sun, has been a subject of great interest, especially since it was found that the orbits of several well-known comets were identical with those of some of the meteoroids—the Leonids and Perseids, for instance. That there is a very intimate connection between meteoroids and comets is now certain, but whether meteoroids are parts of old and broken-up comets, or whether comets themselves are condensed portions of the meteor streams, cannot yet be stated with certainty. The fact that some periodic comets have become smaller at successive apparitions, while others have broken up, as in the case of Beila's comet, might help the former proposition. The evidence of the spectroscope points to a similar constitution of matter in both.

The orbits of many of our comets, as well as some of the meteor streams, extend far beyond the orbit of Neptune into the apparently untenanted space between our solar system and the nearest fixed stars. Does, then, the matter of which the meteors and meteoroids are composed, and of which fragments are constantly falling on the earth, belong only to the solar system, or is it only a portion of the universal cosmical matter pervading all space? These small bodies only become visible to us when heated by collision either with our atmosphere or with other matter or bodies of considerable density, and therefore may pervade space in almost any conceivable quantity, and yet be invisible except under certain conditions. In support of such a suggestion we know the metallic meteors falling to the earth have hydrogen occluded within their substance, and are composed of elements whose spectra are for the most part visible in many of the fixed stars that have been examined, and hydrogen, we know, is an important component in very many stars. It may thus be that meteoric matter is a tangible connecting link between the solar system and the rest of the visible universe across that great wilderness of space by which they are separated. Some very important suggestions by Mr. Norman Lockyer upon the classification of heavenly bodies, and I may almost say a new theory of the universe, have been laid before the scientific public through the Royal Society of London. In brief it may be stated as follows:—Space is a plenum of meteoric matter. All self-luminous bodies in the celestial spaces are composed of meteorites or meteoric vapour produced by heat from condensation of meteor swarms due to gravity. He assumes some at least of the meteoric matter to have orbital motion. Some may be in motion, some at rest, but all visible evidence of this matter appears as stars, comets, or nebulæ, between which no distinction can be made on physical grounds. Visibility is brought about by collisions of meteoric particles, and according to the profusion of sparseness of the meteoric particles in space, where collisions occur by intersections of orbits with matter at rest or with bodies in other orbits, we have nebulæ of the several kinds, comets, nebulous stars, and even concrete stars themselves. This may be called the meteoric hypotheses, and as the conception has for its foundation a mass of indisputable facts, the result of long and laborious research with the spectroscope in the laboratory, compared skilfully and patiently with facts revealed by spectroscopic examination of all classes of celestial objects, I can but regard it as a most important step in physical astronomy, destined, I believe, to make a new epoch in the science. The idea that meteoric matter or bodies pervade all space is not in itself a new one, for when we consider (accepting Professor Newton's estimate) that 20,000,000 meteorites fall to our earth daily, it is evident that space is, astronomically speaking, full of them; nevertheless, by the same calculation by which Professor Newton arrived at the foregoing number, he ascertained that sparseness to be such that the meteorites must be 250 miles from each other in space. As regards the effects of collisions of meteorites, the speed of visible meteors can be measured, and it is reckoned to be at an average 30 miles a second. If, then, the specific heat of the material of which they are composed is ·10, the increase of temperature when their motion was arrested by a full collision would amount to 2,700,000 degrees centigrade (steel being fluid at 3,552deg. Fahr).

In conclusion, I now come to the question of recent methods of research in observational astronomy and the difficulties in the way of future progress.

The telescope, of course, is the chief instrument of the astronomer, and it has been brought to a stage of great perfection, yet at its best it is very far from what is wanted.

In almost every astronomical instrument the loss of light due to numerous surfaces of lenses and mirrors rapidly limits their efficiency. We endeavour to make up for this loss by increasing the dimensions of the first light collecting element of the instrument, such as the mirror or object glass in telescopes.

So far, however, with a few exceptions, it has been found there is a limit which appears to have been rapidly appproached in some of the largest telescopes recently constructed.

In the case of refractors of 26 to 30-inch aperture, the lenses of the object glass become so thick as not only to absorb a serious proportion of the light it grasps, but its weight brings about flexure of the glass itself, and strain which greatly interferes with good performance. It now seems likely, if larger apertures are attempted, some supports for the centre of the lenses must be devised, which of course will to some extent diminish the aperture it was sought to increase.

Although the same class of objections do not lie against reflecting telescopes, yet it does not at present seem profitable to go beyond the dimensions now used—say 6 feet diameter at the extreme, for no reflector of even 4 feet aperture exists that is free from serious defects arising from weight and difficulties of preventing flexure, detrimental, if not ruinous, to good performance in the mirrors and other parts of the instrument. So far, then, I think we may state generally that increase in size of telescopes has not been followed by that increase of usefulness which largely increased cost naturally demands. It has been said the most important part of the astronomical telescope is the observer's eye; this cannot be made more perfect, still its imperfections are a bar to further advance in some directions. No two eyes are alike, and no two see an object exactly alike, and so there is always an outstanding doubt between results of two or more observers. Again, there is that nerve personality which is a great drawback in observational astronomy, and is due to different individuals possessing nerve current velocity of different degrees.

The question of stability of astronomical instruments is of the utmost importance, but we know now there is no such thing as stability on the earth's surface, and we are not only subject to incessant tremors but actual movements, which may be periodic and oscillating, or permanent and sliding. To ascertain these movements and provide against their results upon celestial measurements forms a large part of the practical astronomer's work.

With the astronomical spectroscope loss of light through multiplication of surfaces and absorption of the material of which the prisms are made is the great difficulty, except where there is abundance of light, as in the case of the sun. For this reason spectroscopic observations of the smaller stars and nebulæ is extremely tiring and difficult. Photography comes in as a great aid in some researches in this direction, chiefly because the sensitised plate will receive and record impressions that our eyes fail to grasp. So for telescopes and spectroscopes we ask more light or larger apertures, better glass, and more perfect surfaces.

Photography has for a long time been an indispensible handmaiden to the astronomer, and great things have been accomplished by its aid, more especially in the departments of solar and stellar physics; it promises to be of immensely wider importance as progress in the art is secured, not only in the departments of physical but mathematical astronomy also. We are now preparing for a great work, in which photography will be the chief implement. I refer to the proposal to make a complete photographic chart of the heavens, not only of all stars visible, but of all that can be seen with moderately powerful telescopes, whose numbers will probably amount to several millions if all down to the 15th magnitude are included, as is proposed. You already know that arrangements have been made by which various nations have agreed to join in this great undertaking, each one taking a portion of the celestial sphere as his field of operation. The preliminaries are nearly all arranged. The character and size of the instrument, the kind and dimensions of the sensitive plate, have been decided upon, and it is expected that most of the instruments will be in their place, and work commenced sometime next year (1889). It is thought we may complete this work in ten years, and quite possibly in less. There is an interesting point in connection with this comparatively new astronomical method arising out of the power possessed by the photographic film of recording impressions far too faint to stimulate the eye to vision. It has been found in photographs of stars that the latter are frequently recorded on the plate that cannot be seen by the eye even in powerful telescopes, because the light they emit does not come within its limit of wave period, although it suffices to decompose the silver film. It is highly probable, therefore, that one of the results of this great work will be the discovery of numbers of bodies, dark stars and nebulæ, minute planetoids, and perhaps even comets and meteroids, that have so far escaped detection through the limitation of the powers of the eye to light of certain wave lengths only.

The requirements, optical, chemical, and mechanical, for the successful prosecution of this undertaking would have been considered a few years ago almost insurmountable. As regards the telescopes and photographic films they seem to be already met. The great mechanical difficulty, however, of keeping a large heavy telescope following the motion of the earth so precisely as to keep a star bisected by a spider web at its focus for one, two, or three hours together has presented a serious difficulty, which until very recently was feared would embarrass the undertaking.

We have reasons now, however, to believe that this too has been overcome by the ingenuity and patient experimenting of Sir Howard Grubb, of Dublin, to whom the manufacture of several of the instruments destined for this undertaking has been entrusted, among which will be those for Sydney and Melbourne.

In closing, permit me to express the hope that if not the next, at the next following gathering of this Association both I and my friend Mr. Russell may have a good account to give of the commencement and progress of the Australian share of the photographic charts of the southern heavens.

The following papers were read :—

1.—ON THE LAW OF MOLECULAR FORCE.

By William Sutherland, M.A., B.Sc.

The object of this paper is to apply the hypothesis of a molecular force, varying inversely as the fourth power of the distance, already discussed by me in certain of its aspects in the Philosophical Magazine for August, 1886, and July and August, 1887, to the subject of capillarity, with special reference to the recent beautiful discoveries of Eötvös and Robert Schiff in that subject. The results obtained are :—First, the following law of the parameter A, in the expression $\frac{m^2}{r^4}$ for the force between two similar molecules of mass, m at distance, r apart. In compounds containing C, O, and H, the molecules may be considered to have a volume to which each atom of H contributes an amount very small in comparison with that contributed by an atom of O or C, while an atom of O, when singly bound to another atom, contributes an amount equal to that of two C atoms, and when doubly bound, to that of three carbon atoms. The volume of such a molecule can then be expressed in terms of that of a carbon atom, and *the parameter* A *varies inversely as the surface of the molecule.*

By the volume of a molecule is not meant what is usually called the molecular volume, which is really the domain of the molecule, but the actual volume of the molecule.

Second, this law, that the rate of change of the translatory kinetic energy of nearly all liquid molecules with temperature is the same when measured at low constant pressure.

Let a denote the surface tension of a liquid, and v its molecular domain (usually called molecular volume) measured by m/ρ where m is the molecular weight and ρ the density of the liquid.

Then Eötvös announces (Wiedeman 27) the remarkable law,

$$\frac{d}{dt}\left(av^{\frac{2}{3}}\right) = .227$$

for nearly all liquids; water, the alcohols, and the fatty acids are exceptions at the lower ranges of temperature.

If now we evaluate the attraction of a meniscus bounded by a hemispherical surface on a column of liquid of unit section, and terminating at a distance e from the surface on the hypothesis of a force Am^2/r^4 between the molecules, we find that

$$a = \frac{\pi A e}{3(2 + \sqrt{2})} \hat{\rho}^2$$

where $\hat{\rho}$ is the average density of the surface film.

We do not know $\hat{\rho}$; in order, therefore, to deduce from the experimental values of a, the relative values of A for a number of compounds, we make the reasonable assumption that we cannot make any serious error if we assume that in all liquids at their ordinary boiling points the ratio of $\hat{\rho}$ to ρ, the density in the body of the liquid is the same for all substances. And further, e is the distance at which we must suppose a homogeneous meniscus and a homogeneous column kept apart, in order that their mutual attractions may be the same as that of the corresponding meniscus and column composed of discontinuous molecules; e may be expected to be proportioned to the cube root of the molecular domain.

Thus, then, we get $a = k \, A \, \rho^{\frac{5}{3}} m^{\frac{1}{3}}$ where k is a constant, the same for all bodies.

Applying Eötvös's law we find that $\frac{d}{dt}(k \, A \, m \, \rho)$ is the same for all bodies, hence the parameter A varies inversely as the product of the molecular weight, and the modulus of dilatation, as Mendelejeff proposes to call $d\rho/dt$.

Now, if the pressure is small and constant, the external virial can be neglected in comparison with the internal, and we can write approximately—

Kinetic energy = internal virial.

It is shewn in my previous paper (Phil. Mag., July, 1887) that the internal virial of the mutual attractions of the molecules in unit mass of a substance, according to the law of the inverse fourth power is, $\pi \, A \, \rho, \log. \frac{L}{a}$, where L is a sensible length such as the cube root of the volume of unit mass, and a is a length approximately proportioned to the cube root of the molecular domain (usually called molecular volume.) L/a is so large a number that $\log. L/a$ may be regarded as constant within the limits of present experimental possibility in the variation of L and a. Let E be the translatory kinetic energy, then

$$\pi A \rho \log. L/a = E$$

$$\pi A m \frac{d\rho}{dt} \log. \frac{L}{a} = \frac{d(mE)}{dt}$$

But $A m \frac{d\rho}{dt}$ has been shown to be the same for most liquids, so that $d(mE)/dt$, or the temperature rate of variation of the translatory kinetic energy of nearly all molecules, is the same when measured at low constant pressure. This is an important result in molecular dynamics; its similarity to the law of Dulong and Petit as to the constancy of the molecular heats of the elements is obvious and suggestive, while its bearing on the physical meaning of temperature is worth noting.

To obtain the relative values of A for a large number of liquids, I have used the fine abundance of experimental measurements of surface tensions made by Robert Schiff (Annalen der Chemie 223, Wiedemann Beiblätter 9), whose remarkable discovery of a definite law connecting chemical constitution and the number of molecules raised in a standard capillary tube, opened up the possibility of finding the relation of the parameter A to chemical constitution.

By means of the formula $a = kA\rho^{\frac{5}{3}} m^{\frac{1}{3}}$ it is possible to find kA as Schiff has determined a & ρ at the boiling point for a large number of organic liquids. Arranging the value of kA in descending order and studying them, one soon sees law among them; for example the values are ·707 for $c_6 H_{14}$ ·706 for $c_6 H_{10}$ and ·705 for $c_6 H_6$ and these suggest that the number of hydrogen atoms in a molecule exercises little effect on the value of kA, this holds throughout the whole of Schiff's determinations. Other things remaining the same, an increase in the number of carbon atoms reduces the value of kA, and a study of the whole series of values for kA shews that the introduction of a single-bound atom of O exercises the same influence as that of 2 atoms of C, and a double-bound O atom is equivalent to 3 atoms of C; we can state these facts briefly by saying that the parameter equivalent of C being 1, that of H is 0, of O′ is 2, and of O″ is 3. If, then, the parameter-equivalents of the molecules are evaluated according to these values for the elements, we can find a mean value of kA, corresponding to each value of the molecular parameter-equivalent n. The following little table contains in the first row the value of n, in the second the mean value of kA corresponding, and in the third the products $k A n^{\frac{2}{3}}$:—

n	5	6	7	8	9	10	12	13	14	15	16
1000 kA	794	700	620	567	525	468	435	414	387	379	365
100 $k A n^{\frac{2}{3}}$	232	231	227	227	227	217	228	229	225	231	232

This table shews that kA varies inversely as $n^{\frac{2}{3}}$

If, then, we regard n as measuring the actual volume of the molecule we find that the parameter A varies inversely as the surface of the molecule. The parameter equivalent of cl is about 5 or 6; of N in the amines, ·8 in the nitrides and nitrates, ·6; while in the amides it varies with the molecular weight of the radical to which the N atom is attached. The organic bromides and iodides are also exceptional, as the introduction of more carbon atoms raises the value of k A a little instead of lowering it a little, but the want of symmetry in the union with such massive atoms as those of Br and I will account for the exceptional results.

The law known as Waterston's law can be obtained immediately from the law of the inverse fourth power, if we make the assumption that the latent heat of evaporation is proportional to the change of the mutual potential energy of the molecules in passing from the liquid to the gaseous state. The potential energy in the gaseous state is negligible in comparison to that in the liquid, so that we can consider the change of potential energy as $\frac{2}{3}\pi A \rho \log. \frac{L}{a}$

Let λ be the latent heat of the liquid, then λ varies as

$$A \rho \log. \frac{L}{a}$$

and we have shewn that a varies as $A \rho^{\frac{5}{3}} m^{\frac{1}{3}}$

$$\therefore \frac{m \lambda \rho^{\frac{2}{3}}}{a m^{\frac{2}{3}}} a \log. \frac{L}{a} = \text{constant.}$$

This is Waterston's law; but the roughness of the assumption made above is shewn by the roughness of the approximation of the experimental values of $m \lambda \rho^{\frac{2}{3}}/am^{\frac{2}{3}}$ to constancy, as they range from 4.4 to 6.9, even when such cases as those of the alcohols and fatty acids are excluded, on account of their departure from Eötvös's law.

2.—MOLECULAR REFRACTION.

By William Sutherland, M.A., B.Sc.

Newton was led by the emission theory of light with the hypothesis of an attraction between material molecules and the corpuscles of light to expect that $(n^2-1)/d$ or the excess of the square of the index of refraction of a substance over unity, divided by its density should be the same for all bodies, and he found it to be approximatly so. Laplace shewed that on the emission theory and according to his treatment of molecular force $(n^2-1)/d$ ought to be the same for a given substance whatever the density is, and in the case of gases $(n^2-1)/d$ was found experimentally to be constant. But on the establishment of the undulatory theory, the theoretical foundations of the above relation between index and density fell to the ground. Gladstone and Dale, however, devoted themselves to the study of the relation from its purely empirical side, and found that when the density of a liquid is caused to change by variation of temperature $(n^2-1)/d$ does not approach so nearly as $(n-1)/d$ to constancy. The empirical relation $(n-1)/d =$ constant is known as Gladstone's law.

If M is the molecular weight of a substance then M $(n-1)/d$ is the molecular refraction, and was shewn in a large number of cases, by Landolt, to be the sum of certain definite refraction equivalents for the elementary atoms in the molecule. Gladstone shewed that structure in certain cases influenced this molecular refraction, and Brühl discovered a certain measurable connection between the amount of the molecular refraction of a molecule, and the linkings of the polyvalent atoms.

But the large number of researches undertaken by chemists on this subject, all depended on the purely empirical law of Gladstone, no corresponding connection between index and density having been deduced from this undulatory theory, when Lorenz of Copenhagen, and Lorentz of Amsterdam brought out a theoretical deduction from the undulatory theory according to which $(n^2-1)/(n^2+2)d$ is constant for a given substance. Lorenz obtains this result by applying to the discontinuous distribution of molecules and ether a differential equation for the vibratory motion, which involves the idea of variable amplitude, but invariable wave length, namely, the mean wave length in this medium. His investigation involves integration throughout a single molecule; but as the mean wave length may be very different from the actual wave length in a molecule, this application of a mean wave length in a region where it does not actually hold may lead to invalid results. Lorenz applied a very strict test to his formula by comparing the liquid and vapour states of several substances, in each case $(n^2-1)/(n^2+2)d$ proved to be the same for the two states, whereas $(n-1)/d$ varied as much as 10 per cent. But soon after Quincke submitted the Newton, Gladstone, and Lorenz formulæ to a comparative test by measuring the change of index of various liquids with pressure, and found that Gladstone's law is the only one which expresses the actual facts. It is, therefore, only fortuitously that Lorenz's formula bridges so accurately the great change of state from liquid to vapour, and on the whole from an experimental point of view Gladstone's is the preferable statement.

To obtain a theoretical foundation for Gladstone's formula, we have only to regard the question of the transmission of an undulation in a discontinuous medium from a *time* point of view; if it is propagated more slowly through matter than through ether, then it loses time in travelling through a molecule—strewn medium. The total loss of time by a wave will in a first approximation be proportional to the loss of time in a single molecule, to the fraction of its surface which at any instant passes through molecules, and to the length of the path travelled, and to the number of molecules in unit volume. Let s be the length of the path considered, l the mean distance through a molecule, a its mean sectional area, m its mass and d the density of the medium, so that d/m is proportional to the number of molecules in unit volume. If v is the velocity of light in free ether, and V in the matter of the molecule, then the loss of time in a molecule is $l/V - l/v$, and we can write the whole loss of time as $k\frac{a\,s\,l\,d}{m}\left(\frac{1}{V}-\frac{1}{v}\right)$, k being a constant. But if v_1 is the mean velocity of light in the medium then the loss of time is $s/v_1 - /sv$.

$$\therefore \quad \frac{s}{v_1}-\frac{s}{v}=k\frac{a\,s\,l\,d}{m}\left(\frac{1}{V}-\frac{1}{v}\right)$$

$$\therefore \quad \left(\frac{v}{v_1}-1\right)\frac{m}{d}=k\,la\left(\frac{v}{V}-1\right)$$

$$\therefore \quad (n-1)\frac{m}{d}=k\,la\,(N-1)=\text{constant}$$

where n is the index of the medium and N of the matter of the molecule. This is Gladstone's law.

If m/d is regarded as the domain of a molecule (usually called the molecular volume), while la is the true volume of the molecule, we see that if la is supposed identical with m/d, n becomes identical with N, so that the value of k is unity, and the above relation may be written in the symmetrical form $(n-1)u=(N-1)U$. This is a first approximation only as we have taken account only of delay produced and actual loss of time in the molecule, there is a secondary cause of delay in the wavering motion of the broken wave front. The amount of this vanishes with the density and is proportional to the length of the path, so that we may express it by $s\,(bd+cd^2)$ where b and c are constants which may depend on the arrangement of the atoms in the molecule, and adding this to the right hand side of our original equation we get

$$\frac{s}{v_1}-\frac{s}{v}=\frac{s\,a\,l\,d}{m}\left(\frac{1}{V}-\frac{1}{v}\right)+s\,(bd+cd^2)$$

$$\therefore \quad (n-1)\frac{m}{d}=la\,(N-1)+m\,(b+cd)$$

$$m\,(n-1)/d=\text{constant}+ed$$

both b and c would. from the argument by which they were introduced, be expected to be small compared to $la\ (N-1)/m$.

To test this last formula the results of Lorenz's very delicate experiments are available, as he has determined n and d for a number of liquids at 10°, 20°, and for their vapours at 100°; from the results for 10° and 20°, we can find the constant and c, the constant ought to be the same as the value of $(n-1)/d$ for the vapour, and this is found to be accurately the case in 4 out of the 5 liquids available for the comparison.

In this manner, Gladstone's formula is established and extended to meet the difficulty of its incomplete bridging of the change of state from liquid to vapour.

THURSDAY, AUGUST 30.

This Paper has not received the final corrections of the Author, owing to a mistake for which he is not responsible.

THE following pages contain the result of an attempt, made in the midst of other pressing duties, to collect into a concise form the history of what has been done in New South Wales for Astronomy and Meteorology. As it is the first attempt to do so, it is hardly necessary to say that it has involved a considerable amount of trouble, and that many points are not yet fully made out, but a search, specially amongst astronomical publications, has cleared up many points of interest which at one time seemed buried in oblivion. I have also had, through the courtesy of the Principal Under-Secretary and others, access to official records which otherwise would not have been available.

LIEUTENANT DAWES.

IN 1786, Nevil Maskelyne, Astronomer Royal, in a paper, read before the Royal Society, points out that Halley's celebrated comet of 1682 would re-appear in 1788, and be first visible in the southern skies, and hence it was that a young and energetic Astronomer found himself with all the incongruous surroundings in the first fleet of ships bound to Australia. No time was to be lost in setting up the Observatory, for although the comet was not expected until September, 1788, it might be before its predicted time. The only records of his work that I can find are the following, which shews that he determined the latitude and longitude of the Observatory, but nothing is said to lead one to suppose that he observed the comet:—

Colonel Collins in "An Account of the English Colony in New South Wales" (Vol. I, 1798, p. 15, Feby. 1788), says:— "Among the buildings that were undertaken shortly after our arrival must be mentioned an Observatory, which was marked out on the western point of the cove, to receive the astronomical instruments which had been sent out by the Board of Longitude, for the purpose of observing the comet which was expected to be seen about the end of this year. The construction of this building was placed under the direction of Lieut. Dawes, of the marines, who, having made this branch of science his peculiar study, was appointed by the Board of Longitude to make astronomical observations in this country.

"The latitude of the observatory was 33° 52' 30″ S.

"The longitude, from Greenwich, 151° 19′ 30″ E

In August, 1788 (*loc. cit.* p. 37), an observatory, on the west point of the cove, is mentioned as being in progress this month. Collins adds:—

"'The observatory, which was erected on our first landing (*loc. cit.* p. 75, July, 1789), being found small and inconvenient, as well for the purpose of observing as for the residence of Lieutenant Dawes and the reception of the astronomical instruments, the stone-cutters began preparing stone to construct another, the materials for which were found in abundance upon the spot, the west point of the cove' (Bunkers Hill.)

"In October, 1879 (*loc. cit.* p. 83), the observatory is said to be in same place as the magazine; and (*loc. cit.* p. 189, November, 1791); "A corporal's guard was also mounted daily in the building which had been used as an observatory by Lieutenant Dawes." He must, therefore, have gone before this.

Captain Flinders.

The astronomical work of Capt. Flinders, Commander of H.M.S. "Investigator," during her exploring voyage to Australia, was important. On the 19th January, 1801, Matthew Flinders was appointed Lieutenant in Command of H.M.S. "Investigator" (heretofore known as the "Xenophon") for her exploring voyage to Australia. Mr. John Crossley was appointed astronomer, but owing to ill-health was obliged to leave the ship at the Cape of Good Hope, and his duty was assumed by Flinders in addition to his other duties, and probably a better observer could not have been found. For all the principal places on the south coast of Australia he determined the longitude by direct lunar observations, and without giving details, which may be found in the "Voyage to Terra Australis" (Vol. I., 1814, App. p. 259), it may be stated that he made the longitude of Dawes' Point (called Cattle Point) 10h. 4m. 47·3s. east of Greenwich; the recent value found by cable is 10h. 4m. 49·5s., a wonderfully accurate result considering the instruments of those days! He mentions that the Spanish Admiral D'Espenosa found the longitude of the same place to be 10h. 4m. 51s. These are remarkable results, and well worth recording as the earliest careful attempts to find the longitude of Sydney; there was far less uncertainty about it than Flinders himself thought, but a recognition of the care and ability which he brought to bear upon his work is one of the greatest honours which we can pay to his memory. He made the latitude 33° 51′ 45-6″, but there is not now, unfortunately, at least so far as I can learn, any clue to the exact part of Cattle Point on which he set up his instruments; the latitude of the present Observatory is 33° 51′ 41″, and that of the extreme point (Dawes' Point) is 33° 51′ 21″, so that he was very little out.

While at Sydney he also determined the magnetic variation and made it 8° 51′ east, a result quite as remarkable for its accuracy as the others.

Although, not bearing directly upon astronomy or meteorology in Australia, it is important to note that during his work on the Australian coast Flinders discovered the cause of the local attraction of the ship on the compass, and the account of it is best given in his own words (*loc. cit.* p. 1, Preface): "A variety of observations with the compass had shewn the magnetic needle to differ from itself, sometimes as much as 6° or even 7° in or very near the same place, and the differences seemed to be subject to regular laws but it was so extraordinary in the present state of navigation that they should not have been before discoverd, and a mode of preventing or correcting them ascertained, that my deductions and almost the facts were distrusted; and in the first construction of the charts I had feared to deviate much from the usual practice. Applications was now made to the Admiralty for experiments to be tried with the compass on board different ships; and the results in five cases being conformable to one of the three laws before deduced, which alone was susceptible of proof in England, the whole were adopted without reserve, and the variations and bearings throughout the voyage underwent a systematic correction," Such is the simple story of the discovery of one of the most important facts connected with the use of the compass at sea that has ever been made. It is usual in books upon magnetism to say that the fact of the ship's attraction on the compass was first observed by Mr. Males, the Astronomer of Captain Cook, when he was sailing along the coast of New Holland; but if that be true it is strange the Admirality knew nothing about it, and that in the Navy generally it was an unknown fact; certain it is, that Flinders was the first to see and trace the fact, and work out the laws which govern it. Flinders himself shews (*loc. cit.*, Vol. II., App. p. 512) that Mr. Males had observed the fact that magnetic bearings on ship board were unreliable, but he attributed it to faults in the compasses and imperfections in construction, and it is quite evident that he did not see the real cause, viz.: the ship's magnetism, which Flinders did and worked at it until he found the law of change, viz.: that it was in proportion to the lines of the angles of deviation, due to the ship's position and could thus correct every observation. Flinders communicated his discovery in a paper read before the Royal Society, (Phil. Trans., 1805, p. 186.)

Barlow very soon after proposed that an iron plate should be put below the compass in wooden ships. Airy, the Astronomer Royal, proposed a steel magnet below the compass, but neither suggestion was of much use, and the discussion going on upon the subject led to the Rev. Dr. Scoresby's voyage to Australia, with the object of working out a true theory of correction, with the result that he proposed placing it aloft out of the reach of the ship's attraction, a method still in general use. And finally to Sir William Thompson's method of correcting the ship's magnetism by a series of magnets placed below the compass.

Admiral Phillip Parker King.

Captain P. P. King, the son of Governor King, was one of the earliest workers in the field of science in Australia.

In the year 1817 the British Government resolved to send him, then a lieutenant, to complete the surveys of the coasts of New South Wales. He arrived in Port Jackson in September, 1817, with Messrs. Bedwell and Roe as his assistants, and in Sydney his party was joined by Allan Cunningham, "the King's Botanist" in the Colony.

In these voyages, which extended over four years, December, 1817, to April, 1822, during which he received promotion, Captain King, in addition to his maritime discoveries and to the study of natural history in general, gave much attention to the physical conditions and climate of the various parts of the coast which he visited, and also to the customs and language of the aboriginal inhabitants.

He also carefully determined the longitude of a number of important positions in the survey.

In recognition of his ability and services the Royal Society elected him as one of its Fellows, and he was also elected as a Member of the Linnean and Royal Asiatic Societies.

The result of his survey was published in two volumes, entitled "A Narrative of a Survey of the Intertropical and Western Coasts of Australia." (2 Vols. 8vo., London, 1827.)

Charts of the coast henceforward designated by him and others at the suggestion of Captain Flinders "Australia," were compiled and published under the authority of the Hydrographer to the Admiralty.

In preparing his narrative for the press he was ably assisted by Dr. J. E. Gray of the British Museum in vertebrata and mollusca, by Mr. Vigors in respect to some of his birds, and Mr. William Sharpe McLeay in his collection of insects; also by Mr. Robert Brown, the eminent botanist of Flinders' voyage in the "Investigator," and Dr. W. H. Fitton, in geology. These distinguished men classified and described the numerous specimens of natural history which he had taken to England, many of which were new to science.

From 1826 to 1830 inclusive he conducted a survey of the southern coasts of South America, having under his command two ships, the "Adventure" and "Beagle." In conjunction with Captain (afterwards Admiral) Fitzroy he published a narrative of the voyage, and in after years, at his own private printing press, produced four pamphlets apparently for private distribution, a copy of each of which is in the possession of his son, the Venerable Archdeacon King, of Sydney.

No. 1. Treats of the specific gravity of sea water in different parts of the North and South Atlantic Oceans, and in the South Pacific near the western coast of South America; nearly two hundred determinations are given and fully discussed. (14 pages.)

No. 2. Contains selections from a Meteorological Journal kept on board H.M. ship "Adventure" during the voyage to the southern coasts of South America. Observations give the temperature of the air at various places and are fully discussed. (42 pages.)

No. 3. Refers to longitudes and gives the observed transits of the moon and moon culminating stars over the meridian of Tahlee, Port Stephens, N.S.W., 1843 to 1849, and the resulting longitudes from them. Also observations of eclipses of the sun and occultations of the fixed stars by the moon at the same place. (14 pages.) Longitude thence 10h. 8m. 11s.

No. 4. Gives a description of instruments in the observatory and the observations for determining the latitude of Tahlee, Port Stephens, 1841 to 1848. Observations made with an altazimuth instrument. Nearly three hundred separate star observations for latitude are given and the resulting latitude, 32° 40′ 17″.74. Also a list of about one thousand places for which latitude and longitude, and at most of them magnetic variation and time of high water are also given. (25 pages.)

The determination of the longitude of marine positions has ever been an anxiety and a trouble to naval surveyors, and to Admiral King not less than to others. In so remote a position as the southern extremity of South America it was obviously of importance that such a turning point as Cape Horn should be acurately placed in this respect. And with this in view he devoted much attention to astronomical observations, setting up whenever his ship was likely to be detained, an observatory in which he had his own private transit instrument, and in addition to his purely professional duties he devoted himself to every scientific pursuit within the range of his stock of instruments, and opportunities for collecting specimens of natural history. The narative of his voyage shews also the interest he took in the intercourse he had with the Patagonian and Fuegian natives. Differences of longitude by chronometric measurements—and lunar observations, magnetic intensity by means of a small apparatus given to him by Professor Hansteen, the temperature of the sea and its specific gravity in different latitudes, observations of the "dewpoint" with Daniell's Hygrometer and the prevalence of winds and ocean currents were his continual study.

In continuation of Capt. King's survey, Capt. Robert Fitzroy re-commissioned the "Beagle" in 1831, and proceeded to South America. He had supplied himself partly from the Admiralty, but also on his own account with twenty chronometers, eleven of which kept fairly accurate rates during the voyage, which lasted five years. With these he carried a connected chain of chronometric measurements of differences of longitude from station to station round the globe. The result is given in the appendix to the "Narrative of the Surveying Voyages of H.M.S. "Adventure" and "Beagle," (8vo., London, 1839.) On completing his observations and calculations, Captain Fitzroy found that the aggregate of all the differences amounted to thirty-three seconds of time in excess of the true sum of exactly twenty-four hours, or an error of $8\frac{1}{4}$ miles of longitude.

This error, neither he nor Captain King, who took much interest in the work, could account for, but it is now ascribed to what is known as the "personal error" of an observer. Sir John Herschell, who was at the Cape of Good Hope when Captain Fitzroy touched there, told him he need not expect to bring any result within some minutes of time of the twenty four hours. This chain of measurements corroborated Captain King's longitudes determined in the previous expedition.

On Captain King's return to Australia, he retired from active service in the navy, and amongst other works of utility, applied himself to the advocacy of the use of the "Inner Passage" to and through Torres Straits. To the Captain of every ship bound from Port Jackson in that direction he gave the fullest information of the track he had himself proved to be safe, and which is laid down in modern charts as Captain King's Track. Many followed it, and sent back to him letters of approval and thankfulness, whilst others took their own way outside the Barrier reef, and several are known to have been wrecked upon it.

For the remainder of his life his devotion to the science of Meteorology continued unaltered. During his residence at Dunhered from 1832 to 1839, and at Tahlee, Port Stephens, to 1848, he kept his observatory in full work with the transit and other instruments he had had with him on his voyage, and kept regular registers of the barometer, shade thermometers, the wet and dry bulbs, and much time was given to the amplitude of the atmospheric tide, or diurnal variation of air pressure in conjunction with similar observations made by Mr. Dunlop at the Parramatta Observatory—who from sixteen days' hourly* observations made the highest point of the barometer at 9·24 a.m., and the lowest at 3·17 p.m., but who said that the night tide was irregular.

The first five years work at Tahlee was published in the Tasmanian Journal, No. 6, a copy of which is in the Sydney Observatory—with the remainder of the observation in MSS.—where they have been deposited for reference by his son, the Hon. P. G. King, of Sydney.

During Sir Thomas Mitchell's explorations in the interior in 1835-6, Captain King, by arrangement with him, kept a careful record of his more than usually frequent barometer readings ; so that it should be possible to find a corresponding value of the pressure for any time or place at which Sir Thomas might have read off his barometer in the interior ; the two barometers, separated by some hundreds of miles, were wonderfully accordant in their movements.

On one occasion when Captain King was working up the results for the purpose of proving the elevation of Sir Thomas' positions on a particular observation, made his camp 40 feet higher than it ought to have been by the preceding and following observations, what had otherwise shewn in a remarkable way the gradual slope of the country, but on reference to his diary Sir Thomas found that fearing a flood, he had pitched his camp on that occasion on an elevation above the river bank which he was following up.

Amongst Captain King's papers are records of the determination of latitudes and longitudes of Fort Macquarie by other observers : Of Latitudes—

Captain Flinders in 1795 and 1803, gives	33°51′ 46·6″
De Freycinet in 1802	33 51 21
Malaspina, Point Bennilong or Fort Macquarie, 1793	33 51 28

*These observations were taken hourly but only for eighteen out of the twenty-fonr, so that Mr. Dunlop was not in a position to say what the night tide was. The original observations are in one of his books now in the Sydney Observatory.

Sir Thomas Brisbane, 1822	33°	51′	30″
Captain King, 1817	33	51	18
Mean Latitude of Fort Macquarie—	33	51	28
Of Longitudes—			
Captain Cook in 1770	151	11	32
Hunter, 1788	,,	19	43
Lieut. Dawes	,,	18	50
,, Bradley	,,	20	38
*Malaspina, 1793	,,	17	53
Broughton and Crossby	,,	9	3
Captain Flinders, 1795-6	,,	17	12
,, ,, 1802	,,	11	49
De Freycinet, 1802	,,	8	32
M. D. Espinosa, 1793	,,	12	45
Sir Thomas Brisbane	,,	15	32
Rumker, 1822	,,	17	30
Captain King, 1817	,,	17	29
Mean of all—	151	15	16

Captain P. P. King's paper on the Maritime Geography of Australia which is given in Baron Field's "Geographical Memoirs," was read 2nd October, 1822, before the Philosophical Society of Australia. It gives a short note of Flinders' and Oxley's discoveries, and then a narrative of his own in continuation of the foregoing. He mentions, (p. 285), that the spring tides rise thirty feet at Prince Regent's River, and sometimes ran at seven knots. He also mentions the general productions of intertropical Australia and the natives of New Holland.

In the "Narrative of a Survey of the Intertropical and Western Coasts of Australia," (Vol. 1, p. 349), Capt. King mentions that the southerly current on the coast had set the vessel one hundred and fifty miles south during the storm, and for twenty-four hours at the rate of three miles per hour. He also gives details of winds, weather and currents on the coast of Australia, variation and dip of the magnetic needle of nine places on shore, and at fourteen places at sea; with the geographical positions of a number of points in his survey. (p. 404.)

In the Royal Astronomical Society's Notices there are eight papers by Captain P. P. King. Four refer to observations of comets, amongst others, the Great Comet of 1843; one to an occultation of Jupiter and his Satellites; another to a lunar eclipse; another to a transit of Mercury; and the last to a solar eclipse.

When the present Sydney Observatory was talked about, Admiral King was the adviser of the Government as to where it should be placed. (See Votes and Proceedings, N.S. Wales, 1852.)

* Owing to some mistake Collins gives this 151° 18′ 8″.

For nearly all the facts in this account of Admiral King's work in Australia I am indebted to the Honorable P. G. King, M.L.C.

Sir Thomas Macdougall Brisbane.

We come now to Sir Thomas Brisbane, a man whose enthusiasm for science, and especially for Astronomy, knew no bounds. In the midst of harassing marches in the great Continental war, with the enemies' bullets always whistling about him, his sextant was always in his baggage, and came into active service directly its owner was off duty. His appointment as Governor of New South Wales marks an era in the history of Australian Science, and his princely munificence in the erection of the Parramatta Observatory and cost of maintaining it for four years, will never be forgotten. Sir Thomas Brisbane entered the army in 1790, fought in the first battle of the war, and in 1794 had to sleep six nights in the snow with nothing but his cloak and the canopy of heaven over him. Each morning he found himself frozen to the ground, and during one of these nights 900 soldiers were frozen to death around him. He fought in fourteen general actions, twenty-three great affairs, and assisted at eight sieges. He crossed the equator twelve times, yet throughout this busy active life he always found time to cultivate his favorite study, Astronomy, and when it was proposed to send him to govern the far-off Colony of Australia, Lord Bathurst informed the Duke of Wellington that he "wanted a man to govern, not the heavens, but the earth." Sir Thomas appealed to the Duke to say whether science had ever stood in the way of his duty as a soldier. "Certainly not," said the Duke, "I shall say that you were never in one instance absent or late in the morning, noon, or night, and that in addition you keep the time for the army."

It is not surprising that a man of such antecedents, persevering and methodical in his habits, and having a passion for astronomical pursuits, should catch the feeling of the day, which asked for two astronomical observatories to explore the wonders of the southern sky, and when he found the Government would not give the money, put his hand into his own purse and found all that was required. Arrived at Parramatta, the instruments were unpacked and used within a few days to observe the solstice in December, 1821, before there was an observatory to cover them; and that he might devote every spare moment to the work he built the Observatory alongside his residence, and there is abundant evidence to prove that at first, and before his official position brought so many worries, Sir Thomas was one of the most active of the three observers.

It was in recognition of his princely patronage of Astronomy, and for the abundance of observations that came pouring in from Parramatta, that in 1828 the Royal Astronomical Society awarded him the Gold Medal for the Parramatta Catalogue of Stars and

General Observations, amongst which were observations of the length of the seconds pendulum in 1823, printed by the Royal Society in their Transactions. Sir John Herschel, at that time President of the Astronomical Society, said, in presenting the medal:—"We give this medal, accompanied with the strongest expressions of our admiration for your patriotic and princely support given to Astronomy in regions so remote. It will be to you a source of honest pride as long as you live to reflect that the most brilliant trait of Australian history marks the era of your government, and that your name will be identified with the future glories of that colony in ages yet to come, as the founder of her science. It is a distination worthy of a British Governor. Our first triumphs in those fair climes have been the peaceful ones of science, and the treasures they have transmitted to us are imperishable records of useful knowledge, speedily to be returned with interest, to the improvement of their condition and their elevation in the scale of nations."

Having formed the resolution to establish an observatory in New South Wales, Sir Thomas made a collection of astronomical books and instruments, and engaged two gentlemen, Mr. Charles Rumker, who had already attained a position as a good astronomer and mathematician, and Mr. James Dunlop, whose great natural ability, and especially his fondness for and success in mechanical appliances and instruments, had pointed him out as a most suitable man for second assistant in the Observatory in an out of the way place like Parramatta, where nothing towards the repair of the instruments could be done outside the Observatory. They arrived in the colony in November, 1821. A site was immediately chosen for the Observatory close to Government House, Parramatta, only about one hundred yards from the back door. Men were at once set to work, and by the end of April, the building was completed, and the instruments erected.

The building* was not loaded with architectural ornaments, the walls being quite plain, 11 feet high, and 28 feet on each side; the roof was flat, but at each end, north and south, small domes, 11 feet 6 inches in diameter, projected above the flat roof, The east and west walls were entirely without windows, but on the north and south sides there were five windows in each, three being in a circular projection of the wall, which formed half the base of the dome, the other half, inside the building, being supported in each case by four pillars; transit openings were made through the roof on each side of the domes, and carried through the wall to one of the windows, which could be opened, if required, to allow of seeing objects on the horizon. The transit instrument was placed under the western opening, and the mural circle under the eastern one. The 46-inch long achromatic telescope under the south

*A plan shewing details of the building will be found as a frontispiece to the Parramatta Catalogue of Stars.

dome, and the repeating circle under the north dome; one dividing wall extended from the entrance, and only door, on the east side, across the building to the west side, so dividing it into two rooms, but as both transit and mural circle were on the south side of this wall, it had an opening in it from roof to floor for each instrument; there was no fireplace, nor any sign that the building was meant for habitation, indeed the instruments were so distributed as to make that almost impossible; later, *i.e.*, in 1832, a residence was built on the west side. When the new transit circle was put up, it was placed on the eastern side of the old building.

The instruments (see Appendices B and G) mentioned in the introduction to the Parramatta Catalogue, as belonging to the Observatory, were, a 5½ feet Transit Instrument, by Troughton; a 2-foot Mural Circle, having a telescope of the same length, by the same maker; a 16-inch Repeating Circle, by Reichenbach; a 46-inch Achromatic Telescope, with equatorial motion and wire micrometer, by Banks; a Clock by Hardy, shewing sidereal time, and another by Brequet shewing mean time. All these instruments were placed on solid piers of masonry. These are all that are mentioned in the Parramatta Catalogue. But Rumker, (Memoirs, Royal Astronomical Society, Vol. III, p. 277), says:—"The pendulum apparatus was made by Fortin of Paris, and brought to the colony by Sir Thomas Brisbane. It consisted of a *platinum ball*, the cap for the ball (which was attached to it by excluding the air with a little grease); the knife edge suspension with the wire; the steel rod, the supporting plane; the horizontal plane, capable of being elevated and depressed, but there was no standard of length with it"; he then gives a figure of it. And in his astronomical observations (Phil. Trans. 1829, Part III., preface), he, in addition to the instruments already recorded, mentions two instruments for observing the dip and variation of the magnetic needle."

Appendices B and G give the complete list of Sir Thomas' fit-out for the Observatory; and of them I have now in the Observatory in a more or less complete state the following:—

The Transit Instrument,
Mural Circle,
Repeating Circle,
Equatorial,
*Pendulum apparatus,
Hardy clock,
Brequet clock,
Magnetic dip instrument and the books,

but the magnetic variation instrument I have never seen. It is

* It is worth mentioning that in the Philosophical Transactions, 1823, Captain Kater says:—" This Pendulum belongs to the Board of Longitude; he is speaking of the one Sir Thomas took to Parramatta, and which he sold to the New South Wales Government for £85. (See Appendix, date 10 Sept., 1827.)

probable that it was lost while the things were in the ordnance store; the only thing connected with it is a mahogany box with tube for suspension filaments, glass window for observing magnet, etc., with a small copper tube telescope, evidently intended to carry a magnet, but the Dolland's Magnetic Transit with telescope for observing sun, and microscope for reading circle (Phil. Trans., 1829, Part III., pp. 1 and 2), I have never seen.

In the Introduction to the Parramatta Catalogue (p. 5) it is stated that "the Observatory was built and furnished with books and instruments,. and conducted during Sir Thomas Brisbane's governmeut solely at his expense. On his departure from the colony in the end of 1825, he transferred the whole to the Colonial Government, who repaid the original cost of the instruments,* and in 1826 appointed Mr. Rumker, Astronomer, at a salary of £300 per annum. He retired in 1829 and returned to Europe. Mr. Rumker's letter of appointment is dated 16 July, 1829, about three years after he actually began the work.

Sir G. B. Airy, (Second Report Brit. Assoc. Adv. Science, 1832, p. 130) says on Observatories:—Sir Thomas Brisbane on leaving Parramatta "presented the instruments, etc., to the British Government, on condition that the Observatory should be maintained in an efficient state. The condition was accepted and an observer (Mr. Dunlop) is *now*, 1832, maintained by the British Government at this distant station."

It is evident from Governor Darling's letter, (Appendix B) that Sir George Airy was not fully informed; the Government accepted the instruments, but paid a long price for them, and from the fact that they appointed Rumker, and requested him to undertake the measurement of an arc of the meridian it is evident that they meant to turn the Observatory to some good use, an intention which seems to have been abandoned when Dr. Rumker resigned.

Another very important work carried out by Sir Thomas Brisbane, was the formation of the Philosophical Society of Australia. The only full account of it which I have met with is by the Rev. W. B. Clarke, (Trans. R. Soc. N.S. Wales, 1867.)

"In the year 1821 a Company of gentlemen, consisting of
Alexander Berry, Esq.,
Henry Grattan Douglas, Esq., M.D.,
Barron Field, Esq., Judge of the Supreme Court,
Major Goulburn, Colonial Secretary,
Patrick Hill, Esq., Colonial Surgeon,
Captain Irwin, XI Bengal N.I.,
Captain P. P. King, R.N.,
John Oxley, Esq., Surveyor-General.
Charles Stargard Rumker, Esq., Astronomer; and
Edward Wolstonecraft, Esq.,
formed themselves into the Philosophical Society of Australasia, under the presidency of His Excellency Sir Thomas Brisbane, K.C.B., F.R.S.L. & E. * * * * * This early union appears to have

* See Appendix A. The price paid was £1614 13s.

partaken rather of the character of a Mutual Friendly Association, than of that of a more formal body. It was, in other words, a Scientific Club. At that time there were no public libraries and scarcely a bookseller's shop in the Colony; but the members possessed books of their own; these were catalogued and lent by one to another, so that the use of them was reciprocal. The business of the Society was transacted at the dwelling-houses of the members in succession, where memoirs, prepared on an alternative of a fine of ten pounds sterling, were read and discussed, the only refreshment allowed being a cup of coffee and a biscuit, an arrangement still in vogue, I believe, in England, and which was followed here in later times at the meetings of our Society in 1855-56.

I have not been able to discover more than four of the papers read by members, and these were preserved as a portion only of the Society's Transactions, and edited by Judge Field in his "Geographical Memoirs of New South Wales by various hands," published by John Murray, of Albemarle Street, in the year 1825. These papers were the following:—

1. "On the Aborigines of New Holland and Van Dieman's Land," by Barron Field, Esq., read 2nd January, 1822.
2. "On the Geology of part of the Coast of New South Wales," (from the River Hunter to the Clyde), read in the same year by Alexander Berry, Esq.
3. "On the Astronomy of the Southern Hemisphere," by Dr. Rumker, read on the 13th March, 1822; and
4. "On the Maritime Geography of Australia," by Captain Philip Parker King, R.N., read 2nd October, 1822.

In Mr. Field's book there are also papers by Mr. Oxley, and meteorological notices by Major Goulburn and Sir Thomas Brisbane. We have evidence, therefore, that at least seven of the twelve were working members.

Mr. Allan Cunningham, the Botanist, (whose death I recollect at the Botanical Gardens shortly after my arrival in 1839), also contributed two papers, the one describing his traverse from Bathurst to Liverpool Plains in 1823; the other "On the Botany of the Blue Mountains," as observed in November and December, 1822.

As these last papers do not appear to have been read before the Society, it is probable that Mr. Cunningham was not a member of it. But, without doubt, the actual members did good service to the Colony. Of only one of these memoirs do I venture to form an opinion, and that is one which I expressed in 1860 in my book on the Southern Gold Fields, in the following words:—"In the year 1822 my respected friend, Alexander Berry, Esq., read a very interesting paper on the geology of the Clyde River before the Philosophical Society of Australasia. At that early period Mr. Berry had successfully made out all the prominent features of the district, as well as along the coast, and has pointed out the vertical strata of schist, the quartz, the trap, and the sandstone, with their order of succession. It gives me great satisfaction to mention this," (p. 45.) * * * *

The Philosophical Society, which thus commenced with flattering promises of future usefulness, was destined to only a brief period of service. A question arose between the Government and some of the members which led to estrangement. The friendly meetings became fewer, and the fictitious* variable value assigned to the dollar (the coin then current) was the cause of breaking up the little band who cultivated science for the love of it.

Judge Field thus speaks of that mishap, in connection with the seven memoirs before mentioned;—"Such of them (*i.e.*, of the several documents in his book) as are parts of the Transactions of the Philosophical Society of Australasia are printed by permission of their respective authors; for I am sorry to add, that the infant Society soon expired in the baneful atmosphere of distracted politics which unhappily clouded the short administration of its President, the present (*i.e.* the then) Governor of New South Wales."

* Official History of New South Wales says Sir Thomas Brisbane had established a currency which had the effect of raising the pound sterling 25 per cent. (p. 36.)

During his life after leaving Sydney, Sir Thomas Brisbane founded two other observatories, one at Makerstown and the other at Brisbane, in Scotland. Sir Thomas died in February, 1860. (Royal Astronomical Society's Notices, Vol. XX., p. 118.)

He contributed some papers about Parramatta work to the Royal Society of Edinburgh, 1821 to 1824, but I have not a complete file of the Transactions* for reference; he also contributed to the Royal Astronomical Society thirteen papers.

Sir Thomas Brisbane's first knowledge of Astronomy had been gained at sea. Struck with the importance of knowing how to navigate a ship, he went to work with the energy that marked all his actions, and soon mastered the situation and become a first-class observer with the sextant, but I cannot find that he had any experience in fixed observatories until he got to Parramatta, and therefore, very little, if any, knowledge of large and fixed instruments, hence I think the whole difficulty with the observations at Parramatta ; he bought large but essentially faulty instruments† without knowing it, and found this out when it was too late to remedy the evil.

The published work of the Parramatta Observatory under Sir T. Brisbane, is represented by the Parramatta Catalogue of Stars, and some papers upon latitude, longitude, comets, &c., published in the Royal Astronomical Society Notices, the Philosophical Transactions of the Royal Society, and the Transactions of the Royal Society of Edinburgh, and some meteorological observations for one whole year and part of a second.

The Catalogues of Nebulæ and Double Stars by Dunlop were his private work and not made at the Observatory, but at the house in Parramatta, and the work published by Rumker in the Philosophical Transactions 1829, part III, was done at the Parramatta Observatory after Sir Thomas Brisbane left the colony. All the books in which this work was recorded have disappeared, but in the Royal Astronomical Society library at Burlington House is preserved the MS. of the Parramatta Catalogue.

At this time the Government seems to have hesitated about keeping up the Parramatta Observatory, and the Royal Astronomical Society urged the matter as follows :—

[*Extract from the Minutes of the Royal Astronomical Society, Nov.* 11, 1828.]

Present — Mr. Herschell, President ; Mr. Baily, Mr. South, Mr. Strathford, Captain Beaufort, Mr. Gomperty, Mr. Riddle, Mr. Sheepshanks.

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* Vol. IX. contains two, first a memoir on the Repeating Reflecting Circle, and secndly a Method of determining the Latitude by a Sextant or Circle, with simplicity and accuracy from circum-meridian observations taken near noon.

Vol. X. contains one paper on Astronomical Observations made at Parramatta and Sydney, by Sir Thomas Brisbane and Mr Rumker, which was read Nov 3, 1823. This paper contains Elleptic Elements of the Comet in September, 1822, by Rumker; Observations of Transit of Mercury, Nov. 3, 1882; Observations of Winter Solstice, 1822, by Sir Thomas Brisbane, and Observations of Encke's Comet, June 2 to 23, 1822.

† I speak from personal examination of these instruments since they have been in the Sydney Observatory.

Resolved unanimously—That this Council are decidedly of opinion that the continuation of the Observatory at Parramatta as a national institution, in addition to that already existing at the Cape of Good Hope, would be of the highest importance to astronomy, and they ground this opinion on the following reasons, in which it will be observed that they do not contemplate a removal of the Cape Observatory, as precluded by its very advantageous situation on the same meridian with the principal Observatories of Europe, and from the great expense already incurred and powerful instruments erected in that establishment.

First—The great difference of geographical situation, in longitude and of climate, of the Cape and Parramatta, which renders it practicable to obtain numerous observations at each not susceptible of being made at the other, either from cloudy weather or from the circumstances that the phenomena take place below the horizon of either Observatory, or may actually happen at the one and not at the other.

Secondly—The effective verifying check and corroboration, and the great increase of diligence and accuracy to be expected from the emulation of rival observers.

Thirdly—The remarkable and also highly advantageous geographical situation of Parramatta, it being almost exactly at the antipodes of Greenwich, and the peculiar excellence of its climate.

Fourthly—The very imperfect state of Southern Astronomy, and the wide field of research which has been laid open by the observation of new stars and nebulæ already made, which the Council consider as affording ample employment for two of the most active observatories without interfering with each other.

Lastly—The indispensable importance of a long-continued and exact series of observations at a fixed station on some part of the immense Australian continent, for the purposes of a geographical and hydrographical survey of its interior and of its coasts, when the circumstances and extent of the Colony shall render such operations necessary, and which ought to be commenced as early as possible in order to give time.

And the Council cannot but regard their opinion of the future importance of an Observatory at Parramatta as strongly sustained, whether by the re-discovery of Enche's Comet when not visible in Europe, or by the important mass of observations already forwarded from it to this country by Sir Thomas Brisbane.

Dr. Charles Stargard Rumker.

Rumker, whom Sir Thomas Brisbane selected as first assistant, was at that time a man of acknowledged ability as an Astronomer, and Mathemetician, but I find no record of his previous history, excepting some Astronomical papers in Baron de Zach's correspondence. He accepted the position in Sir Thomas's private Observatory, and it is evident that he was well received and taken into a confidential position at once.

It is, perhaps, worth mentioning that in all the papers he communicated to the Royal Astronomical Society, in his long life, and they numbered eighty-eight, he is called Mr. Charles Rumker, and in his work in the Philosophical Transactions, 1829, he calls himself Charles Rumker. But he read one paper before the Philosophical Society of Australia, in 1822, and he is then (Judge Field's Memoirs) called Dr. Charles Stargard Rumker.

In the grant of land given to him here, he is called Charles Luis Rumker. The Royal Astronomical Society gave him a Silver Medal for his work on Encke's Comet, and in presenting it the President said, I have peculiar satisfaction in presenting to Dr. P. Karl Rumker, the Superintendent of the Parramatta Observatory. And when he was appointed Astronomer at Parramatta in 1827, by the Colonial Government, he is called Charles Luis Rumker, the same in his grant of land. There cannot in any of these cases be any question as to his identity.

In proof of the early confidence, it may be mentioned that in the Philosophical Transactions for 1823, (p. 308), Sir Thomas published his observations made with the pendulum apparatus he took to Parramatta, he swung it frequently before he left London, and in all cases it was Rumker who was called in to work with him, but we hear nothing then of Dunlop. At Parramatta, four months after the observatory work began, Sir Thomas again got to work at the pendulum, but called Dunlop and not Rumker, and in these observations, which were published with those made in London, Captain Henry Kater, who read the paper, says: one series was made at Parramatta, by Mr. Dunlop, a gentleman of whose zeal and scientific abilities Sir Thomas Brisbane expresses himself in the highest terms.

Of Rumker, so late as 17th January, 1823, Sir Thomas in a paper to the Royal Society of Edinburgh (Vol. x, p. 112), says these results are exclusively by Mr. Rumker to whom it "is impossible for me to give adequate praise, either for zeal, assiduity or intelligence."

In the Introduction to the Parramatta Catalogue it is stated that Rumker made the meridian observations, and from those published by him in the Philosophical Transactions in 1829, it appears that he also made special observations for latitude and longitude, the dates given in these observations shew that he continued observing there in the ordinary way until June 15, 1823, and it is stated in the Introduction to the Parramatta Catalogue that he left the Observatory on June 16, 1823. There is a gap then of thirteen months in his observations, and nothing to shew what he was doing, but page iv. of the Parramatta Catalogue says he remained in the colony; and his observations, I find, begin again at "Stargard" on July 15th, 1824. (Philosophical Transactions, 1823, Part III., p. 63.) It appears from the latitude and longitude of this place, which he gives, that it was about 40 miles north, and 20 miles west from Parramatta, and in the Royal Astronomical Society's Memoirs (Vol. II. p. 284), he says:—"'Stargard' is the name I have given to my farm." It is evident, therefore, that having fallen out with Sir Thomas Brisbane, he retired to his farm and remained there until the latter left the Colony, making obsverations until December 20, 1825. On the 10th May, 1826, his observations begin again in the Parramatta Observatory, and it is worth noting that Sir Thomas Brisbane gave up his appointment on December 1st, 1825, and that Dunlop remained in Parramatta Observatory until March 2nd, 1826. From May 10th, 1826, Rumker was a most active observer for latitude, longitude, pendulum and other observations, until December 26th, 1828, which is the date of his last observation. The results are published in the Philosophical Transactions, 1829, Part III, and occupy one hundred and fifty-five pages, and in the Royal Astronomical Society's Memoirs (Vol. III., pp. 100 and 277), occupying thirty-four pages.

The Royal Astronomical Society's Notices also contain notes of papers by him, written while he was in Australia, as follows:—

Vol. 1, page 75, On the length of Pendulums.
,, ,, ,, 78, Results of observations at Parramatta.
,, ,, ,, 98, December solstice.
,, ,, ,, 125, Solstice and equinox in 1827, and others.
,, ,, ,, 183, Observations on a passage from N.S.W. also to England.

It appears on the title page of his observations in the Philosophical Transactions for 1829, that the printing was paid for by His Majesty's Colonial Department. This work consists of a vast number of observations to determine the latitude; a few to determine the longitude; a number of comet observations, and others to determine latitude by the sun's solstice; observations of the moon and planets, etc.

Every care has evidently been bestowed upon these observations, and their subsequent reduction, and it was no fault of Mr. Rumker's that the observations are affected by incurable errors depending upon the imperfect instruments with which he was obliged to work. Of these Mr. Rumker was fully conscious, and by every means in his power tried to eliminate them, but they were of such a nature that all his efforts necessarily failed to produce the desired results.

I find by reference to official letters that Mr. Rumker's promise of appointment is dated 21st December, 1827 (see Appendix C); but his observations began in Pararmatta in May 1826, he must, therefore, have been appointed by the Governor, subject to confirmation by the Home Government. (See Appendix D,, letter of July 16, 1829, his actual appointment.)

Rumker, (Philosophical Transactions, 1829, part III., pp. 29 and 151), says:—

The longitude of Parramatta as a mean of all is—

Parramatta	10h.	4m.	6.25s.
*Port Jackson—by Brisbane observing at Government House, August 16, 1822	10	5	17.89

*By the Map referred to in next note the longitude of Government House Observatory is given as 151° 15′ 20″ or 10h. 5m. 1.33s. which does not agree with any of those given above. See also Capt. King's results already given.

Difference between Parramatta and Sydney, by chronometers, Capt. P. P. King	0h.	0m.	51.93s.
Mean of several observed differences;			50.88
this added to Parramatta longitude makes longitude, Sydney...	10	4	57.13
†Government House, Sydney, by Admiral Bligh	10	5	10.5
Government House, Sydney, by Capt. King	10	5	8.2

Rumker, (Royal Astronomical Society Proceedings, Vol VI., p. 213), gives a final correction for the longitude of Parramatta as the result of a second calculation from his moon observations there, and makes it 10h. 4m. 7s.217. Date, April, 1845.

Some unimportant letters were sent by him from Parramatta and published in Baron de Zach's Correspondence, and he read one paper before the Philosophical Society of Australia on March 13, 1822, on "The Astronomy of the Southern Hemisphere," which is published in Baron Field's "Geographical Memoirs of New South Wales," but it is of no value to science, as it simply points out the advantage of the geographical position of Parramatta for observations, a fact which did not need a paper before the Society to make it obvious.

In searching for other information in the Survey Office Mr. W. D. Campbell, C.E., found under date May 1828 correspondence between the Surveyor-General and the Colonial Secretary in reference to an *additional* grant of land given by Sir Thomas Brisbane to Mr. C. Rumker.

Rumker left the colony in the end of 1828 or beginning of 1829, and became Superintendent of the Nautical School of Hamburgh and Director of the Hamburgh Observatory, and on the 10th February, 1854, the Royal Astronomical Society conferred on him their Gold Medal for his extensive observations chiefly of comets, and a catalogue of twelve thousand stars. Royal Astronomical Society'sNotices, Vol. XIV., p. 43.) He died February, 1863. (Royal Astronomical Society's Notices, Vol. XXIII., p. 127.)

There is one point in connection with Rumker, at Parramatta, of which it is difficult now to give the true version, and it cannot well, be passed over, seeing that it changed the whole course of Astronomy in this colony. I allude to the sudden termination of his connection with the Parramatta Observatory. Report here

†By the Map of Sydney made in 1822 which is now in the Parliamentary Library it appears that old Government House stood on the north side of Bridge street and west side of Phillip street, but it faced north-west, and one corner came nearly across what is now Bridge street. The two old pine trees that stood in the street until about 1880 then stood over Government House gate. On that Map, No. 70, is the Governor's Observatory, and it stood as nearly as possible at the point which is now, 1888, the north-west corner of the intersection of Bridge and Phillip streets.

said it was wholly due to some sudden incompatibility of temper, and many years afterwards when Sir George Airy, as President of the Royal Astronomical Society was presenting to Mr. Rumker, the Gold Medal, said "some misapprehension on one side or the other as to the precise terms of his engagement brought the connection with Sir Thomas Brisbane to a close! I am totally unable to say with accuracy what was the point under discussion or the merits of the two views of it." It is, however, quite evident that Rumker did not return until Sir Thomas had left, and that in all his subsequent writings about Parramatta, he entirely ignores the fact that Sir Thomas Brisbane was the founder of the Observatory, and for a time his chief.

Again, it appears from correspondence in the Survey Office, found by Mr. W. D. Campbell, C.E., and given to me that on "January 8th, 1828, Rumker made a requisition for the rods and cylinders for the trigonometrical survey in connection with an arc of the meridian, which he had undertaken to measure," and, as we have already seen, he gave up the observations at Parramatta in December, the same year. As the apparatus could not have been obtained from England under one or two years, and it would have taken a number of years to measure the arc, it is evident that there was a sudden change of purpose between 1828 and 1830, by Mr. Rumker, and that he threw up his appointment while in Europe, where he seems to have gone in December, 1828, or the beginning of 1829.

By a letter which I found in the Colonial Secretary's Office, date 1st September, 1830, it appears that Mr. Rumker was in England and preparing to return to the colony, (Appendix E.) It seems, therefore, probable that he had been granted leave of absence to go to England and superintend the purchase of instruments for the survey, and that while there he suddenly changed his mind and threw up his appointment.

James Dunlop.

We are told in the introduction to the Parramatta Catalogue "that James Dunlop was one of two gentlemen selected by Sir Thomas Brisbane to act as Astronomers in his Observatory," and there is nothing said beyond this as to their relative rank; but from the fact that before starting Mr. Rumker was selected to take part with Sir Thomas in very important work, it seems probable that Rumker was first assistant and Dunlop second. From the time of his arrival in Sydney, Dunlop seems to have worked with a zeal and perseverance that not only justifies his selection, but made Sir Thomas speak more highly of him than he did of Mr. Rumker, and set him to do specially difficult work, such as the observations of length of pendulum, &c. With Rumker, he observed regularly for the formation of the Catalogue. Both instruments, the transit and mural circle, were used for each star, the one for its right ascension and the other for its declination; and it is probable that one worked at each instrument, but it was soon found that the transit was very defective and gave such unsatisfactory results that it was worse than useless. We are not told when its use was given up; but we are informed (Introd. Parramatta Catalogue, p.7), that during the greater part of the time embraced by the Parramatta observations, Mr. Dunlop was the only observer*; and, with a view to complete the observations for the formation of an extensive Catalogue he abandoned the Transit instrument, and fixing the Mural Circle as nearly in the plane of the meridian as he could, he commenced observing every star that circumstances permitted, as it passed the central wire registering the time of transit, and reading off as many microscopes as the interval, before another object came to the wire, would allow.

In the period of about two years and a-quarter he observed in this manner above 7,000 stars, and made nearly 40,000 observations, besides an extensive series of observations upon double stars and nebulæ, an amount of labour which, perhaps, has never been performed before by any one within the same time. This change of instrument was made during the time Sir Thomas was there, and must have been with his consent, and it is very much to be regretted that it ever was made, as it would seem for the purpose of observing a great *number of stars;* because the Catalogue is practically useless, and its weakest point is the right ascension of the stars, and bad as the old transit instrument was, I know from working with it that it was capable of giving very much more accurate right ascension results than the mural circle, which has a short axis, and such a form of construction as to render accurate work in the meridian impossible; and there can, I think, be no doubt that the time mentioned, two and a-quarter years, is wrong, for the following reasons:—Rumker left the Observatory 16th June, 1823, and Dunlop on March 2nd, 1826 (Introd. Parramatta Catalogue), an interval of two years and eight months, and he says in a letter to Sir Thomas Brisbane (Royal Astronomical Society's Memoirs, Vol. III., p. 257), that he stayed behind to follow out his favorite study, *i.e.*, double stars and nebulæ, the meridian work in the Observatory having prevented him from doing so. He does not say how long he spent over this work, but it is evident from an extract which follows that he arrived in England in time to reduce most of these observations there, and have them ready to be presented to the Royal Society on 20th December, 1827. They did not require much reduction; probably a month would be time enough. Allow four months for

* I cannot find anything to shew how much work had been done towards the Catalogue when Rumker left the Observatory. Except that in January 1823, Sir T. Brisbane writing of Rumker, says, nearly ten thousand stars have been observed (i.e. in eight months), perhaps it should read, observations have been made for the finished catalogue has not one thousand stars in it, and most of that work was done by Dunlop.

the passage to England, and it would appear that he left Parramatta about the end of June, 1827, which would have given him sixteen months for nebulæ and double stars, and two years and eight months for meridian work, or, in all, four years, not two and a-quarter years as stated.

A catalogue of six hundred and twenty-one nebulæ and clusters of stars observed at Parramatta by James Dunlop was presented to the Royal Society in 1828, by Sir John Herschel, and read on December 20th, 1827. In a letter with this Mr. Dunlop says:—The following nebulæ and clusters of stars in the Southern Hemisphere were observed by me at my house in Parramatta, situated 6″ of a degree south and about 1.78″ of time east of the Brisbane Observatory. The reductions and arrangement have been principally made since my return to Europe."

Dunlop further says:—"'The places of the small stars in the nebulæ, major and minor, and also those accompanying Eta Robur Caroli (*Eta argus*), I ascertained by the mural circle in the year 1825, at which time I was preparing to commence a general survey of the Southern Hemisphere." The nebulæ are arranged in order of polar distance for the Epoch 1827, and in a paper read before the Royal Astronomical Society (p. 258) on May 8th, 1828 he says in a letter to Sir Thomas Brisbane:—"You are aware that during your administration of the Government of the Colony of New South Wales, my time and attention were wholly devoted in your employ to the Parramatta Observatory, in the miscellaneous observations which occurred, and principally collecting materials towards the formation of a catalogue of stars; and your departure from the Colony prevented me from pursuing that branch further. Finding myself in possession of telescopes* (a nine-inch reflector, nine-feet focus) which I considered capable of adding considerably to our knowledge of the nebulæ and double stars in that portion of the heavens, I resolved to remain behind to prosecute my favorite pursuits in collecting materials towards the formation of a catalogue of nebulæ, &c. In the case of stars marked with an asterisk their positions, declinations, &c., are the result of micrometrical measurements with the forty-six inch† achromatic telescope, mounted on the equatorial stand, which you left with me. The micrometers were constructed by myself, consisting of a parallel line micrometer, the screws of which I bestowed great pains upon, and which I consider very excellent and uniform."

It is evident from these extracts that Dunlop's survey of the heavens was projected before Sir Thomas left or resigned his authority on December 1st, 1825, and that he lent Dunlop the

*He uses the plural. but I have only found the dimensions of one reflecting telescope.

† Now in Sydney Observatory

forty-six-inch Equatorial from the Parramatta Observatory which belonged to the set of instruments which he brought out.

The estimate in which Dunlop was held in England at this time is evident from the fact that the Royal Astronomical Society gave him its highest honour, a Gold Medal, in presenting which, on the 8th February, 1828, Sir John Herschel said:—"I have now, gentlemen, to call your attention to the award of another gold medal, this time to Mr. Dunlop, Sir Thomas Brisbane's assistant, who went out with him in 1821, and who has since the middle of 1823, when his companion, Mr. Rumker, left the Observatory, remained in sole charge of the instruments, and up to the departure of Sir Thomas from the colony, continued an uninterrupted series of observations with a care and diligence seldom equalled and never surpassed. The records of this Society bear sufficient testimony to the merits of Mr. Rumker, and to our sense of them. But in Mr. Dunlop were combined qualities, rendering him, above all others, the very individual fitted for the duties imposed on him—zealous, active, ready—but above all (and the combination is not an ordinary one) industrious and methodical. In the vast mass of observations made and registered by him all is equable and smooth as if the observations had been made at a sitting. No long intervals of inactivity; nothing hurried or sketchy, but the same painstaking laborious filling in pervading the whole and shewing that the observers whole heart was in his work.

"These considerations alone would have rendered it impossible to your Council to disunite in any expression, or mark of their approbation, individuals who have thus, each in his sphere, gone hand in hand together towards the perfection of Southern Astronomy, even had the labours of Mr. Dunlop been confined to the ordinary business of an Observatory, or to the observation of fixed instruments. But this is very far from having been the case. The nebulous, as well as the sidereal heavens have occupied his attention, and in the prosecution of this most difficult and delicate branch of astronomy, he has availed himself entirely of his own resources in the most literal sense. The instrument which he used being not only his *own*, but the work of his own hands*; and the observations being performed by him after the departure of Sir Thomas Brisbane from the colony, at a personal sacrifice of his private interests, and in the face of difficulties which would have deterred anyone not animated with a real and disinterested love of science, from their prosecution. The results of these observations have been the description and determination of upwards of 600 nebulæ and clusters of stars, and 253 double stars."

* A reflecting telescope, 9 inches in diameter, and 9 feet focus, mounted as a transit instrument, at his private house in Parramatta. I have tried repeatedly to trace this instrument, but it was never seen at his house at Brisbane Water, and I do not find any reference to it during his second stay at Parramatta, 1832 to 1847; and it seems probable that it was left behind in Scotland, perhaps with Sir Thomas Brisbane.

Mr. Dunlop got two other gold medals, which are now in the possession of his relations in this colony. I have seen all of these. Mr. James Kay, of the Colonial Architects Department, who married Mr. Dunlop's niece, has the medal presented by the Royal Astronomical Society, which has on one side a head with the words "Royal Astronomical Society of London, instituted MDCCCXX, *Nubem pellente mathese*," and on the other side Lord Ross' telescope, with the words "*Quicquid nitet notandum*, James Dunlop, 1828;" and Mr. Robert Dunlop, of Sydney, nephew of the astronomer, has the one presented by the Royal Institute of France. This has on it the words "Institute Royal de France," and on the other side "*Prix D'Astronomie, M Dunlop Astronome.*' "*A La Nouvelle Hollande, 1835.*" The third medal was from the King of Denmark, and is now in the possession of Dr. Service, of Sydney. This has on one side a head surrounded by the words "*Fredericus VI. Rex Daniæ*," and on the other "*Non frustra signorum obitus speculamur et ortus.*" In the center a female figure, pointing to a globe held in her left hand, and below the words "*Cometa visus*, Sept., 1833," and engraved on the edge "Dunlop." Mr. Dunlop's letters were lost or destroyed before he died, and there are no recorded particulars relative to the two foreign medals.

Once in England Dunlop went back to his old chief, and became his assistant in the Observatory which he had established at Makerstown, and from time to time we find references to his work there. In the Royal Astronomical Society's Notices, (Vol. 1, p. 120) is a paper containing the places of Encke's Comet as reduced from thirty observations made by Mr. Dunlop, between October 26 and December 25, 1828, at Sir Thomas Brisbane's Observatory, at Makerstown, Roxburghshire.

Again a letter from Sir T. Brisbane contained nineteen occultations of stars observed at Makerstown, during 1829 and 1830, chiefly by Mr. Dunlop. (*Loc. cit.* Vol. 1, p. 196.) And another letter from Sir Thomas Brisbane, containing observations of the moon and moon culminating stars, in which he says these observations were almost entirely made by Mr. Dunlop, in 1829 and 1830. (*Loc. cit.* Vol. II., p. 30. Dunlop evidently worked up the whole of these observatilons before he left Makerstown, and the result was communicated to the Royal Astronomical Society, April 8, 1831. He must have left England almost immediately after this, for the official record here shows that he was appointed Superintendent of the Parramatta Observatory, on November 11, 1831. From this time forward no record of his work is to be found in the Royal Astronomical Society's Memoirs or Notices, and the only records I can find is contained in eight books of MS. observations which came with the instruments and are now in Sydney Observatory. In the first book the record begins in January 1832, and in that year there are upwards of two thousand star observations, in 1833 about the same, and this book ends May 26, up to which time the observations were carried on at the same rate. The next book takes the record on to July 1835, and it is recorded that on April 28, 1835, he began to use the then new Transit Circle; observing the same star with it and with the Mural Circle; with a view of finding the errors of the Mural Circle After July, 1835, there is a gap, perhaps a book missing (Dunlop, Appendix J. says there were five), until March 1838, when the record again runs on up to January 1839, which is the latest Astronomical observation. Another volume contains a few Comet observations, some hourly meteorological observations taken out of the ordinary course, &c.

There are also four smaller books containing astronomical observations with the Transit Instrument from August 1832 to April 1838, with some gaps. There are frequent references to the weather, but no regular meteorological observations. (See Appendix J, where the books are mentioned.)

None of the observations have been reduced. It is evident that from the end of 1831 onwards for some years, a record of the rainfall and probably barometer and thermometer was kept, because searching for other information recently, Mr. W. D. Campbell, C.E., found in "Votes and Proceedings, N.S. Wales" 1837, a report on the water supply of Sydney, by Busby's Bore, and with it a return of the rainfall at Parramatta, from January 1st, 1832, up to September, 1837. From the Astronomical books I have completed this record to the end of 1838, with only a few breaks. (See Rain and River Report for 1887.)

Several notes were made in the observing books, that the observer (*i.e.*, Mr. Dunlop was laid up with "protracted sickness"), and it is evident that his health was gradually failing, and in a despatch by Sir Charles A. Fitzroy, dated 11th July, 1847, he says, "Mr. Dunlop is anxious to resign his appointment on account of the state of his health, which renders him incapable of attending to his duties." (See also Appendix J.)

When Sir J. C. Ross was in Sydney on his exploring voyage in July, 1841, he took his chronometer to the Parramatta Observatory in order to correct his time, the Observatory being a well determined point of longitude and supposed to have accurate time. I cannot find any record of the interview, but I was told by one who was in Parramatta at the time that Mr. Dunlop, being out of health, replied to Sir James C. Ross' request to be supplied with the correct time in such a way that Sir James was deeply offended, and owing to this, and what he saw of the unsatisfactory state of the Observatory, he felt it to be his duty to report the state of matters to the Admiralty, who thereupon appointed a Commission of Enquiry into the state of the Parramatta Observatory. The members were Captain P. P. King, Lieutenant-Colonel Gordon, Commanding Engineer, and the

Ordnance Storekeeper. A contemporary living in Parramatta when the Commission sat told me that Captain King, to whom the Commission was entrusted, called at the Observatory and told Mr. Dunlop that in two months the Commission would call upon him with the object of enquiring into the state of the Observatory. This was carried out, and when Mr. Dunlop was asked for the records of his observations, he pointed to a series of bound books on the shelves and said, "There they are."

Many of the books were found to have been destroyed by the white ant, and hence probably some of the early observing books were destroyed in that way; but it appears from Appendix G that the written report said that the "instruments and books generally are in good condition, but the buildings are in a delapidated state." (See Appendices G and J.)

In Votes and Proceedings 1852, 57a., it appears that Dunlop himself packed the Parramatta instruments carefully into boxes, and that they were sent to, and stored in the Ordinance Stores, Sydney,; but unfortunately many small pieces, insignificant in themselves, but important for the instruments, have been lost for want of that care on the part of the storekeepers which can only be given by some one who understands such instruments. It should be mentioned that the Platinum Ball, which was about two inches in diameter, and formed the bob of the pendulum, the length of which was measured at Parramatta, was sold by the Rev. W. Scott, with the consent of the Government, in 1859, with the view of adding to the useful instruments in the Observatory.

There can be no doubt of the great natural ability shewn by Mr. Dunlop at Parramatta, and the amount of work he got through in those early years is very surprising. It is true that it was done at high pressure and to meet Sir Thomas Brisbane's wish, and there can be no doubt that Mr. Dunlop was fully aware of the imperfections of the instruments, imperfections which were in them when purchased and for which he was in no way responsible. Still, it is very much to be regretted that so many observations were made; a smaller number observed with greater care would have been of far more value than the host of roughly observed stars found in the Parramatta Catalogue. In forming an estimate of this work, however, it is hardly fair to judge it by present standards, then a less degree of accuracy satisfied the majority, because instruments were less perfect, and it may be said that the southern heavens were a new field in which most men would be tempted by quantity rather than quality.

Mr. Dunlop's career was a remarkable one. Selected by Sir Thomas Brisbane, and taken from a subordinate position, he was by him placed in a very responsible one, and praised on every occasion. He shared with him the honour of the work done at Parramatta, and took him as his private Astronomer at

Makerstown; he became, in fact, the honored and trusted fellow worker of Sir Thomas Brisbane.

The following notice of his retirement appeared:—

[SYDNEY MORNING HERALD, *9th Nov.*, 1847.]

Mr. Dunlop, the Astronomer Royal of this Colony, has resigned his appointment. During the many years Mr. Dunlop has held this most distinguished appointment he has made it a fixed rule of his life to distribute in acts of charity the salary he received from the Admiralty, with whom the appointment is vested. He was appointed Corresponding Member of the Institute Royal de France, received the Gold Medal of the Royal Astronomical Society of London and other due recognitions of talent. A public Testimonial Committee is appointed in Parramatta.

In a letter, signed James Dunlop, he says that in May, 1843, he had looked over the South Head barometer readings and found the points of the curves later than at Parramatta. Hence it is evident that in May, 1843, he was keeping a Meteorological Record. (His letter is with the South Head Observations in Sydney Observatory.) In Captain King's "Hundred Observations," also, it is incidentally mentioned that Mr. Dunlop had determined the diurnal curve of the barometer by sixteen days of hourly readings. These observations are in one of the remaining books, but the observations are not for every hour of the twenty-four; from six to eight hours are omitted each night.

Mr. Dunlop was born on 31st October, 1793, at Dalry, Ayrshire; resigned his position at Parramatta, August, 1847; died 23rd September, 1848, and was buried at Kincumber within thirteen months of his leaving Parramatta.

P. E. DE STRZELECKI.

In a carefnlly prepared work by P. E. de Strzelecki, "Physical Description of New South Wales and Van Dieman's Land," published in London, in 1845, will be found a very valuable contribution to the Meteorology of the period 1838 to 1842 inclusive, The work, or rather this part of it is largely a compilation from the official records kept at Sydney and Port Macquarie; from observations made in Tasmania at Woolnarth and Port Arthur; from his own observations made during his stay of five years; and from the observations of Captain P. P. King, from which particulary he derives the account of the circulation of winds round the coast, and he concludes that the monsoon winds which are supposed to blow round Australia, must necessarily (p.169) impart to the remaining central atmospheric fluid certain regular *eddies*, similar to those observed in the sea or large rivers. Further, that this circulation striking on the high chain of mountains to the west of Tasmania "naturally gives rise to a subordinate eddy," which gives the prevailing winds to Tasmania and Victoria. There is a very interesting chapter on hot winds, and he points out that Australia and Tasmania are not the only countries subject to them. The atmospheric pressure, temperature, rainfall (no details of rain) and evaporation are very fully discussed. A very full account of his *Observations on the Diaphaneity of the Atmosphere* as determined by himself from observations on the direct effect of the sun on a thermometer fully exposed or placed under white wool or black wool, is given, He comes to the conclusion that the intensity of the suns rays is greater in Tasmania than Australia (p. 212), then some interesting experiments on radiation of heat are given, and upon dew and the moisture in the atmosphere, etc. The essay covers 82 pages out of 462 which make up the book.

Captain J. C. Wickham.

Captain J. C. Wickham kept a meteorological record at Brisbane, from January 1st, 1843, to the end of 1846, and for part of the time thermometer readings. These were published with three years rainfall, 1840-41 and 1842, in the *Moreton Bay Courier* for Janurry 23rd, 1847; the quantity of rain for each month is given. Copies of the *Courier*, containing these observations are with Captain P. P. King's papers now in Sydney Observatory.

Rev. W. B. Clarke, M.A.

It is not my intention to say anything of the life.work of the late Rev. W. B. Clarke, of that I am not in a position to speak, and it is moreover in abler hands; but I cannot pass over the very important contributions which came from his busy brain and pen. Meteorology with him was but the amusement for the leisure moments snatched from his favourite study, and from the time he landed in the colony in 1839 until 1847 he kept a careful diary, and very frequently recorded his results in the public press, and it is quite true to say that the number of these contributions on this subject no man knows. Even his own record in the sketch of his life published in the *Sydney Mail*, July 13, 1872, he said was very incomplete, and I know that several important papers are not mentioned. In 1842 upwards of twenty-one papers on Meteorology were published in the *Sydney Morning Herald.*

1844.—On Paragreles or Hail Guards.
1848.—On the Conditions of June and July, 1846
1850.—Investigations of Hurricanes.
1857.—Influence of Monsoons on the Climate of Sydney.
1857.—Meteorological Observations during an Eclipse.
1864.—On Australian Storms.
1877.—Effects of Forests on Climate.

To our own Royal Society he read eighteen papers.

In all there are twenty-nine papers on Meteorology, and I feel sure there were many more, from what I have heard Mr. Clarke say, and from references to them, but I have no idea at what time they were written; they would however probably be found in the *Sydney Morning Herald.*

In the Royal Astronomical Society's Notices I find three contributions—

1.—Remarks on the Great Comet of 1843.
2.—Observations made at Parramatta during the Solar Eclipse, February 1, 1851.
3.—Observations made at Sydney during the Solar Eclipse, March 26, 1857.

But Mr. Clarke was not content to work single-handed, he felt that a storm must be viewed from more than one point if he wanted to see it properly, and therefore meteorological observatories were established at his own expense at Castle Hill, near Parramatta, in February, 1842, and kept up to September, 1844; at Dooral, near Parramatta, in November, 1841, and kept up to April, 1846; at Campbelltown, in November, 1845, and kept up to November, 1847; also, at Naas Valley, near Queanbeyan, in November, 1843, and kept up to June, 1847. Returns were regularly forwarded to Mr. Clarke and are now in the Sydney Observatory in manuscript, only the rainfalls have been published. In 1852 also, Mr. Clarke induced the late Mr. Boucher, B.A., of Bukelong, Bombala, to keep a meteorological record, and that record was kept continuously until the time of Mr. Boucher's death in 1885. The record of rain prior to 1858 was made with a raingauge which Mr. Boucher thought not satisfactory and he would not give a copy of them. The record in the Observatory given at my request begins in 1858. Mr. Clarke kept his own record most carefully from the time of his arrival in the colony in 1839 until 1857; at first, at Parramatta, from 1839 to 1847; and subsequently at St. Leonards, North Shore, Sydney. He took particular interest in the thunderstorms at Parramatta, and worked out their life history if I may so speak, which he detailed in a series of valuable letters to the *Sydney Morning Herald;* later he turned his attention to the storms on the coast and studied them most carefully, recognising their cyclonic character as far back as 1848. In Meteorology as in all that he did, Mr. Clarke was a most indefatigable worker and painstaking investigator, and it is very much to be regretted that in those days there was no Scientific Society to receive and publish such work, and hence it was given to the daily paper, and is therefore not so accessible as we could wish.

Mr. Clarke was called away from his labours before he had time to carry out his intention of putting all this work into a book and making it generally available. All through there is evidence that every opportunity was seized to compare his instruments with standards in ships of the Navy commissioned for surveys and others, and an amount of labour was given to investigations in reference to the temperature and pressure of the atmosphere that seems almost incredible to me when I know that his life's work was in Geology and Mineralogy, and that Meteorology was only an amusement in his leisure moments.

Yet every page of it bears evidence of careful study and a wide acquaintance with the writings of others on the same subject. Each subject of enquiry presented to his mind was worked out until he felt he had clearly mastered it. On one occasion, speaking to me of thunderstorms, he said, "I have followed them through every stage of their existence, and now I could make them."

Rev. A. Glennie.

The Rev. A. Glennie kept a Meteorological Journal of all rainy days, floods and heights of floods being given in many cases; also, thunder and hailstorms at Paterson, Lochinvar, and Brisbane Water, from January, 1837, to the end of October, 1870, rain measures being taken during the last two years at Lochinvar—

At Paterson, 1832, to January, 1850.
Brisbane Water, August, 1850, to June, 1863.
Lochinvar, August, 1863, to October, 1870.

Extracts were published in the "Climate of New South Wales," by H. C. Russell, 1877—(Government Printer); and a full copy of the Journal is in the Library of the Observatory.

E. C. Close.

The late E. C. Close, kept a Journal of Floods in the Hunter, 1831 to 1864, from which extracts were published in the "Climate of New South Wales," by H. C. Russell, but the journal in full was not presented to the Observatory and is in the possession of his son.

Sir William Macarthur.

The late Sir William Macarthur, of Camden Park, kept a Journal of the Weather for many years, and Rain Measures, from 1860 to 1875. Extracts, including a rain table for the whole period, will be found in the "Climate, of New South Wales," by H. C. Russell, extending from 1860 to 1875, and a number of notes in the historical part of the volume; but the journal is still at Camden Park.

J. Boucher.

J. Boucher, of Bukelong, Bombala, kept a Meteorological Register from 1852 to 1885. Copies of the rain measures from 1857 to 1885, given to me, were printed in "Rain Results" for 1885. Copies of his barometer, thermometer, and wind observations were not given to me.

S. H. Officer.

S. H. Officer, kept a Rainfall and Weather Record at Murray Downs Station, on the Murray River, from 1864 to 1885. These, with valuable notes of the seasons, will be found in "Rain and River Results" for 1885.

John Wyndham.

John Wyndham, of Dalwood, Hunter River, kept a Rainfall Record, 1863 to 1885; it will be found in "Rain and River Results" for 1885.

William Stanley Jevons.

William Stanley Jevons who held a position in the Royal Mint at Sydney from 1854 to 1859, took the M.A. degree in 1862, and was afterwards Professor of Logic, and Mental and Moral Philosophy, etc., at Owen's College, Manchester. He wrote while in Sydney, a most valuable essay "On some data concerning the Climate of Australia and New Zealand," containing fifty-two pages. It was published in Waugh's Almanac for 1859, and also in a pamphlet form. The essay is divided into seven chapters devoted to the discussion of the following subjects :—

No. 1.—On the Temperature of the air in Australia.
No. 2.—Rain in Australia.
No. 3.—History of Floods and Droughts in New South Wales.
No. 4.—Periodicity of Floods and Droughts discussed.
No. 5.—Water Courses of Australia.
No. 6.—The Barometer.
No. 7.—Concluding Remarks.

Mr. Jevons said "my object has been to present in an available form, such accurate numerical data as are attainable; and secondly, to group together general information as to the winds, rains, rivers, floods—the geographical features of the country and the meteorological circumstances of this part of the globe, so as to shew what remarkable problems have to be solved; and what interesting connections of cause and effect may ultimately be traced and proved."

This was the most valuable contribution to the meteorology of Australia that had been made up to the time of its publication; perhaps, the most valuable chapter is that upon the history of the floods and droughts; but every part of it bears marks of most careful work in consulting all the available data then known, and the clear and logical mind of the author. Some of his conclusions more recent observations and investigations have shewn to be wrong, but they were entirely in accord with the facts then available, and he presented the most concise and accurate account of the climate which had been written.

Mr. Jevons contributed papers to the Philosophical Society of New South Wales, these were published in the Sydney Magazine of Science and Art—

1.—On a New Sun Guage, July 8th, 1857.

2.—On Clouds their various forms and producing causes, December 9th, 1857.

He also contributed to the same paper (Vol. II,, pp. 161 and 173). Meteorological Observations in Australia, being a continuation of those published in Waugh's Almanac for 1859 ; also a paper on the Geological Origin of Australia, (Vol. II., p. 89), and Earthquakes in New South Wales (Vol. II., p. 93); also Meteorological Observations three miles west of Sydney, at Petersham, eighty-five feet above the sea from July 1855 to February 1857 ; and then at Double Bay two miles east of Sydney, eleven feet above sea till June, 1858 ; readings at 9 a.m. and 9 p.m., published weekly from August 1856, in the *Empire* Newspaper and Monthly in the *Sydney Magazine of Science and Art* from May 1857 to June 1858 ; also several letters on scientific subjects to the daily press. Mr. Jevons was only nineteen years of age when he came to the colony, and twenty-four when he left. His observations fill up a gap in the official meteorological record between the closing of the South Head Observations and the commencement of observations at Sydney Observatory.

ESTABLISHMENT OF METEOROLOGICAL OBSERVATORIES.

Colonial Secretary's Office,
Sydney, 10th March, 1840.

Sir,—I am directed by His Excellency the Governor to transmit to you the copy of a circular despatch, dated 29th November, 1838, from Lord Glenelg, relating to the "*Collection of Facts respecting Storms*," and to acquaint you that persons who have been under the instruction of the Astronomer at Parramatta have been appointed to register observations at Port Phillip and at Port Macquarie respectively, with an allowance of 1s. 6d. per day each, in lieu of clothes and rations.

I am further directed to inform you that as these men are convicts taken from the class of specials who not being assignable are always maintained at the expense of tho Government, the charge above mentioned will properly be defrayed out of convict funds.

I have, Sir, &c.,
E. D. THOMSON.

The Deputy Commissary-General.

Meteorological Observatories were accordingly established at South Head, Sydney, Port Macquarie, and Port Phillip (*i.e.*, Melbourne), and observations began in April, 1840.

In each case educated men amongst the convicts were selected as observers, and it appears from a despatch from the Secretary of State that the Home Government refused to find salaries for these Observers or to maintain them in any way after their term of service was over, hence the observations ceased at all these places with the exception of Sydney, where the observer was kept on until 1855, when for some reason not stated he suddenly left the colony. It seems probable that he had grown lax in his duty and that the advent of an energetic Governor, Sir William Denison, made it, in his opinion, undesirable that he should remain at his post any longer, particularly as the Governor was known to take a deep interest in astronomy and meteorlogy.

[*Votes and Proceedings, N.S.W.*, 1848.]

In 1851, however, Captain King wrote; "I have reason to believe that the South Head Observer, Mr. Peacock, would be a proper person to make the observations. I think he is punctual and correct, on which everything that makes such records valuable depends,"

The Government, however, would not continue to pay observers, as appears by the following letter:—

Copy of Despatch from the Right Honorable the Secretary of State to His Excellency Sir C. A. Fitzroy.

No. 162 Downing Street,
3rd June, 1847.

Sir,—I have to acknowledge the receipt of your predecessor's Despatch No. 144, of the 7th July, 1846, containing the explanation he had been called upon to give in respect of the expense, and other circumstances relating to the question of the maintenance of the offices of Astronomer at Parramatta, and of the Meteorological Recorders at Port Macquarie, Melbourne, and South Head.

I have also received your Despatch of the 30th October last, No. 45, having exclusive reference to the three last mentioned appointments, and especially as regards the sources from which the charge of the salaries of the Recorders, when the convicts who now perform that duty shall become free.

I referred copies of both these Despatches to the Boards of Treasury and of the Admiralty, and the result of the correspondence which has since taken place on the subject has been to show that the advantages, in a scientific point of view, arising from the Observatory at Parramatta are not such as to justify its being continued at the cost of the British Treasury.

It will therefore be your duty to acquaint Mr. Dunlop that his services, as Superintendent, will not be required after the 31st March, 1848, up to which period only provision will be made for his salary in the estimates for expenditure connected with the Convict Establishment in New South Wales.

With respect to the three offices of Meteorological Recorders already noticed, Her Majesty's Government consent to the present rate of allowance (*i.e.*, 1s. 6d. per day) being paid to them only so long as the parties employed in the service are convicts, and who must otherwise be maintained at the expense of the Home Government.

I have, &c.,
(Signed) GREY.

Governor Sir C. A. Fitzroy, &c., &c.
A-55.

The observations were accordingly discontinued in Melbourne in 1850, at Port Macquarie in 1850, and in Sydney in 1855. The manuscript returns are in the Sydney Observatory; but part were published in the current numbers of the *Government Gazette.*

In passing thus briefly over the work done by so many pioneers in Astronomy and Meteorology in this colony, I have endeavoured to shew what has been done and where it is to be found. It will be evident to you there is more to be written yet, but many of the facts have been difficult to get and others have so far eluded my efforts to find them.

It is quite evident that Sir Thomas Brisbane, when he came to the Colony, contemplated the measurement of an arc of the meridian as part of his scheme, and that he brought with him suitable astronomical instruments and the special apparatus for determining the length of the seconds pendulum, and the following letter shows that he was using his influence to induce the Government to undertake the work, or rather, provide the money.

In Labilliere's History of Victoria, (Vol. I., pp. 1-185), is a letter from Sir Robert Peel, 20th October, 1823, in which he says:—

Sir H. Davy and his colleagues at the Board of Longitude have entire confidence in the scientific persons whom Sir T. Brisbane has on the spot, particularly Mr. Rumker, and gives the following letter:—

My Lord—The Right Honorable His Majesty's Secretary of State for the Home Department having done me the honor to inform me that your Lordship was favorably disposed to an undertaking which the Council of the Royal Society consider as important in the interests of Science. viz., the measurement of an arc of the Meridian in New South Wales, I take the liberty, at their request, of transmitting this to your Lordship. Several arcs have been measured in the Northern Hemisphere, but only one, and that at a time when instruments were very imperfect, in the Southern. The present moment appears peculiarly favorable for such a work to the Council, as there are persons at Parramatta who are able Astronomers, and who are in possession of the necessary instruments, with the exception of a Zenith Sector. The measurement of an arc in New South Wales would not only be of importance to Astronomy in affording data for determining correctly the figure of the earth—a matter of great interest to navigation—but would likewise be useful in laying the foundation for a correct survey of our Colonies in that great and unexplored country. Your Lordship's liberal and enlightened mind will. I am sure, require no apology for this communication which, as President of the Royal Society, the interests of Science call upon me to make.

I have the honor to be, my Lord,
With the greatest respect,
Your Lordship's obedient humble servant,
HUMPHREY DAVY,
President of the Royal Society.

The unfortunate interruption of Sir Thomas' design by the action of Mr. Rumker made this impossible, and when Rumker was appointed by the Government it was evidently understood, although not conveyed to him in his letter of appointment, that he should measure an arc of the meridian. Mr. W. D. Campbell in searching for other things connected with the surveys of the Colony, found amongst the MS. Correspondence, Surveyor-General to Colonial Secretary, (Vol. I., p. 507, 8th January, 1828)—"The requisition for the rods and cylinders for the Trigonometrical

Survey was made by Mr. Rumker, the survey being in conjunction with the measurement of an arc of the meridian, which Mr. Rumker had undertaken to execute."

And the pendulum apparatus which was used by Rumker at Parramatta, and with which he made the length of the Seconds Pendulum there to be 39.0891435 inches, was evidently brought out to be used in connection with the measurement of an arc of the meridian.

With the instruments that came from the Parramatta Observatory to Sydney, when it was dismantled, was a zenith sector which appears never to have been used, but is a large one and evidently intended for accurate work. A transit circle also came in the same way, and it would appear that this instrument was very little, if at all, used, and there was no room for it in the original building, hence it was set up on the outside of it. It was a good instrument, and, with some repairs, did duty in Sydney Observatory from 1859 to 1876, and it is still there, but not in use.

The transit circle in its day, 1830, was justly considered a first-class instrument, and must have been intended for accurate determination of star positions for the measurement of the arc of the meridian.

[APPENDIX A.]

31st August, 1827.

To Governor Darling.

I have the honor to inform you that I have this day paid to Messrs. Macdonald and Campbell, agents of Sir Thomas Brisbane, the sum of one thousand six hundred and fourteen pounds, thirteen shillings, for the purchase of certain Astronomical instruments and books left in the Observatory at Parramatta, and referred to in Mr. Macleay's letter to me on 27th September last.

(Signed) EDWARD BARNARD.

[APPENDIX B.]

Government House,
10th September, 1827.

The Right Honourable the Secretary of State for the Colonies, has communicated in a despatch, No. 96, dated 1st March, 1826, that His Majesty's Government with the view of promoting the interests of science in this part of the globe, has consented to the purchase from Sir T Brisbane, of certain astronomical instruments, specified in the enclosed list which in compliance with the Address of the Council had been left by him in the Colony, for the sum as valued by him of £1,614 13s.

He has directed that the necessary remittance of this amount should be made to the Colonial Agent to enable him to reimburse Sir Thomas Brisbane for the instruments in question. Let the necessary communication be made to the Auditor and Treasurer as to the remittance of this amonnt in order that it may be duly provided for by the first opportunity, and let Mr. Rumker be called upon for a list of the articles left by Sir Thomas Brisbane in the Observatory under his charge, that it may be compared with the specifications herewith.

(Signed) R. A. DARLING.

To Colonial Secretary.

Minute, No. 58.

LIST OF INSTRUMENTS (with LETTER from GOVERNMENT ASTRONOMER.)

	£	s.	d.
Four Astronomical Clocks, best description ...	£490	0	0
Mural Circle, by Troughton	200	0	0
Transit Instrument, 5½ feet, ditto	105	0	0
Repeating Circle, 16-inch, Reichenbach ...	130	0	0
Equatorial Telescope, &c. (by Banks)	60	0	0
French ditto	42	0	0
Declination Instruments, complete, by Holland	30	0	0
Inclination ditto, Gambey, Paris	42	0	0
Borda's Pendulum, complete for determining the figure of the Earth	85	0	0
? Mountain Barometers, by Troughton ...	11	0	0
Magnetic Transit, by Josker, Paris	15	0	0
Observatory Barometer and Four Thermometers	10	0	0
Kater's Azimuth Compass	10	0	0
Pair 18-inch Globes, Loudon	19	0	0
Levelling Telescope, complete	12	0	0
Astronomical Books, &c.	353	13	0
	£1,614	13	0

[APPENDIX C.]

Minute, No. 98.

GOVERNMENT HOUSE,
21st December, 1827.

Let Mr. Rumker be informed that he will be immediately notified as Government Astronomer of this Colony, and that he will be allowed a salary of £300 a year from the time of his taking charge of the Observatory, until His Majesty's Government shall fix the salary to which he may be considered entitled.

(Signed) R. A. DARLING.

[APPENDIX D.]

GOVERNMENT HOUSE,
16th July, 1829.

Let it be notified that the Secretary of State has been pleased to confirm the appointment of Mr. Rumker, as Government Astronomer, with a salary at the rate of £300 a year; and also sanctions the expense which may be incurred in providing Mr. Rumker with accommodation at the Observatory.

(Signed) R. A. DARLING.

Rumker's last work at Parramatta was in December, 1828, and it would appear that he then left the Colony to go to England and get instruments for the Trigonometrical Survey.

[APPENDIX E.]

Minute, 130.

1st September, 1830.

The Secretary of State having signified his desire (Mr. Twiss' letter, 21st December, 1827), that accommodation for the Colonial Astronomer, proposed to be added to the Observatory, should be expedited as Mr. Rumker was preparing to return and resume the duties of his situation. Let the Director of Public Works Captain Dumaresque and Forbes be requested to proceed to Parramatta and examine the Observatory, so as to ascertain whether the building is sufficiently good to have the proposed additions made to it. If not, let them examine whether there is any more eligible site in the neighbourhood for establishing the Observatory.

(Signed) R. A. DARLING.

It will be observed that so late as September 1st, 1830, Rumker was preparing to return.

[APPENDIX F.]

GOVERNMENT HOUSE,
22nd April, 1831.

Let it be notified that the Secretary of State has been pleased to appoint Mr. James Dunlop, Superintendent of the Government Observatory at Parramatta, with a salary of £300. Mr. Dunlop will be allowed one-half salary from the date of his embarkation.

(Signed) R. A. DARLING.

[APPENDIX G.]

28th June, 1847.

Board reporting on state of Observatory Establishment at Parramatta.

Sydney, June 26th, 1847.

Forwarded to H. M. Secretary of State by Despatch, No. 141/1847

SIR,—Referring to your letter of the 14th April, the receipt of which we have the honour to acknowledge, appointing us Members of a Commission for the purpose of examining the Inventory of all the Instruments, Books, &c., belonging to the Observatory in this Colony.

2. We have the honour to report to you for the information of His Excellency the Governor that on the 21st of the month we repaired to the Observatory, Parramatta, and there examined the Instruments and Books in the charge of Mr. James Dunlop, the Astronomer; a report of which we have the honour to enclose.

Duplicate copies of this and of the Report of the Commission will be required for transmission to the Secretary of State, Mr, Dunlop should also be called upon to furnish the Report required from him by the Secretary of State's Despatch, 17th July.

3. We regret to state that the building is in a very delapidated state of repair, and the Instruments are likely, unless they are immediately protected from the weather, to be very much injured.

4. The floor and partitions of the building seem to be entirely destroyed by the white ant, and the building itself is so dilapidated as to require to be rebuilt.

5. Under these circumstances we would beg to recommend that the building be covered in such a way as may be considered best to secure the Instruments from further injury, where they may remain until another Observatory be built, the sight of which should, we respectfully suggest, be better left for selection by the Astronomer who may be appointed to succeed Mr. Dunlop, who is desirous of being relieved, inasmuch as his health entirely incapacitates him from the fatigue of observing.

Mr, Dunlop, 24 July, 1847.

The clock and smaller instruments might for greater security be packed up and enclosed in cases. but the instruments which are fixed had better be secured in their present positions, whereby there would be less risk of their receiving injury.

One copy herewith, 24 July, Another copy required 13 August, by the 23rd, December 20, returned to be put away, 21,

We have the honor to be, Sir,
Your most obedient humble servants,
PHILLIP P. KING,
Captain R.N.,
J. A. GORDON,
RICH. ROGERS,
Ordnance Storekeeper.

The Hon. the Colonial Secretary.

47/5007.

Report of a Commission appointed by the order of His Excellency the

Governor, dated 14th April, 1847, for the purpose of examining the Inventory of Instruments and Books, &c., belonging to the Observatory at Parramatta.

INSTRUMENTS.

Forwarded to H. M. Secretary of State by Despatch. No. 141/1847

Copy required for Duplicate Despatch, 13th August, by the 23rd. Returned to be put away. 21.

An Astronomical Clock, by Brequet, with two square pendulums ; reported to be in good order but not kept going.

An Astronomical Clock, by Hardy, in good order, going at Sidereal Time.

An Astronomical Clock, by Barraud, in good order, but not going

An Astronomical Clock, by Gremalde, recently cleaned and in good order, stated by Mr. Dunlop to be in the Hall of Government House, where it has been seen by Captain King.

A Mural Circle, by Troughton, with four eye pieces. The Instrument is stated to be in good order but requires cleaning. The pillar to which it is fixed has given way.

A five and a half feet Transit, by Troughton, complete with Ys and hanging level. This Instrument was taken from its place to make room for the Meridian Circle, it is in good order and ready for use.

A sixteen inch Repeating Circle, by Reichenbach, the Verniers have been removed from the Instrument, but are ready to be fitted. The pillar has given way.

An Equatorial Stand, and forty-six inch Achromatic Telescope, by Banks. Both require cleaning but otherwise are ready for use. There is also a Micrometer Eye-piece in a separate case.

A Parallactic Instrument, by Cambrier and Le Noir. Much damaged and unfit for use.

A Magnetic Transit, by Dolland, apparently fit for use.

A Dipping Needle, by Gambey, apparently fit for use.

Borda's Apparatus, for measuring the length of a Pendulum—damaged.

A Platina Sphere, with knife-edges.

A Diurnal Variation Instrument.

A Mountain Barometer, by Troughton, in good order.

A Mountain Barometer, now at the South Head of Port Jackson.

A Barometer, by Banks, in order, but not in use.

A Kater's Azimuth Compass, in good order.

A pair of eighteen inch Globes, date 1791, much injured.

An Eirometer, by Jones, in order.

An Hygrometer, by Saussiere, damaged.

A Zenith Sector, in two cases, apparently having never been used, and considered to be in good order.

A Night Glass—useless.

Several Thermometers, broken and useless.

A Telescope, by Berge, one of the glasses in the Eye-piece broken.

A Sextant, by Jones, in order.

An Artificial Horizon, by Jones.

A Microscope, by Banks.

A Meridian Circle, forty-two inches diameter, by Jones, the Telescope having an aperture of three and three-quarter inches. This Instrumant is set up where the five and a half feet Transit was fixed. The level is broken, and the Index Circle very badly graduated, the setting vernier is fixed very inconveniently for directing the Telescope to the object, and is not graduated ; not even *with a Zero Line.* Mr. Dunlop complains generally of the Instrument, as being so very unsatisfactory in its fittings and the graduation of the Circle itself as to be *quite useless.*

Connected with the Meridian Circle is a thirty inch Transit, the Ys being fixed on stone pillars to serve as a Collimator.

A Pocket Chronometer, by Dallas, requiring slight repairs.

A Box Chronometer, by Dent, No. 220, in good order.

A Levelling Telescope, Rod and Chain, Staves, &c., complete, in good order and ready for use.

The Instruments above enumerated have been individually seen by us ; but the Mural Circle and the Sidereal Clock only are in use. Generally the Instruments require to be cleaned, and the stone pillars which have been erected on a bad foundation have sunk so much as to be out of the perpendicular.

The Building is in a very delapidated state, the partition walls having settled ; the floor and partitions perfectly rotten from the effect of the white ant ; and the roof admitting rain in most parts, the canvas coverings of the domes are quite rotten and torn, and affords no protection to the Instruments ; in fact, they are all but entirely exposed to the weather, and will soon be destroyed unless steps are taken to protect them, until another building be erected.

BOOKS.

VOL.
One Navigation, by Dulague.
One Bonnycastle's Astronomy.
One Diviseurs des Nombres par Siddonne.
One Simpson's Conic Sections.
One Instruction sur les poides et les mésures.
One Arithmétic de Mauduit.
One Barlow's Theory of Numbers.
One Etude de Ciel par Mallet.
One Dowling's Key to Hutton's Course of Mathematics.
Two Annales de Chimie.
Six Dictionnaire de Physique.
One Plates to do.
One Mackay's Mathematical Tables.
One Treatise on Fluxions, by Vince.
Leslie's Philosophy of Arithmetic.
Three Salande's Astronomy.
One Salande's Navigation.
One Tables du Soleil par Delambre.
Three Delambre's Astronomy.
Three Base du Systéme Métrique.
Two Leçons Mécanique par Prony.
One Delambre's Histoire de l'Astronomie.
One Wollaston's Fasciculus.
Two Long's Astronomy.
One Memoire sur l'Astronomie pratique.
One (Fifth Vol.) Mécanique Celeste.
Two Euler's Algebra.
Three Shubert's Astronomy.
One Algebra by Le Cloud.
Two Ferguson's Astronomy.
Two Traité de Géodesie par Puissant.

One Traité de Géodesie par Puissant
Two Woodhouse's Astronomy.
One Woodhouse's Astronomy, duplicate.
Three Biot's Astronomy.
One Biot's Trigonometry.
Two Nicholson's Philosophy.
One Ozanam's Trigonometry.
One Leçons de Géometrie.
One Traité des Pierres.
One Astronomy de La Caille.
Four Recréations Mathématiques.
One Aritmétique de Bezout.
One Introduction to Callett's Logarithms.
One Ferguson's Exercises.
Two La Place, Système du Monde, translated by Pond.
One Francœur's Uranographie.
Three Hutton's Course of Mathematics.
One Traité d'Optique par La Caille.
One Leslie's Elements of Geometry.
One Tables de Logarithmes portateres,
One Keith's Trigonometry.
One Gnonomonique Elémentaire.
One De Zach's Tables de la Lune.
One Ewing's Astronomy.
One Brent's Astronomy.
One Biot's Tables Barométriques.
Four Playfair's Works.
One Œvres de Clermont.
Two Numbers of 13th Book of Mécanique Celeste.
One Piazzi's Observations for 1814.
Two Voyages aux Terres Australes par Freycinet
Two Flinders' Voyages (no charts.)
One Dupuis' Cours de Géometrie.
La Place Mécanique Celeste.
One Fauchen's Météorologie.
One Brooks' Guide to the Stars.
Two Annales de Travaux.
Two La Croix, Traité de Calcul differentiel.
Eleven De Zach's Correspondence Astronomique.
Four Philosophical Magazine.
Five Arts and Sciences.
One Cagnoli Trigonométrie.
Thirty-seven Philosophical Transactions.
Two Philosophical Transactions (Edinburgh.)
One (Third) Mudy's Trigonometrical Survey.
One De Zach Catalogue.
One Piazzi's Catalogue.
One Callett's Logarithms.
One Bode's Uranographie (maps.)
One La Croix Géometrie et Algèbre.
Two Hutton's Mathematical Dictionary.
One Jones' Geometry.
One Journal de Physique.
One Taylor's Logarithms.
Seven Bessel's Observations.
One Catalogue of Stars not inserted in the British Catalogue.
One Hutton's Powers and Products of Numbers.
One Maskelyne's Tables of Aberration and Notation.
One Taylor's Sexagesimal Table.
One Mendoza Rios' Navigation Tables.

One Barlow's Mathematical Dictionary.
One Hutton's Logarithms.
One Bode's Jährbuch.
One La Caille's Astronomy, by Robertson.
One hundred and four Connaissance des Temps.
One Hutton's Mensuration.
Two De Zach's Tables of Aberration and Notation.
One Collection of Astronomical Tables.
One Astronomie des Marins.
Three Beaux Arts.

Works received recently by Mr. Dunlop.

Six Greenwich Observations.
One Greenwich Reductions.
Three Greenwich Appendix.
Twelve Parts Cambridge Observations.
One Account of John Flamsteed, and Supplement.
One Beaufoy's Nautical Experiments.
Five Edinburgh Observations.
Three Numbers Cape of Good Hope Observations.
One Number Cape of Good Hope Observations, in sheets.
One Number Cape of Good Hope Observations, in boards.
Four Numbers Madras Observations.
One Groombridge's Catalogne of Circumpolar Stars.
Nine Numbers Philosophical Transactions.
Six Numbers Observations Magnétiques Météorologiques.
Four Dorpat Observations.
One Parramatta Catalogue.
One Halley's Comet.
Eight Astronomical Society.
Two Parts Theory of the Moon.
Fourteen British Association Reports.
Five Radcliff's Observations.
A Collection of old Nautical Almanacs, Distances of the Moon from the Planets, and several pamphlets and old books, more or less injured from damp, and of no value.
Five Volumes of Observations made by Mr. Dunlop, partly reduced.

PHILLIP P. KING,
Captain R.N.,
J. A. GORDON,
RICH. ROGERS,
Ordnance Storekeeper.

Parramatta, 21st June, 1847.

[APPENDIX H.]

Copy of a Despatch by Governor Fitzroy, (78.)

11th July, 1847.

My Lord,—With reference to your Despatch, on the Observatory at Parramatta, and to the instructions therein contained, I have now the honor to inform your Lordship that I lost no time in calling upon Mr. Dunlop, the Superintendent of the Establishment, to furnish me as soon as possible with the report required by your Lordship for the current year, This report has not yet been forwarded to me, but it shall be transmitted to your Lordship by the earliest opportunity after I receive it.

In further obedience to your Lordship's instructions, I appointed a commission, consisting of *Captain King, R.N., Lieutenant-Colonel Gordon, Commanding Engineer*, and the *Ordnance Storekeeper*; and I have the honor to forward the Inventory made under their inspection of the Instruments and Books belonging to the Observatory.

Your Lordship will perceive that the *Commission report that the Instruments and Books generally are in good condition, but that the buildings from want of timely repairs, are in a very delapidated state ;* and on this point (as the Observatory is within one hundred yards of the Government House at Parramatta, and immediately under *my own eye) I can* state that I *am clearly of opinion that no repairs* which could now be executed—short of entirely rebuilding the premises—would put them in a habitable or efficient state.

Your Lordship will further observe that Mr. Dunlop is anxious to resign his *appointment on account* of the state *of his health,* which renders *him incapable of attending to his duties.* And as, since receiving the report of the Commission, I have been informed by Lieutenant-Colonel Gordon that the building cannot be even temporarily repaired without considerable expense, I have, in order to preserve the Instruments, etc., from further injury, *directed that they should be packed up in boxes and placed in charge of the Ordnance Storekeeper,* until your Lordship's further wishes are made known to me.

I have, etc ,
(Signed) CHARLES A. FITZROY.

To EARL GREY.

[APPENDIX I.]

13th August, 1847.

Reported to H. M, Secretary of State by Despatch, No, $\frac{141}{1847}$

Since the Report of the Board was sent in I have seen Colonel Gordon, who said that Captain King concurred with him in thinking that instead of incurring the expense of covering in any portion of the Observatory for the preservation of the instruments, it would be better to have them put up in boxes and placed in the Ordnance Stores.—4th August.

A, J. F.

7/500.

[APPENDIX J.]

47/6561.

OBSERVATORY, PARRAMATTA,
18th August, 1847.

TO THE BOARD OF VISITORS OF THE PARRAMATTA OBSERVATORY :

Forwarded to H. M. Secretary of State by Despatch, No. $\frac{176}{1847}$

GENTLEMEN.—The observations were commenced by me about the middle of January, 1832, with a five-and-a-half ($5\frac{1}{2}$) feet transit and a two (2) feet mural circle by Troughton, and continued until the transit was replaced by Jones' three-and-a-half ($3\frac{1}{2}$) feet transit circle in the middle of the year 1835, after which the mural circle was principally used, the circle by Jones being very difficult for one person to work.

The observations consist of right ascensions and polar distances with moon, culminating stars, comets, &c. The reductions of a portion of the observations between 1832 and 1835 have been proceeded with, but, having no assistant or clerk, they have not proceeded so far as I could wish.

The buildings of this Observatory are in a very bad state of repair. The white ant has been most destructive, and, as the surrounding ground is full of them, it would be fruitless to attempt a repair, which could not last above two or three years at most. The building was originally of a very inferior description, being only intended as a private establishment and not calculated to last beyond a few years. (The building was commenced in December, 1821, and the instruments were fixed and the observations commenced about the 11th of March, 1822.)

The subsoil is alumina schistose, into which the stone piers are sunk several feet, and from the access of air and water the alumina is gradually dissolving and the pillars sinking, and some of them unsteady.

The Library is in much the same state as it was when I took charge of it in 1832.

The manuscript observations are contained in five volumes and six or seven smaller volumes.

The instruments and clocks are in good working order. The spirit level of the transit circle, by Jones, burst by exposure to the sun a few months after it was set up, the tube being filled with sulphuric ether, which boils at a very low temperature, far below the powerful influence of the solar rays.

This circle would have been a more powerful instrument had it read off with four microscopes instead of three. The errors arising from eccentricity (if any) would thereby in a great measure have been neutralized, which cannot be the case with three microscopes. Altogether it is an unhandy instrument.

As the building cannot long protect the instruments in safety, I would recommend their removal to one of Her Majesty's Stores in the Military Barracks.

The site of the present building is what I could not recommend for the erection of a more complete and useful establishment, not only on account of the poisoned state of the ground by the white ant, but its local situation, and also its distance from Sydney, the sea-port.

I think a very desirable and convenient site may be obtained on the high grounds on the North Shore in the vicinity of Sydney, out of the smoke of the city and in view of the harbour and shipping, which would give to the masters of vessels the desirable opportunity of obtaining their time, and ascertaining the rate of their chronometers by signal or ball as practised at Greenwich and other places.

For myself, I have now weathered it nearly three-score years, and I find the last quarter of a century spent in this country has considerably blunted my energies of body and mind. With your recommendation to His Excellency the Governor, it is my wish to try a change of scene and occupation with what little health and strength remains, to endeavour to weather it a few years longer.

I have the honor to be, Gentlemen,

Your very humble servant,

JAMES DUNLOP.

[APPENDIX K.]

Respecting Removal of Books and Instruments from Parramatta.

Sydney, 23rd August, 1847.

M, 7785.

Forwarded to H. M. Secretary of State by Despatch, No. 176/1847

SIR,—

1. In reference to the accompanying letter from Mr. Dunlop, the Astronomer at Parramatta, we beg to request the authority of His Excellency the Governor for the instruments and books belonging to the Parramatta Observatory being packed in cases and deposited in either the Royal Engineer Office or Ordnance Store in Sydney.

2. Captain King, R.N., the senior Commissioner for visiting the Observatory, previously to his leaving Sydney acquiesced in the propriety of this measure as the best that could be

adopted for the safety of the instruments and books pending the construction of a new Observatory.

3. It is proposed, subject to the approval of His Excellency, to charge to the Engineer Estimate for Convict Services the expense to be incurred in providing the packing cases and in the removal of the instruments and books.

We have the honor to be, Sir,
Your most obedient humble servants,
J. A. GORDON,
Lt.-Col. Com. Roy. Eng.
RICH. ROGERS,
Ordnance Storekeeper.

The Honorable
The Colonial Secretary, &c., &c.

Commissioners infd. 4 Sept, 1847.

Let the instruments and books be packed and removed according to the recommendations of the Commissioners. I do not exactly understand the nature of Mr. Dunlop's application in the last paragraph of his letter, whether it is for leave of absence or for permission to resign his situation altogether.

26 Aug. E. D. T.

The ambiguity will perhaps be explained by a reference to the 5th paragraph of the report enclosed, marked (See Appendix G.) 28th.

The paragraph referred to reports Mr. Dunlop's wish to resign. Let his resignation be accepted accordingly.

30 Aug. E. D. T.

[APPENDIX L.]

Downing Street,
14th April, 1848.

Sir,—I have the honor to acknowledge the receipt of your Despatch, No. 141, of the 11th of July last, with its enclosures, communicating the result of an enquiring which you had directed to be made by some of the officers of your Government, into the state of the instruments and books, &c., belonging to the Observatory at Parramatta in the charge of Mr. J. Dunlop, the Astronomer; and also reporting upon the state of the building itself.

In another Despatch, dated 30th August last, No. 176, you announce the resignation of that gentleman of his appointment, and that you had given the necessary authority for packing and depositing the above-mentioned books and instruments in the Ordnance Stores at Sydney. I approve of your having authorised the charging to the Engineer Branch of the Convict Service the expense which has been incurred in this service, and with further reference to the suggestion contained in Mr. Dunlop's letter which you have forwarded, of the 18th August, 1847, you are authorised to make over the transit instrument to the possession of the Colonial Government, provided they should be willing to make arrangements for the construction and maintenance of a time ball establishment. As regards the other instruments, with the clocks and chronometers, no time should be lost in disposing of them to the best advantage, in the Colony, as they are likely soon to become deteriorated if left in the Ordnance Stores in Sydney.

I have, &c.,
(Signed) GREY.

Governor Sir Charles Fitzroy, &c., &c.

[APPENDIX M.]

48/11736.

The Commanding Royal Engineer to the Honorable the Colonial Secretary, respecting the sale of instruments belonging to the Parramatta Observatory.

Royal Engineer's Office,
Sydney, 31st October, 1848.

Under the report it would not be ad-

Sir,—Adverting to your letter of the 11th ultimo, conveying to me the orders of His Excellency the Governor to

visable to attempt to sell these instruments in the Colony without further instructions from Home. Let a Despatch be prepared enclosing a copy of this communication with reference to Lord Grey's Despatch, No. 68, of the 14th April last.
E. D. T, 4th Nov.

Dft. of Despatch, 23rd Nov. 48/12623

Commanding Roy. Engineer 10th Nov, 1848.

Forwarded to H. M. Secretary of State by Despatch No. 250, of 23 Nov., 1848.

take the proper steps for selling to the best advantage the instruments, &c , belonging to the Parramatta Observatory, I have the honor to submit for the consideration and further orders of His Excellency the following observations:—

After the most careful enquiry I am led to believe that it would not be expedient to sell on tbe spot the large instruments of the Observatory. I have consulted Captain King on the subject, and he agrees with me in opinion that there would be no competition for the purchase of these large instruments should they be offered for sale in the Colony.

The following are the instruments which it is considered could not be disposed of on the spot, and Captain King and myself think it would be expedient to cause them to be returned to England:—

1st. The 42-inch meridian circle, by Jones; the vernier not graduated, and the instrument in other respects requiring to be put into the hands of a skilful instrument maker to render it serviceable. The late Mr. Dunlop never used it.

The 30-inch transit belonging to this circle Captain King thinks would be quite sufficient for the purposes of a time ball.

The 5-feet transit being unnecessarily large for this purpose, he thinks it would be advisable to return it to England, and keep the 30-inch instrument in the Colony.

2nd. The mural circle by Troughton.

3rd. The 16-inch repeating circle by Reichenbach.

5th. The zenith sector, in two cases, which appear to have never been unpacked.

I have the honor to be, Sir,
Your most obedient humble servant,
J. A. GORDON,
Lt.-Col. Com. Roy. Eng.

The Honorable
The Colonial Secretary, &c., &c.

[APPENDIX N]

[*Copy of a Letter from Captain Phillip P. King. R.N., to the Honorable the Colonial Secretary.*]

PORT STEPHENS,
December 21st, 1848.

SIR,—It is some years since the question of the boundary between the provinces of South Australia and Australia Felix, or Port Phillip, was mooted and when, as you will doubtless remember, Mr. Assistant Surveyor Tyers was directed by His late Excellency Sir George Gipps to ascertain the exact position of the boundary line, that officer accordingly made a very detailed and, as it appeared to me, a very careful triangulation of the country between Melbourne and the Glenelg river, by which by astronomical observation, and by chronometric measurement he fixed the eastern point of the entrance of the "Glenelg" in longitude 141° 1′ 23″, or 1′ 23″ within the province of Port Phillip.

Mr. Tyers' calculations were examined by Captain Owen Stanley, R.N., who, it appears, re-calculated the trigonometrical and chronometric measurements, and found the longitude to be 16″.2 to the eastward of Mr. Tyers. They were, however, questioned by that eminent geographer, Mr. Arrowsmith, who, in a map published under the authority of the South Australian Company, had placed the mouth of the Glenelg some eight or nine miles within the province of South Australia.

Being at that time a question of great interest, I took pains to satisfy myself upon the subject, and I found, from the observations of sixteen different observers, from Captain Cook to the expedition of Sir James Ross to the antartic seas, (using 10° 10′ 30″ as the difference of longitude between Sydney, Fort Macquarie, and Melbourne) that only two place the river Glenelg to the westward of the 141st degree of longitude.

By the observations of Sir Thomas Brisbane and of Mr. Rumker (now Director of the Observatory at Hamburg), Parramatta, was considered to be in longitude 10h. 4m. 6s..25 or 151° 1′ 33″.7 east, from which Mr. Tyers deduces that of the Glenelg to be 141° 1′ 34″; but Mr. Rumker after re-calculating his observations, gives a more easterly position to Parramatta, viz., by 14″.52, so placing the disputed point 1′ 48″.5 within the boundary of Port Phillip.

But there is good reason to believe that Parramatta is yet more easterly, at least 17″ or in 151° 2′ 18″ east. and if so, the mouth of the Glenelg will be in 141° 2′ 18″.3 east. This is yet to be determined.

I have taken the liberty of troubling you with this matter to shew the importance of the re-establishment of the Observatory, if it be only to decide a question which, at some future time, may give rise to very disagreeable disputes. I could advance much stronger arguments for its re-establishment had it not already been decided that science did not require it, but I think that its usefulness, for the purpose I have described, would be very great.

The instruments and books are, as I understand, to be sold by public auction; if so, they will fetch but a mere trifle. The erection of an Observatory may at present not be desirable, for various reasons, but at some future time such an event might be necessary, and then it would be a cause of great regret that such valuable instruments, as some are, should have been lost.

I have therefore, the honor to request, that you will convey to His Excellency the Governor the following proposition.

"That His Excellency would delay the sale of the following list of Instruments until it be ascertained whether they may not be kept in store until an Observatory be established, or until they may be more advantageously disposed of, viz.:

One Astronomical Clock, by Hardy.
Do. do. do. by Barraud.
Do. do. do. by Grimaldi.
Mural Circle, 5½ inch Transit.
16 inch Repeating Circle.
Equatorial Stand and 46 inch Telescope by Banks.
Mountain Barometer, by Troughton.
30 inch portable Transit for Collimator.

Among the books there are several of value to an Observatory that would fetch little more than as waste paper if brought to the hammer.

There are other Instruments in the list of those that belonged to the Observatory, but not desirable to retain, although they would scarcely realize *here* the value of their weight in metal.

I have, etc.,
(Signed) PHILLIP P. KING, Capt., R.N.

[APPENDIX O.]

No. 17.

[*Copy of a Despatch from the Right Honorable Earl Grey to Governor Sir Charles A. Fitzroy.*]

Downing Street,
14th December, 1849.

Sir,—I have received your Despatch, No. 57, of the 26th April last, relative to the disposal of certain instruments belonging to the late Observatory at Parramatta.

I referred that Despatch for the consideration of the Lords Commissioners of the Treasury, and I transmit for your information a copy of a letter in reply from the Secretary to that Board, with its enclosures.

You will perceive that the Lords Commissioners agree to the transfer of those instruments to the Colony, and I trust that there will be no difficulty in acting on the suggestions of the Astronomer Royal, and the Hydrographer to the Admiralty, for the establishment by the Colonial Government and the maintenance of a Time Observatory near Sydney for the purpose of giving time to ships frequenting that port.

I have, etc.,
(Signed) GREY.

Governor Sir Charles A. Fitzroy, etc., etc.

The Hydrographer said I am of opinion that it would be a great boon to vessels if the transit instrument were to be employed at Sydney in regulating their chronometers, and in dropping a daily time ball; and the Astronomer Royal (9th November, 1852), said it appears to me that it would be perfectly proper to retain the principal instruments in Sydney for the purpose of giving time to ships, and although some of the instruments at Parramatta would not be strictly required for an observatory for time signals, yet I would attach the whole of them to it.

[APPENDIX P.]

No. 21.

[*Copy of a Letter from the Colonial Secretary to the Commanding Royal Engineer.*]

COLONIAL SECRETARY'S OFFICE,
Sydney, 19th October. 1850.

SIR,—Referring to my letter of the 21st December, 1849, relative to the Astronomical instruments belonging to the late Observatory at Parramatta, now in the Ordnance Stores, I am directed by His Excellency the Governor to inform you that the reply of the Home Government having been received with respect to the disposal of the instruments, they will be taken over by the Colony, with a view to the establishment of a time ball.

I have been in correspondence on this subject with Captain P. P. King, R.N., to whose care the instruments named in the annexed list are to be committed, and I have accordingly referred that gentleman to you in order that they may be handed over to him. Captain King proposes, whilst selecting those instruments, to examine and report on the state of the other instruments, as packed, which are to remain in the Ordnance Stores at present.

I have, &c.,
(Signed) E. DEAS THOMSON.

The Commanding Royal Engineer.

A long correspondence (see Votes and Proceedings, N.S. Wales, 1855) then followed as to the position of the Observatory, extending over the years 1851, 1852, 1853 and 1854.

Upon the arrival of Sir William Denison as Governor, in 1853, he immediately took steps to get the Observatory established, and the following papers show that he did so to some purpose.

[APPENDIX Q.]

31st March, 1853.

I heard with some regret a few years since that the Observatory at Parramatta had been broken up. I am aware that this was in great measure due to the misconduct of the person then acting as Astronomer, in consequence of which some doubt was thrown upon the correctness of his observations, and consequently on the value of the results deduced from them. This was perhaps a sufficient reason for the withdrawal by the Home Government of the allowance granted to an observer in these latitudes. But there are many circumstances which would, in my opinion, make it very advisable to re-establish the Observatory, not on the old site, but upon one in the immediate vicinity of Sydney. In the first place, provision has already been made for the erection of a building to contain the machinery of a time ball and for the purchase of the machinery, but the time ball will, in point of fact, be worse than useless unless there are means for determining the time correctly—that is, unless there are proper clocks and proper instruments for determining the time; and these instruments are in the hands of an observer responsible to the Government for their proper application. I say that a time ball would be worse than useless without these; for as the time ball is established for the purpose of enabling captains of vessels to rate their chronometers properly, any error in the time given by the ball has the effect of deceiving the captain as to the quality of his chronometer, and as to the daily rate at which it either loses or gains; and a very trifling error in the rate, accumulating daily, will in the course of a month amount to a serious error in time, and a still more serious one in longitude.

In the second place, I am anxious for the establishment of an observatory in the immediate vicinity of Sydney, as affording to all persons, and especially to those educated at the University, a practical example of the application of science to the determination of matters altogether beyond the scope of our ordinary or uneducated reason. The student sees in the results deduced from the observation the application of those truths or principles which have been put before him at school in an abstract form, and he begins to comprehend that what he has hitherto been engaged in is to be looked upon in the light of an apprenticeship, during which he has learned to handle the tools which he will from henceforward have to apply to the purposes of life.

In the third place, I am desirous to establish an observatory for the purpose of connecting it with the trigonometrical survey of the country, and thus, by means of the perfect and absolute determination of the position on the earth's surface of one point, to be enabled to lay down with perfect accuracy the whole of the remainder of the country, not merely with relation to that spot, but with relation to the remainder of the earth's surface.

In the fourth place, I am anxious for the establishment of an observatory as a means of connecting this Colony with the Scientific Societies of Europe and America. I have no doubt but that from my acquaintance with the Astronomer Royal I shall be able to obtain from him a recommendation of a person thoroughly qualified to take charge of the Observatory, and we can then procure assistants from the youth of the Colony, some of whom will be trained up to take the place hereafter of the Astronomer at first supplied from England. The instruments in our possession already are of great value, and I believe only require to be properly adjusted to allow of their employment at once. Provision should be made for a building to contain them, for such repairs as may be found necessary to the instruments themselves, for a house for the Astronomer in the immediate vicinity of the Observatory, and such additional accommodation for computers, &c., as may probably be required.

It would also be desirable to provide for the purchase of a dozen sets of meteorological instruments, for the purpose of establishing at different points throughout the extensive area of the Colony such observations as to temperature, moisture, direction of wind, and generally of such atmospheric phenomena as may afford data from which we may be enabled at some futnre period to deduce the laws upon which these phenomena depend or by which they are regulated.

31st March, 1855. W. DENISON.

APPENDIX R.

[*Proceedings of the Executive Council on the 4th April, 1855, with respect to the re-establishment of an Observatory in this colony.*]

Extract from Minute No. 55/12. Confirmed 17th April, 1855.

2. The Council express their entire concurrence in His Excellency's views, and they advise that the Legislative Council be invited to make the necessary provision for a building in or near Sydney to contain the valuable instruments already in the possession of the Government—for such repairs to these instruments as may be requisite—for a residence for the Astronomer in the immediate vicinity of the Observatory,—and for such additional accommodation for computors, etc., as may probably be required.

3. It may also be desirable to provide for the purchase of a dozen sets of Meteorological instruments for the purpose of recording at different points throughout the extensive area of the colony, observations as to temperature moisture, direction of wind and atmospheric phenomena.

MICHL. FITZPATRICK,
Clerk of the Council.

APPENDIX S.

[*Specifications for Observatory by Sir William Denison, written 7th April.*]

Mr. Weaver to be written to on the subject and desired to report as aoon as possible.

Col. Architect and Auditor-General, 12 April, 1855.

On 1 May, re-submitted, 2 May, Not answered, 4 May, Not received, 15 May.

The buildings for which the Colonial Architect will have to estimate in addition to the mere foundations for the Time Ball will be as follows: 1st.—A building about 36 feet long by 15 feet wide divided into two rooms, one 24 feet long and the other 12 feet, with two gable ends having two openings in the roof of the main room, which openings will be prolonged through the walls to within 3 feet of the ground.

The object of these openings is to allow an observer to direct his telescope to any portion of the meridional circle which may be required. The opening must have proper shutters working with pulley and counter weights so as to move easily, but yet close enough to keep out the weather completely.

The floor must be of wood raised some distance from the ground and so framed round the pillars which carry the instruments as to leave them quite clear and independent. The pillars which carry the instruments should be of single blocks of sound stone—the foundation for which should be carried up from the solid rock, the foundation being kept quite clear from the sides of the pit in which it is placed. If it be necessary to quarry for this foundation, that is if the rock comes near the surface, the pit should be taken down five or six feet.

2nd.—A circular building about fifteen feet in diameter with a roof revolving upon balls or rollers, with a shutter opening like those of the last described roof, but without any openings in the walls. This building is for extra meridional observations. A single pillar will be required in this building, the walls may be raised to the same height as those of the other building, but the floor should not be more than 6 ft. or 6 ft. 6 in. below the wall plates. The building should be placed so as to have a clear view all round to within 15° of the horizon.

3rd.—Dwelling house for the Astronomer, consisting of four rooms with detached kitchen and offices.

4th.—Fence to enclose a good space of ground round the Observatory.

5th.—Buildings for meteorological observations at twelve different points of the colony—these will average about £50 each, they are mere wooden buildings to shelter the instruments and will be placed in the vicinity of the house of the observer. In every part these observations can be carried on.

Provision must be made for salary of Astronomer at rate of £500; for a clerk or computer, say a second-class clerk; for stationery, fuel, &c. (a moderate allowance.)

W. D.—7th April, 1855.

[APPENDIX T.]

COLONIAL ARCHITECT'S OFFICE,
Sydney, 4th June, 1855.

SIR,—In attention to your letter of the 8th of May last, No. 242, respecting the establishment of an Observatory, procuring meteorological instruments, &c.

1. I do myself the honor to state that I have obtained several estimates of the prices of new instruments, and find from them that such a set as will be necessary will cost £20. I have accordingly included in my estimate for 1856, £240, for the purpose of providing twelve sets.

2. With reference to the repair of the instruments already in possession of the Government, I have seen Captain King, who informs me that they were examined and repaired under his own directions a short time since, and that he does not think any further repairs will be required to them until the instruments are set up in their places in the Observatory, when whatever may be necessary can be better effected.

I have the honor to be, Sir,
Your most obedient servant,
WM. WEAVER, Col. Arct.

[APPENDIX U.]

TIME BALL BUILDINGS.
DEPARTMENT OF LAND AND PUBLIC WORKS,

Sydney, 12th November, 1856.

SIR,—With reference to my letter of the 7th instant, I am now directed to inform you that from a report which has been received from the Auditor-General it appears that the sum of £600 was voted by the Legislative Council in the year 1852 for the erection of a building at Fort Phillip for a time ball, and for quarters for the Meteorological Recorder, and that out of this sum, £423 10s. 2d. has been expended by the Colonial Agent-General in the purchase and transmission of a time ball, leaving a balance unexpended of £176 9s. 10d. to be added to the £7,000 voted in 1855 as a further sum for the erection of the buildings in question.

I have the honor to be, Sir,
Your most obedient servant,
MICH. FITZPATRICK.

The Colonial Architect.

With this money the present building was put up, and observations began in the middle of 1858.

[At the close of the Paper Mr. Ellery added several particulars as to the work of early observers; and this led to further remarks by Mr. Russell and the Hon. P. G. King. Mr. Sutherland suggested the advisability of the Section forming a committee for the collection of Meteorological data and the organisation of

Meteorological Research. This proposal received the commendation of the President. Mr. Russell added several examples of the difficulty which he experienced in clearing up matters of fact of even comparatively recent date. This was endorsed by the President, who remarked that one of the first things he heard about the Parramatta Observatory was that at the time in question it was being used as a dog kennel; and had even received the distinction of an inscription on its walls "*Sic transit gloria mundi.*"]

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2. NOTE ON THE POLARITY OF MAGNETIC ROCKS.

By Professor Arthur Rücker.

Professor Rücker mentioned in a letter to Prof. A. Liversidge that he had noticed during the magnetic survey of the United Kingdom that in some places there was a definite local attraction of the South Pole of the ordinary compass. The obvious explanation was shortly stated; and information was asked for as to whether such effects were observable in Australia.

[A letter had already been received by the Royal Society, N. S. Wales, stating the existence of one such spot at least, viz., Balfour's Peak, Gragin, Inverell, where the North Pole of the compass may be made to point due south by placing it on a rock at the top of the Peak. The writer of this letter was Mr. G. H. Gordon, of Gragin, Inverell.

The Secretary stated the question at issue; but while attesting to the interest of the phenomenon thought that its importance was easily capable of exaggeration. In this the Secretary was supported by Mr. Ellery, who considered that as variations of all degrees were known to occur rather as a rule than the exception, it mattered comparatively little whether they attained a maximum at any particular spot.

An interesting remark was made by Mr. Graydon to the effect that while surveying a tract of country in Victoria, along the junction of the trap and the Silurian, he had noticed a constant error all along the line. The Hon. P. G. King also gave evidence as to the unreliability of the compass. Mr. Sutherland observed that more evidence might be usefully collected.]

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3. ON THE VARIATION OF BAROMETRIC PRESSURE AND OF WIND.

By N. A. Graydon.

[*Abstract.*]

The author proposed a theory in which the ether had a prominent place, and which he considered would meet certain cases not properly accounted for by ordinary theory.

4.—ON THE NEW PHYSICAL LABORATORY AT THE UNIVERSITY OF SYDNEY.

[Begun in February, 1887 ; handed over June, 1888.]

By Richard Threlfall, M.A., Professor of Physics, University of Sydney.

The question of money is obviously the most important matter to be discussed before commencing any building. The first vote for the Physical Laboratory amounted to £8,000, and this has been increased to £13,000, for which sum it is expected the building will be completed. As nearly as I can reckon, the cost of laboratory building here is about twice as much as it is in England. The Laboratory which has been erected must therefore be regarded not as the best possible one, but as the best—as I hope—which could be obtained for the money spent. It was clear at the outset that we could not afford any expenditure on architecture, even if we had desired it—and therefore it became equally clear that the building must be erected behind the main front of the other University buildings so as not to disfigure them. As we had plenty of ground I decided to have a house all on one floor, having learned by experience how great is the inconvenience which can be caused by having to carry apparatus up and down stairs. Again I have long seen that a laboratory ought to be constructed so that anything and everthing may be done in any room. Unless this is provided for, there is always the risk of having to do part of an experiment in one place, and part in another. This of course entails waste of time, and this I have regarded as the most serious evil a designer of a laboratory can bequeath to his successors. In fact the whole of the arrangements and appliances about to be described have been designed with this single end in view. To construct a laboratory so as to entail the least waste of time on those working in it seems to me by far the most important thing. Who I wonder having any laboratory experience has not chafed at having to spend valuable time in doing little odds and ends of carpentry or metal work with inferior appliances, or in trying to heat a furnace with a throttled gas supply? In my experience experimenting is neither more nor less than doing a number of small jobs; ones thoughts are always far ahead of the particular part of an experiment one may be engaged on; and hence the quicker we can make the satisfaction of our experimental needs, the more efficient will our work become. It is for this reason among others that I prefer a good big place to work in—a place where every part of an experiment can be done—and where loss of time through running about shall be reduced to a minimum. Even for purposes of instruction I utterly fail to see the advantages arising from the use of antiquated or inefficient appliances. Experimental facility can I believe be acquired just as well by working with good tools as with bad ones: and the amount of ground got over is greater, the greater the efficiency of the appliances. Of course I do not mean to say that students should be furnished with all their experiments ready set up—this I believe to be a great mistake—I think the best work for students is the most difficult and tiresome—and that requiring the greatest accuracy—but why should we add to that the annoyance of insufficient or make-shift appliances? I am of course talking of Physical work—in such cases as Mineralogy—where the student will in after times have to work with meagre instrumental assistance, handiness and a power of adaptation of things to want—are the most valuable possessions that education can furnish; so that much apparatus may in this case be a bad thing. But this is not to any extent the case with Physics. It is true of course that many great men have performed great experimental feats with the simplest of apparatus; but the contemplation of such cases has always stirred within me some feeling of regret that the means were so inadequate, and this has quickly overpowered the feeling of delight in the results attained. On the whole I conceive that the work done in a Physical Laboratory is not unlike the work done in an instrument maker's shop; and that both should be contructed on the same principle of time-saving. Everybody interested in the subject will know that he is always busy with many more experimental projects than he can carry out; and will I think agree with me in recalling the pain he has experienced in having to spend hours where minutes would suffice were his appliances sufficient. The moral of all this, as far as my Laboratory is concerned, is to be found in the following facts.

The floors of nearly all the rooms have been made as solid as possible, some with concrete, and some with massive woodwork: slate working tables independent of the floors have been set up in every working room. A plentiful supply of gas, water, electricity, gas and electric light, air blast, steam, oxygen and vacuum pumps have been laid on in practically every room. A means of perfect darkening by shutters or blinds has been provided everywhere and its usefulness has already been demonstrated.

A glance at the plan accompanying this paper will show that the building is erected on sloping ground, and will also disclose at once the extreme simplicity of its construction. As we decided to give up all thoughts of architecture and put the Laboratory in an inconspicuous place it was felt that we must endeavour to obtain the greatest possible accommodation with a minimum expenditure on mere building. This led to the rectangular shape adopted; and motives of time-saving above referred to suggested the adoption of a wide corridor running down the whole length of the building into which all the rooms should open. This corridor in fact is the typical feature of the place. Its great width allows of tables being set in wall recesses; and its magnificent lighting from both sides at the top, aided by the reflection from its white-painted ceiling will make it an excellent addition to the general Laboratory. Ventilation is secured by an air space left all round in the lantern, and by the doors at each end. The tower also acts as a very fine ventilator. All the rooms have large ventilation ports opening into the corridor; and capable of being closed by light-tight shutters. Entering at the back of the building—*i.e.* at the eastern end—the one turned towards the main block of the University buildings, the first room on the right is the lecture room, seated for one hundred and forty students. This room like all the others can be made absolutely dark by black blinds of unbleached painted linen. These blinds are cased at the sides in light woodwork. The overlap is about three inches; and the boxes are painted a dead black inside. Behind these are red blinds of an ordinary pattern. The ceiling is of varnished wood and is not flat, but partly follows the lines of the roof. One of the great beams was purposely placed immediately over the centre of the lecture table above which it runs the whole breadth of the room. This has already proved itself to be most useful as a means of suspending wires, etc. To avoid expense the seating is in straight lines instead of being in the form adopted in theatres—as it ought to be. The lecture table is a very solid structure of brickwork with a slate top. I considered the possibility of having a top of thick silvered glass for the sake of shewing up the apparatus, but had to abandon it, chiefly through wondering how it would look when scratched or dirty; and how it would stand accidental contact with hot bodies. The length of this table is about twenty-five feet; it is three feet six inches wide and two feet five inches high. The object of having it low is to enable the seats to be lower and hence the windows at the back larger. The advantage of having a direct illumination on the black-board placed behind the table is that the glare of light reflected at a high angle directly into the eyes of the audience is thereby avoided. In the centre towards the audience a pillar is built out about two feet square of the same height as the table, and continuous with it. This is designed as a stand for a magic lantern. The screen for the lantern is of drawing paper stretched on linen, and capable of being raised or lowered with a roller at the bottom to keep it stretched. This screen can be pulled up out of sight into a box at the top of the black-board. This board covers almost the whole side of the room behind the lecture table. On the south-west side beyond the door opening into the instrument room is a long pier of brick work set in cement and covered with slate. The direction of the long axis of this pedestal is perpendicular to that of the lecture table; it is about thirteen inches wide and five feet long. An arc lamp is permanently set up against the wall, and on the end nearest the lecture table there is a galvanometer or electrometer, or both together, while a suitable scale is placed above the lamp. This apparatus has already worked to great satisfaction, the beam of reflected light being so bright as to be very obvious to everybody in the room even with all the blinds up and the room very light in consequence. I tried various sorts of arc lamps and finally settled on the Brockie-Pell which is noiseless and wonderfully steady, and keeps the carbons for a sufficiently long period at, or near, a single point. I have often used this lamp continuously throughout an hour's lecture, both for the purpose above mentioned and for optical experiments, without requiring to make any re--adjustments. The lamps however are big and heavy, and arrangements are being made to lift them out of their boxes by ropes passing round pulleys in the ceiling. It is advisable to be able to adjust the lamps to different heights in their boxes; and this is much facilitated by having them slung. It will be noticed in the plan that there is a window with a shutter at the north end of the lecture table. Outside on a stone slab is a permanent place for a Heliostat. The shutters which are hinged each on one side and fold towards the centre of the window are kept in place when shut by a heavy gun-metal bar. A rectangular hole is cut into each shutter from its middle edge, so that when the shutters are closed we have a hole about ten inches wide and eighteen inches high. By means of a frame work fitted very simply inside, a slide may be caused to close the rectangular aperture. Several of these slides are provided with slits, circular holes, etc., and as all the shutters throughout the building are on the same plan the same slides will do for all. A fireplace is provided behind the lecture table long enough to hold a combustion furnace; and like all the other fireplaces furnished with an inch gas pipe; in addition there is a rapid water heater permanently fitted up so that the noxious products of the imperfect combustion of gas in this useful apparatus may go up the chimney. The sink at the other end of the lecture table is one of Doulton's, with a receptacle below to catch sand, mercury, etc., before the water overflows into the drain. These sinks are an example of a good idea spoiled by execrable workmanship. The earthenware receptacles above alluded to have had to be removed from every room in the Laboratory and lead ones substituted, owing to the former having their spouts so ill designed as to refuse to carry anything beyond a mere drip of water. I refer to this in case anyone should buy one of these abominations and then suffer the annoyance I have had to put up with. The water supply over each sink consists of three taps with long nozzles, the latter varying from one to five-eighths of an inch in diameter. The valves employed throughout are Peat's Patent—and are admirable when in good order—care has to be taken however to test them—especially the smaller sizes, as small defects in workmanship tend to cause dripping. This is a pity because the principle of these valves is excellent—in fact I know of no reason why any other form of tap should be tight; though some of them certainly are. The great advantage of a screw valve is that the regulation is very perfect, that there is no throttling, and that the tap cannot be turned off suddenly; this by the way is sometimes a disadvantage. There are also two quarter-inch taps above each sink for the purpose of working velocity pumps. These pumps as usually made of glass are generally ineffective owing to the makers being apparently ignorant of the principles on which they ought to work; they therefore require to be tested before they are bought. Great attention has been directed to obtaining a steady water pressure; the solution finally arrived at was to lay on a six inch pipe from the new Medical School tank. This gives us a pressure of about thirty-five pounds per square inch and is practically quite steady as nobody else uses water out of our pipe; and the tank is so large that the differences of level that occur in it are insignificant. The level is kept more or less constant by a ball tap. I find that a pressure gauge on the water supply is most useful; the one I have is a large Bourdon gauge and was tested by me against a column of mercury; its readings as a rule are wrong by about six per cent. The system of lighting adopted in the Lecture room (as in most of the large rooms) depends on the use of a single sun light arranged to act as a ventilator; triple wall brackets carrrying both gas and electric light; and a gas and electric border over the lecture table. The electric light is all controlled by a switch within reach of the lecturer; and by switches under each group of lamps. A similar remark applies to the gas as far as the sun and head lights are concerned. The triple gas and electric light brackets have been specially designed and will it is hoped prove free from the many inconveniences attending such arrangement where the workmanship is bad. However the contact insulation resistance for the whole installation including three hundred lights and the service mains (to be referred to presently) is fixed at four megohms. The work is not finished yet but is quite up to the standard so far, though several brackets have had to be taken out and replaced. Some attention has also to be paid to the slate switches. I have had them all tested by a high resistance galvanometer and megohm, and many have been rejected in consequence. The rest have been baked and lacquered. This hint I owe to Mr. Russell who has long used french-polished slate, an ideal base for many instruments.

Below the projecting top of the lecture table run various pipes.

First the gas—an inch pipe on each side furnished with little swivel arms bent twice, so that they can either come up and lie flat on the table when connected to Bunsens, or fold quite out of the way and tuck in neatly below the slate when out of use. There is good reason to be pleased with this arrangement and I am surprised never to have heard of, or seen it before. Usually there are distributors on the table ; and these are invariably just where you wish to stand the last piece of apparatus ; or the india-rubber tube has either to be bent round, or passed through a hole in the table top—an arrangement inconvenient in itself, and often leading to annoyance by causing the rubber pipe to flatten and cut off the gas. I give a sketch of my arrangement and can thoroughly recommend it. Besides this there is a water-pipe with taps at appropriate intervals but only on one side of the table—viz. that turned towards the audience. The nozzles are about three inches long and vary in diameter from $\frac{3}{8}$ at the points to about $\frac{7}{8}$ inch at the upper end. These nozzles are adopted throughout the building ; they are of course corrugated and one has a chance of making india-rubber tubes really tight on them. There is also a steam pipe (from a tubular boiler in the workshop) running along below the lecture table in a box packed with slag wool. This steam pipe runs throughout the building being well packed everywhere, provided with expansion joints, aud arrangements for letting off condensed water. There is an electric supply laid on from the storage cell house by means of two cables of 19 number 16 wires each. This is tapped by large binding screws at intervals along the facing board, and by an arrangement in the cell house can be supplied with as big a current as it will carry. All binding screws are well insulated from the woodwork with asbestos, the screws passing through carefully dried boxwood sleeves. The positive and negative terminals are distributed in such a way that one sort is always at least a foot from the other in order to lessen the danger of short circuiting. To make all safe the circuit is interrupted by a large plug switch in a locked box near the door. A current from sixty of the largest storage cells, capable of being coupled up almost anyhow, is not a thing to play with. The lecture table is also provided with a pipe carrying an air blast from a Root's blower in the workshop. This terminates in an inch nozzle. I intend to set up a vacuum apparatus such as is used by the Vacuum Brake Company in connection with the steam service ; meanwhile the water velocity pumps do fairly well. I have also arrangements ready for bringing in a belt from the shafting in the workshop, but so far a small electromotor works so well that I have not required it. The ventilation is partly provided for by holes (with gratings) through the walls, partly by the holes opening into the corridor, partly by the windows being of two sashes over-lapping with six inches between, and partly by the chimney and fireplace. In order to avoid having to deal with white ants the whole of the building is first floored by a thin layer of concrete—even where wooden floors are in use. In these cases the wooden floors are high enough above the cencrete to allow of a periodical examination both of the floors themselves – and of such pipes as we have been forced to place there. As a rule however the pipes are all in sight on the walls, and have been painted different colours to enable them to be easily distinguished. About the drain pipes great care has been taken. These are entirely of glazed earthenware and are practically without bends of any kind. They run from below each sink straight to the wall at the nearest convenient place; terminating about a foot above a trapped sink in connection with the main drains—which are all outside. The lavatories, closets, etc., are drained by a long independent drain into the sewer, below the point where a final large trap empties the waste water from the sinks. This portion of the system is also ventilated by a pipe running up in the brickwork of the tower. Great trouble has been taken to make the system perfect, and it is believed to be so.

The Instrument room is placed directly benind the Lecture room and opens into it. There are also two doors from it leading into the corridor—one at each end. This room is thirty-four feet by forty feet, and is not a bit too large. It is fitted round the whole wall space with cases and drawers, and three large cases stand transversely across the floor. I consider that plenty of accommodation for storing instruments is one very important way of saving time. There is not much need to go into any of the details of the room. I am beginning however to wish that it was even larger.

The Library is a small room situated immediately behind the Instrument room in the centre of the building; it has good book-cases, a long table, and is lighted by a sun-light, wall brackets and electric brackets, and pendants. In case it should ever be required as a laboratory it has been fitted with the usual slate table shelving, and gas and water supply.

Before going on to the Laboratories seriatim it may be as well to describe what is common to all of them. First as before mentioned they can all be got absolutely dark either by shutters or blinds. The artificial lighting is accomplished by triple brackets for gas and electric light. The gas globes are opalescent and one out of every three is blue so as to tend to correct the yellowness of the gas. The electric lighting is by means of 100 volt Swan lamps covered with globes mostly white, but relieved here and there where any special effect is to be attained. The sinks have already been alluded to—the water supply to these is the same throughout as it is in the Lecture room. The same may be said of the electric supply—though the leads are in general of somewhat thinner cable. There is a cut-out switch on the electric light circuit just inside the door of each room, so that one set of these burners (its switch being always on) can be turned up directly on entering the room. The slate tables are supported by piers going down to the shale and set in brick and cement, but in cases where the floors are of wood the frame work is independent of these piers. In many of the rooms a second slate slab is provided at a convenient distance above the first in order to accommodate galvanometers. The whole of the western half of the building is free from iron as far as construction goes, and the pipes are of copper. The bricks tested from time to time during the building work were found to be fairly non-magnetic, and in fact experiments lately made have shown that the horizontal intensity of the earth's magnetism is almost the same inside the building as it is outside. In the rooms provided with steady floors these are obtained by removing the earth and filling in with broken stone right down to the shale—in some cases to a distance of ten feet. On the top of this carefully arranged stone heap is a layer of concrete a foot thick. Above this is some fine white sand and on this are laid hexagonal artificial (asphalt) granite blocks ground flat on the top and carefully levelled. These blocks are two inches thick; and the floors as far as tested seem satisfactory. One advantage of these blocks is that if it be desired to fasten down any apparatus to the concrete the blocks can easily be lifted, and if necessary replaced. The fine sand is designed to prevent the transmission of vibration from one part of the floor to another.

ELECTRIC ARRANGEMENTS.

The details of the wiring need not be given as they present no special features—except in the trouble that has been taken to obtain high insulation. The wires are everywhere in places where they can be got at; and the fuses have been reduced to a minimum. The arrangements for cutting out the different portions of the system are very simple; a switch-board with four switches is placed in the corridor so as to break up the service into four sections. The details of the Electric Supply have been already given as far as the connections in the rooms are concerned. The binding screws being below the projecting edges of the working benches, have to be protected against possible wetting from fluids spilt in the process of experimenting. This is attained by cutting a groove on the under surface of the projecting part of the benches. The whole of the lighting and supply circuits are led on to a switch-board in the Battery House, This structure is a glass louvred building standing thirty feet away from the east end of the Laboratory; it is about thirty feet long by twenty wide. A horse-shoe dais is constructed on the concrete floor—and this dais supports the fiftyfive E. P. S. Cells, designed to furnish the current. In this house there is also a large trough-like sink, a long wooden bench, and in general all conveniences for preparing batteries for use in the Laboratory. The cells themselves are charged by a rather small Edison-type Dynamo, made by my brother and myself some years ago—and driven by our eight-horse Otto gas engine. It is probable that this Dynamo will be supplemented by another as it is hardly large enough for emergency requirements. A rather complicated switch-board is supplied in connection with the cells, Dynamo, and supply and light circuits. This board was designed by Mr. Pollock. Arrangements are made for coupling the cells up in almost any desired fashion by bolting and soldering the ends together with copper lugs between them. Voltmeters and ammeters are provided at convenient places on the switch-boards. There are also ten large cells for use locally; these can be charged by means of the supply—without being moved—in whatever part of the building they may happen to be.

LABORATORIES.

GOING down the corridor, the next room to the Library is the Chemical Laboratory. Besides being fitted up with all the fittings described for the other rooms it has a large stink cupboard; a very perfect chemical working bench: a large gas holder from which the Laboratory oxygen supply is drawn; and generally speaking all the fittings usual in a Chemical Laboratory. In this as in the other rooms several gas pipes are passed below the floor, and standards and distributors provided so as to allow of a table with gas supplies being set up almost wherever required. The wooden tables of which large numbers are set up throughout the Laboratory are from a design furnished by the Cambridge Scientific Instrument Company, and have already shewn that they are just the right height and length and breadth. The dimensions are—height to top three feet two inches; length of top, five feet; breadth of top, three feet. The tops of these cedar tables are grooved on the under surface and strapped to the frame work just like drawing boards; this seems to have kept them flat so far. Each table has a groove round the upper edge to catch mercury in. Immediately beyond the Chemical Laboratory lie two advanced Laboratories, each of the same size and furnished with everything. The floor of one of these rooms is especially strong and good. These rooms measure twenty feet by ten feet.

The small rooms round the base of the tower are devoted to lavatory purposes. Beneath the floor of the tower is a room about twelve feet by twelve feet which has no communication with the external air except through a trap door, being for the most part underground. Access is obtained to this place by means of the trap-door and a ladder. It is intended as a constant temperature chamber. The trap-door being in the centre of the horizontal section of the tower—the extra fifteen feet of depth may be utilised for such experiments as the tower is designed to facilitate, seeing that it brings up the effective height of this last to about fifty feet. The tower is provided with a gallery at the top, and a convenient arrangement for fastening apparatus above the central opening in the gallery. The Observatory can be seen from the top of the tower, so that the chronometers can be rated from the drop of the time ball, or from direct astronomical observation, for which purpose instruments will be erected. The main entrance to the Laboratory is below the tower. Partly corresponding to the advanced Laboratories referred to above, but on the opposite side of the corridor, are two small rooms for special purposes. These rooms though small are very perfect in every detail ; the galvanometer shelves having already proved their usefulness. The floors of these rooms are perhaps the most solid in the building, and the aspect being due south, extreme changes of temperature are avoided.

The Private Laboratory is a large room with windows on one side and at one end. It is built on solid concrete arches and has a large and useful cellar below. There are plenty of slate tables and fittings as already described. One corner is fitted with instrument and bookcases, large office table, etc., etc. There is also a regulation drawing table, and one slate bench is provided with drawers between it and the floor. A door opens from this room into the main Laboratory. This is a room thirty-four feet by forty feet, a portion about ten feet wide being separated from the rest by a thin wall for electric testing and optical work The south side of the main portion is occupied by a long working bench with all the usual fittings. The fire places have both gas and air nozzles. This room like the rest can be made perfectly dark. The usual tables are distributed as close as possible over the floor space. The east side is broken up by a balance case and instrument case and drawers. The north side by shelves, and instrument case and drawers, and a door into the corridor. The dark portion has an optical bench running down its whole length, as well as a slate working table and galvanometer shelf on the east wall. The slate bench is so arranged that it can be lighted by small incandescent lamps (with twisted wires) in various sections. I fear however that some vibration may be found to occur in this wall owing to the machinery in the workshop. If this turns out to be the case the galvanometer shelf will have to be moved to the other wall. The floor of the main Laboratory is very good and firm.

The Workshop occupies the most easterly position, it is opposite to the Lecture room. A great deal of pains has been expended to get this department as perfect as possible. The light is very good, both in the day time, and when the gas or electric light is in use. The power is supplied by the engine referred to above. The machines at present set up are :—

One eight-horse Gas Engine.

One large ten inch by eight-foot Lathe, sliding and screw cutting.

One common five inch by three feet single-gear Instrument Maker's Lathe.
One three inch by two feet six inches German Lathe—a very good one.
One Lathe three inches by two feet.
One small Shaping Machine, shaping five inches by one foot.
Two twelve inch Emery Wheels.
One Grindstone.
One Forge and appliances.
One Joiner's Bench.
One Cabinet-maker's Bench.
One Lens Grinding and Polishing Machine.
One small Drilling Machine.
One Combined Circular and Band Saw.
One Dynamo.
One Tubular Boiler, five feet by two feet.

There is about fifty feet of Fitter's benching, provided with tool drawers, etc., and plenty of shelving. There is also a gas oven, a very large and deep sink, and racks for holding materials. The space beneath the raised seating in the Lecture room is utilised for keeping timber in, and is therefore provided with a door in the east wall and a port hole in the northern wall. The arrangements adopted in the workshop for bringing machines in and out of gear have been carefully planned and erected, and consist partially of friction clutches and partly of fast and loose pulleys. The details however having a merely mechanical interest will not be pursued further. The walls of all the rooms are kalsomined a faint green; and painted dark green up to about the height of four feet above the skirting boards which are dark red. The top of the painting is picked out by a square border in red. The wood work being mostly of cedar and colonial pine is not painted but varnished; the effect on the whole is very satisfactory.

November 2nd.—A good deal of work has been done in the Laboratory during the six months we have been in possession, the electric light is still unfinished, but the electric supply and the moveable storage cells have done good service. One drawback of the enormous ventilation which the Sydney summer demands is that thə building is apt to be cold in winter. The small Peat's valves are not quite satisfactory, and the engine exercises a variable magnetic influence in the room next to it. By an oversight the doors in the non-magnetic part of the building have been supplied with ordinary iron locks and these have given some trouble. They will however be replaced shortly by brass locks. We have had to contend with several severe dust storms, to which, from its situation the building is much exposed—the result has been that a good deal of cleaning has had to be gone through.

Friday, August 31.

The President, Mr. R. L. J. Ellery, F.R.S., in the Chair.

The following papers were read :—

1.—EXHIBITION OF A MODEL FOR FINE DISTANCE ADJUSTMENTS.

By H. C. Russell, B.A., F.R.S., Government Astronomer.

[*Abstract.*]

Mr. Russell exhibited a model illustrating the nicety with which distance adjustments can be made by the aid of an electrical contact; even with a very rough arrangement the point of contact was quite definite within about $\frac{1}{30,000}$ of an inch. Mr. Russell gave a description of some apparatus for continuously registering the direction of the vertical, and based on the property above described.

2.—A PROPOSED METHOD OF RECORDING VARIATIONS IN THE DIRECTION OF THE VERTICAL.

BY

H. C. Russell, B.A., F.R.S., Government Astronomer.

Nearly eighteen years since I introduced into the Sydney Observatory a Barograph, which records the variations in the atmospheric pressure by means of an electric contact, and I have often been surprised at the extremely minute changes which it will record. But it was not until the other day that it occurred to me that a modification of the same method would record changes in the direction of the vertical, and I, thereupon, arranged one of the Micrometer Microscopes, so that the motion of the screw brought the two ends of an electrical circuit into contact. I made a great number of experiments myself, and found that contact was always made when the pointer shewed the same place on the divided head of the screw; certainly within $\frac{1}{10}$ of a division which is within $\frac{1}{30,000}$ of an inch. Two assistants then at my request and at different times tried the same experiment, without knowing what had been done, one got exactly the same result as mine, the other thought contact safe within less than $\frac{1}{30,000}$. A larger graduated head was then used for the screw, and it became evident that with proper precautions as to *stability*, contact would be certain within $\frac{1}{100,000}$ of an inch, and since a pendulum of 17 ft. 26·6 in. would change its position by $\frac{1}{1000}$ of an inch for one second of arc change in the vertical, it is obvious that this method is capable of testing and recording on paper, the position of the pendulum at regular intervals of say one minute or five minutes, and shewing changes of $\frac{1}{30}$ certainly, and perhaps $\frac{1}{100}$ of a second of arc.

The details of the machine are not yet complete, but the design is simple enough. Suppose that below the pendulum a very massive piece of cast iron be placed to serve as a foundation for the recording parts and firmly attached to this cast iron an ordinary micrometer, with screw of fifty to the inch; this must be so situated that when the screw is turned the sliding piece will come into contact with the disc at the bottom of the pendulum, and thus close an electric circuit (See diagram.) Suppose this is situated due north of the pendulum, any change in the latter to north or south will be indicated by a difference in the turn of the screw required to make the contact. Now, the screw is not to be turned by hand, but the cylinder which is to receive the record will work on a vertical axis, and have on the top of its rim a segment of a wheel, which as it passes the micrometer will gear into the wheel on the head of it, and give it one turn, so bringing the piece which is worked by it into contact with the end of the pendulum, this contact brings into play an electrically controlled pen which instantly marks the moving cylinder. Now, it is obvious that if the contact is made a little earlier or later next time the cylinder comes round, that difference will be shewn on the paper by the two pen marks; in this way motions of the pendulum to north or south will be recorded regularly once a minute. Now, if we place another micrometer due east of the pendulum, any motions east or west will be recorded on the cylinder in the same way; and by combining the curves any other motion could be discovered, but since it will add very little to the first cost of the machine to put in two other screws, it is proposed to put one on the north-east side, and the other on the south-east. In this way any motion north or south—east or west—north-east or south-west—and south-east or north-west would be recorded, and by combination of curves any other direction. To any one not accustomed to mark with an electric contact of this sort, it will no doubt appear that the means proposed are inadequate to record such minute changes as may be anticipated in the end of the pendulum from changes in the vertical, but eighteen years experience of this method of recording, that is by electrical contact, has given me abundant proof that it is a quite sufficiently accurate result entirely confirmed by the special observations made to test it. In the diagram I have only shewn the method of making contact which depends upon an accurately made micrometer screw. I have not deemed it worth while to do more, as the details are not finally decided upon, all that is shewn is that the cylinder in turning round would gear into the one hundred wheel and so push forward C until it makes contact, at the same time a weight would be wound up, which, directly the wheel and the cylinder ceased to be in gear, would turn the wheel back one turn and so break contact. It is obvious that a series of screw contacts may be placed round A, and that the cylinder would gear into the wheels one after the other and make contact, as proposed. The intention is to make the point of support for the pendulum level with the surface of the ground, and put the recording parts in a well to secure stability and freedom from rapid changes of temperature.

The amount of paper given to each second of arc of change may be made large or small at pleasure on the scale proposed. Each second of arc will be represented by half an inch of paper, and therefore the maximum record possible in one direction would be 10″, because five inches of paper is to be added to each of the four screws or directions. In time, one hour will occupy one inch, which will permit of each individual record being seen if there are sixty in an hour, and the time it was made discovered, because the time will be automatically marked on the cylinder every hour by the standard clock in the Observatory.

[Note added, December 3. Since the foregoing was written this method of recording minute changes has been applied to record the changes in length due to temperature of a piece of zinc tube twenty inches long; and the result is entirely satisfactory; changes of temperature of $\frac{1}{10}$ of a degree are distinctly shewn. As this tube is held by a clamp fixed at one end of a piece of plate-glass, and the screw contact at the other end, it is obvious that the *available expansion* is only the difference between that of the zinc and the glass. This is roughly, (the exact expansion of the glass being unknown) $\frac{1}{40,000}$ of an inch, which is a satisfactory confirmation of the experiments by hand.]

3.—ON THE MEASUREMENT OF HIGH RESISTANCES AND ON GALVANOMETERS SUITABLE FOR THE PURPOSE.

By Richard Trelfall, M.A., Professor of Physics, University of Sydney.

[*Abstract.*]

A galvanometric method was adopted partly with a view to finding how far the sensitiveness of a high resistance galvanometer could be conveniently carried. The substances examined were samples of Australian gums.

In order to obtain an accurate estimate of the specific resistance of a substance, it is in general possible to proceed in one or two ways; either by making a comparison of the resistance of the substance in a known form with the resistance of some standard, or by observing the electromotive force and current. The method adopted by the author may be considered as a sort of compromise, for in it the resistance of the gum under one electromotive force was compared with that of a standard megohm under another. The electromotive force was compared by an extension of Lord Rayleigh's method of balancing and estimating differences instead of ratios, and the experiments were arranged so that alternate equal readings were obtained by means of a galvanometer:—

(*a*) When an electromotive force nE acted through the gum, (*b*) when an electromotive force E acted through a megohm.

The experimental problems are the following:—

1. The production of a slab of gum of accurately known dimensions.
2. The construction of the most sensitive form of galvanometer.
3. The investigation of the sources of electromotive force, and the comparison of the same.

1. The first condition was achieved by the use of accurately flattened brass rectangular plates, covered with an electric deposit of reguline platinum. The measurement of the thickness of the slab of gum was attained by the use of three micrometer screws.

2. A great deal of labour had been wasted in attempting to obtain good results from a galvanometer of the Gray pattern, the fatal objection seemed to be that the time of swing was so great as to prevent a due discrimination of the real deflexions from those produced by unavoidable air currents. The form finally arrived at was exhibited and explained; and a good deal was said about the practical arrangements necessary to secure a fair

degree of astaticism. Some stress was laid on the fact that with a little practice there is no difficulty in mounting fibres of an almost indefinite length. Quartz has been tried but hitherto without any appreciable advantage.* The sensitiveness attained was of the order of 10^{-11} ampères per five scale divisions.

3. The Clark cell was used throughout as the standard of electromotive force ; advantage was taken of a laborious investigation by the author and Mr. Pollock (the subject of the next paper) on the behaviour of Clark cells when made to yield small currents. The reliability of the method was demonstrated by the result of several hundred comparisons. In this application the cells used were of three kinds,

First.—Very large Clark cells used to give the known currents when short circuited through the megohm and a galvanometer

Second.—Thirteen small cells having their positive plates composed of the same sample of mercury as was used by Lord Rayleigh.

Third.—Forty similar cells with mercury electrodes from another sample; and giving identical results with the Lord Rayleigh cells.

In addition there were three hundred and sixty small storage cells of the Hertz pattern.

Some results for grass tree gum were given and those experiments actually in progress on sulphur were described. The arrangement of the apparatus was illustrated by a diagram of a somewhat complex character.

4.—ON THE CLARK CELL AS A SOURCE OF SMALL STANDARD CURRENTS, AND ON A GALVANOMETER FOR THE PRINCE ALFRED HOSPITAL.

By Richard Threlfall, M.A., Professor of Physics, University of Sydney, and Arthur Pollock.

[*Abstract.*]

In this paper it was shewn that when a large Clark cell is short circuited through a sufficiently high resistance a fall of Electromotive force takes place instantaneously, and this does not change appreciably after the first minute or so. The fall is the

*A repetition of the experiment resulted in a decided victory for the quartz thread.

same on consecutive days and is independent, to a very high degree of accuracy, of the previous treatment of the cell. The same property is exhibited by Clark cells of all sizes; but the currents which can be constantly maintained are smaller, the smaller the cells. The law regulating the fall of Electromotive force was investigated with the result that if S E is the fall of Electromotive force then very approximately for the same cell SE = A + Bg where A and B are constants, and g is the current. Generally, the larger the cell the greater is the current that can be taken out of it, in about the ratio of the areas of the zinc and mercury surfaces. In small cells it was noticed that if the current was too large the fall of E.M.F. was very different in different cells. It was found that this did not depend on the amount of zinc surface exposed (the mercury surface being constant), nor on the thickness of the layer of zinc sulphate solution, nor on the amount of solid zinc sulphate present. On the other hand the thickness of the layer of mercurous sulphate seemed to produce a marked effect. This led to a tentative theory of the gradual fall increasing with the time when two great currents were employed. In fine it is shewn, that taking the value of the mean electromotive force of Clark cells at 15C as 1·43500 volts, the E.M.F. of a cell having an area of zinc surface of about ten square inches is 1·43570 volts. The probable error of about two hundred comparisons under all sorts of circumstances is about ·00005 volts. The fall of E.M.F. on short circuiting the large cell through 1423 legal ohms, is in the mean ·00526 volts. During two months the greatest observed fall was ·00664 volts, and the least was ·0045 volts. The behaviour of the cells was compared with that of Daniel cells, and it was shewn that the advantage of Clark cells lies in the two following peculiarities: 1st. the E.M.F. before short circuiting is very constant and definite: 2nd. after short circuiting there is an instantaneous fall which thereafter remains constant. In the Daniel cell the fall of E.M.F. increases with the time, during at all event several hours; in the Clark cell the diminution of E.M.F. is practically over after two minutes. A number of curves establish this result. It follows from the numbers that the E.M.F. of a large Clark cell short circuited through 1423 legal ohms is 1·4304 volts. Since no appreciable change in the E.M.F. is caused by increasing the resistance slightly, we may say that a Clark cell in circuit with 1430·4 legal ohms (of which about five are supplied by the cell) will give a current of ·001 ampères with a probable error of about $\frac{1}{50}$ per cent.

This property had been applied to the construction of a galvanometer for the Prince Alfred Hospital. The coil was movable with respect to the suspended arrangement and two positions were marked. A current of ·001 ampères was always available for testing the instruments; any change of sensitiveness could be set right by a special arrangement of the controlling magnets.

In the second marked position of the coil one scale division corresponds to ·001 ampères.

The scale was so curved as to give readings directly of the tangent of the angle of deflexion and a table of small corrections depending on the finite size of the winding of the coil was provided. Special features were the damping by clove oil, and the fine adjustment of the controlling magnet.

[The apparatus referred to in these papers was exhibited and remarks were made by the President, Professor Bragg, Mr. Sutherland, and Mr. McFarlane.

After a vote of thanks to the authors of the papers, the President, Mr. Ellery, recommended that some steps should be taken with respect to the Meteorological work discussed on the previous day. He proposed that a Committee should be appointed "for the purpose of reporting on the present state of Meteorological Science, and on the best method of arranging some scheme for concerted action." After some dicussion it was agreed that the appointment of such a Committee should be recommended to the Association, and that the details should be arranged by Mr. Ellery.

On the motion of Professor Bragg a vote of thanks was tendered to the President of the Section, and the meeting was adjourned till 1889.]

SECTION B.

CHEMISTRY AND MINERALOGY.

President of the Section: Mr. J. G. Black, M.A., DSc., Professor of Chemistry and Mineralogy, University of Otago, New Zealand.

WEDNESDAY, AUGUST 29.

[The President of the Section occupied the chair and apologised for not having his address ready but proposed to read it on the following morning.]

The following papers were read:—

1.—ON BUTTERINE AS AN ARTICLE OF FOOD.

By CHARLES A. SMITH, F.I.C., F.C.S.

As the substance known here as Butterine has been brought under my notice, and various contradictory statements made regarding its nourishing properties, etc., I take this opportunity of placing before you what information I possess on the subject. Before giving you the results of my examination a little of the general history of the article may be of interest. It appears to have been first made in Holland about 1869 by a man named Fuerge, and considerable quantities were sold in London as butter, until the Health Authorities took the question up, and some heavy penalties were imposed on people selling with intent to defraud. In America also severe legislation is in force with regard to it, going so far even as to enact that it should not be coloured to imitate butter. The law in England compels all manufactories to be registered, all cases containing it to be clearly labelled "Margarine," or Oleo-Margarine, in letters no less than one inch in length, and all quantities exposed for sale to be distinctly labelled.

As to its value as a food substance, it is very hard to say whether it is more or less valuable than the natural butter, certainly it is less palateable than good butter. Even mice, who as a rule are not too discriminating, will leave Butterine untouched when the genuine article is exposed alongside of the substitute.

It must clearly be classed just the same as butter, as one of the animal fats, highly important to the animal economy as a fuel food or heat producer, and the chief points are its digestibility, and as a matter of secondary importance, its flavour.

There can be little doubt that butter is more easily assimilated than any other fat, though this point has been largely disputed by some of the first physicians in England; one of the most eminent strongly upholding dripping as superior, and using it in his own family to the almost entire exclusion of butter; then again different varieties of dripping have had their advocates, such as bacon dripping, and goose grease, each of which has been vaunted by their advocates as the most digestible. In Butterine we have carefully prepared dripping, churned with milk, and coloured to imitate butter, so that its value as a fuel food may fairly be compared with these articles, and asserted to be of equal value. Secondly as to its flavour and appearance,—when freshly prepared in a factory where the niceties of manufacture are carefully carried out, it is difficult to distinguish it from butter, which may be pure, but being carelessly made is extremely nasty.

Butter unless highly salted will not keep any length of time. Butterine will keep longer, but instead of becoming rancid takes on a tallowy flavour, probably owing to some change in the fatty acids. The price at which it can be sold has a large influence on its consumption, for if the poorer classes can get a substitute resembling butter at one shilling per pound, it is extremely unlikely they will pay two shillings for the genuine article, and then often get a rank tallowy substance, closely resembling cart grease. Again it is well known to ladies what good pastry is made with dripping, and Butterine is but carefully prepared dripping. The biscuit manufactories used formerly to use large quantities of low grade butters, but Butterine supplies them with a better article and is largely used, and would be more so, but it pays them better to use a low class butter, that finds no other sale, at six pence, or seven pence, than the purified manufactured fat at ten pence a pound. Butterine when closely examined never has that peculiar bright transparency of genuine fresh butter, neither is it as soft, but it cannot be said to be unwholesome or injurious to the animal economy. But unless the very greatest care is taken in the examination of the fat before it is used, it is quite possible that fat from diseased animals may be used in the manufacture of Butterine. Now one point strongly urged by the manufacturers of this article is that even if the fat were diseased, it is treated to a temperature that effectually kills all germs. It is perhaps hardly satisfactory, but it especially points to the care which is necessary in selecting the raw material to be operated on.

As to its general composition, I find several samples agree, the various constituents being constant, and thanks to Mr.

Hamlet I am enabled to give the results of an analysis made by him, which agrees practically with my own :—

	SELF.	HAMLET.	BUTTER.
Fat...	88·9·0	88·85	83·6
Vol. Fatty Acids ...	·07	·08	4·8
Curd	·25	·20	1·9
Cist	3·39	3·36	2·0
Water	7·36	7·41	7·7
Colouring matter ...	*trace*	*trace*	
	99·97	99·90	100·0
Specific Gravity ...	·9047	·9045	·9121
Melting point ...	83°	83°	86°
Salt in ash ...	2·93%	2·80%	1·63

The samples on which Mr. Hamlet and myself worked were taken about the same time and very possibly from the same batch, though my results are an average of several samples.

After making my analysis I called on the manager of the Company, and he very kindly asked me to visit the works situated at Waterloo, which I did. At present they are small, and only turn out about three tons of the manufactured article per week, for all of which there is a steady sale, there being a great demand for Mauritius and the Cape. To state briefly what I saw, I may say the fat as received from the butchers is weighed and taken to an upper floor where it is sorted, and only the freshest caul and kidney beef suet or fat taken. It is first washed in tepid water, and drained, then placed in a pulping machine, which it leaves in a finely cut state, from here it goes into boilers, is boiled, run off into cans and allowed to cool; afterwards, quantities weighing about four pounds are placed in strong canvas wrappers, and submitted to great pressure, this causes the fat globules or oleo to filter through and flow into cans, cakes of fairly pure stearine remaining in the wrappers. After the oleo is collected it is placed in a churn with cold skim milk and a little liquid colouring matter, churned for some time, then shot into a long trough. The action of placing the warm oleo in the cold milk in the churn, granulates it, and when it is shot into the trough it floats in a finely divided state, from here it is placed in a machine to rid it of the milk, salted, and then is ready for sale in such form as desirable.

The manager informed me that the men employed are only too glad to pay one shilling a pound for the Butterine for the use of their families. When they can get a greater supply of fat they intend to extract the oleo, and either export or store it. At this season of the year they find it very difficult to get a sufficient supply of the raw material, *i.e.* beef kidney and caul suet or fat. They have export orders on hand for sixteen tons for Mauritius, Batavia and the Cape. The substance which I have told you before is called Margarine in England, is regularly quoted in the market reports alongside with butter, and compares very favourably with the latter article in the price it brings. Oleo, that is the crude article, has been successfully and profitably exported from Melbourne, bringing as much as £70 a ton, the average home quotation being about £60 a ton. From this it would appear that the industry would be a benefit, as before the raw material was worth from one penny to three halfpence a pound, whereas now it is made into a readily marketable article worth about ten pence a pound.

In Melbourne it is largely used by biscuit manufacturers, but here where Butterine is ten pence a pound, and butter (?) can be obtained at five pence or six pence the demand is not so great.

This stuff, so called butter, which can be bought for five pence or six pence should be examined by anyone who is curious as to what is put into some of the cakes and biscuits manufactured here. It is certainly butter but of a quality that not even the poorest classes would care to consume. I have often heard it said amongst such that the children do not care for fresh butter as they like something they can taste, and the parents for the sake of economy prefer the stronger Irish butters, of which the children will not require so large a quantity. In conclusion I think we may infer that Butterine, provided it is carefully prepared, is adapted to supply the human frame with a suitable heat-producing food at a minimum of cost, and that it is purely a question for the palate and the pocket, whether it should constitute a part of the daily dietary in the place of butter.

[A discussion followed in which the Secretary, and Mr. J. A. Pond of New Zealand took part.]

2.—ON THE OCCURRENCE OF TELLURIUM IN NEW SOUTH WALES ORES.

By John C. H. Mingaye, F.C.S., Analyst and Assayer to the Department of Mines, Sydney.

I have much pleasure in bringing before your notice the occurrence of Tellurium in combination with bismuth, being the first discovery of that metal combined or otherwise, as far as I am aware, in the colony.

The material upon which I worked was obtained from Norongo, near Captain's Flat, and submitted to me by the Department of Mines for examination.

In an article which appeared in the *Sydney Daily Telegraph*, May 17th 1888, the following description of the locality is given :—

About thirty-five miles to the south-east of Queanbeyan stands a mountainous region called the Jingeras.

* * * * * * *

The main road from Braidwood to Cooma runs through this region, and it borders on Captain's Flat, the new mining centre, where are situated the Vanderbilt, Commodore, Kohinore, and Jaye Gold Mines.

In the heart of the Jingeras a prospecting party, headed by Mr. Harkness, recently made a rich mineral discovery at a place called Norongo, about eight miles south of Captain's Flat.

The Tellurium minerals three in number occur in a gossan lode about sixteen feet wide through which runs the vein containing the Tellurium compounds, being six inches in width, and occurring at a depth of about two feet from the surface.

Two bulk assays were made of average samples for the estimation of the bismuth, tellurium, etc., with the following results :—

No. 1.—Telluri-bismuthic ochre with tetradymite and montanite.

Metallic bismuth	...	16·90 per cent.
Tellurium	... ...	7·04 „

Fine Silver at the rate of 2 oz. 3 dwts. 13 grs. per ton.
„ Gold „ „ 3 dwts. 6 grs. „

No. 2.—Same as former but containing more tetradymite.

Metallic Bismuth	...	27·88 per cent.
Tellurium	... ...	10·42 „

No Gold or Silver present.

After my researches had proceeded thus far, I applied for additional material with the view of ascertaining the relative proportions, and the identification of the respective minerals, and through the kindness of Mr. Price, of 114 King-street, Sydney, I was supplied with specimens shewing the minerals freely, as also with samples of the gossan in which the mineral vein occurs.

The following description of the physical character of the telluric-bismuth ores is by Mr. T. W. E. David, B.A., F.G.S.

"The specimens of telluric-bismuth ores, forwarded for examination, from Norongo, near Captain's Flat, consist of lumps of irregular shape from an inch to nine inches in diameter.

They are associated with an earthy somewhat cellular gossan of a reddish brown colour, and consisting of red and brown ferruginous earth, traversed by numerous thin veins of limonite, the secondary origin of which is evident from its stalactitic structure in places, and from the fact that it forms the lining of old cavities.

Small scales of a pale bronze grey micaceous mineral are plentifully distributed through the ochreous earth. They are much decomposed, and upon slight pressure fall into an ochreous powder. A little original quartz, showing cubical cavities probably resulting from the decomposition of iron pyrites occurs in the gossan in isolated patches.

The lumps of telluric bismuth enclosed in this gossan show on freshly broken surfaces a general concentric structure, due to the tetradymite having been incrusted with successive coats of decomposition minerals. The outermost coat, from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch thick is an earthy mineral the colour of yellow ochre, inclining to orange in places, and showing cubical cavities. Next beneath this telluri-bismuthic ochre is a layer of greenish yellow montanite, having a somewhat streaky structure. In this second layer and occupying former cubical cavities are spots of dark brownish red montanite, from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch in diameter.

Next beneath the second layer and forming the nucleus of the lump is a granular crystalline steel grey mass of tetradymite.

The minerals in these ores may therefore be classed as follows:—

1. Tetradymite.
2. Montanite. { (*a*) Pale greenish yellow variety. (*b*) Ferruginous, dark brownish red variety. }
3. Telluri-bismuthic ochre.

The two first minerals may be further described as follows :—

1. TETRADYMITE, occurs in granular crystalline masses, of a steel grey colour and bright metallic lustre.

Under the microscope the crystals are seen to have a very perfect basal cleavage so that the mineral splits readily into very thin laminæ, over one hundred being visible in one crystal within a space of $\frac{1}{20}$ inch. Most of the crystals appear to be tabular. The orientation of the crystals in each mass is tolerably uniform, and the planes of basal cleavage lying consequently principally in one line the mass has a tendency to split readily along these planes, which accounts for the streaky appearance of the montanite surrounding the tetradymite. The hardness is about $1\frac{3}{4}$, the mineral being unaffected by talc, easily scratched with calcite, and difficulty scratched with selenite. The streak is black and shining, much like that of graphite. The laminæ are flexible.

2. MONTANITE. (*a*) *Pale greenish yellow variety.*

This mineral encrusts the tetradymite, and does not show any crystalline structure. Green tints are observable in this variety wherever the particles of half decomposed tetradymite become abundant, the green being due to the steel grey tetradymite showing through the yellow coating of montanite. The lustre varies from dull earthy to waxy. The hardness is about $1\frac{1}{2}$.

(*b*) *Ferruginous dark brownish red variety.*

This variety occurs in cubical pseudomorphs, single or aggregated, and about $\frac{1}{8}$ inch in diameter.

The colour is dark brownish red excepting on thin edges where the mineral is semi-translucent and of a deep claret colour.

The streak is of a red ochreous colour. The mineral is brittle and has an uneven irregular fracture.

The hardness is about 3, but appears to vary considerably in the different specimens, as calcite will just scratch some but is itself scratched by others.

From the roughly cubical shape of this mineral taken in conjunction with the existence of numerous cubical cavities, like those left after the decomposition of iron pyrites, in the telluribismuthic ochre and gossan, it appears to me highly probable that this variety of montanite is pseudomorphous after iron pyrites, and the analysis proves that the dark brownish red colour is due to the combination of iron with the montanite.

It may therefore be described provisionally as a ferruginous variety of montanite, pseudomorphous after iron pyrites."

On analysis the tetradymite (or bismuth telluride) $Bi_2\ Te_3$ also as $Bi_2\ Te_2\ S$ gave the following composition :—

Metallic Bismuth	59·66	
Tellurium	33·16	
Selenium	*nil*	
Sulphur	4·54	
Iron	·42	} *
Silica	·40	
	98·18	

The above analysis corresponds with the formula given for the compound containing sulphur—$Bi_2\ Te_2\ S$.

The sp. gr. of the mineral is 7·381.

Before the blowpipe the mineral easily melted, coating the charcoal with a yellow and white incrustation, also giving a green colour to the outer flame. No selenium smell observed. Soluble in nitric and sulphuric acids.

It was found that some of the tellurium alloyed with the bismuth on fusion with potassium cyanide, the slag giving a rich purple coloured solution, which deposited the element on standing as a black metallic powder, the solution losing its colour.

This reaction obtained by me in the first case on testing the minerals, was the cause of my suspecting the presence of a considerable quantity of tellurium.

Telluric-bismuth, tetradymite, or bornite is stated to have been found in Virginia, Georgia, North Carolina, Cumberland, and Brazil often coated with montanite $Bi_2\ O_3\ TeO_3 + H_2\ O$ (or $2\ H_2\ O$) bismuth-tellurate—formed through the oxydation of the tetradymite, and is in reality a pseudomorph after the latter on which it forms a coating. The tellurium is sometimes replaced by sulphur and selenium. The sp. gr. is given at 7·2 to 7·9. Hardness 1 to 2.

*These two elements are no doubt impurities, it being found difficult to detach the mineral from the matrix.

The variations in the composition of these minerals will be seen on comparing the following analysis :—

*ANALYSIS.

	Virginia.			Georgia.			Cumberland	Hungary.		Brazil.		Norongo, N.S W.
	Genth.			Genth.		Jackson.	Rammelsberg.	Wehrle.	Berzelius.	Damour.	Damour.	J C. H. Mingaye.
Bismuth	53.0	53.8	51·5	50.8	50.97	79.1	84·33	60.0	58.3	79.1	78.4	59.66
Tellurium	48.2	47.0	49.8	48.2	47,25	18.0	6.73	34.6	36.0	15.9	15.6	33,16
Sulphur	...	...	...	..	..	...	6,43	4.8	4.3	3.1 }	4.5	4.54
Selenium	...	trace	..	trace	trace	1.2	...	...	...	1,5 }	...	...
Metallic Iron	...	...	...	..	...	...	...	..	...	...	...	.42
Silica†	...	...	...	...	...	...	...	...	...	...	...	,40
	101.2	100.8	101.3	99.0	98.22	98.3	97.49	99.14	98.6	99.6	98.5	98.18

Montanite (bismuth-tellurate, $Bi_2 O_3 Te O_3 + H_2 O$ (or $2 H_2O$). This mineral was first discovered by Genth during his examination of the tetradymite of Highland in Montana. It is not crystallised, but exhibits here and there, the scaly structure of the original tetradymite.

As Mr. David points out in his description of the minerals, there is a peculiar coloured variety of montanite present, which is of a cubical shape and dark brownish red in colour. A qualitative analysis was made of some of these cubes, and bismuth, tellurium, water, and a considerable quantity of iron found to which no doubt the mineral owes its colour.

On looking over a large number of specimens I succeeded in picking out a few broken pieces of these cubes (about two grammes in weight), though it was found impossible to obtain them thoroughly free from the tetradymite. The following is the result of my analysis :—

Bismuth Oxide ($Bi_2 O_3$)	50·68
Tellurous ,, ($Te O_3$)	27·65
Iron Oxide ($Fe_2 O_3$)	14·38
Water	6·16
Gangue (Silica)	1·00
	99·87

*Watt's Dictionary of Chemistry, 1883, Vol. V., p. 707.
† Impurities.

Before the blowpipe the mineral gave the reactions for bismuth and tellurium, also a green colour to the flame. On heating in a tube water was given off. Soluble in hydrochloric acid.

Several experiments were made with the view of ascertaining the sp. gr. of the mineral, pieces being picked as clean as possible and the determination made in a 100 gr. sp. gr. bottle.

It was found in every experiment made, that they slightly varied. I give the mean of five determinations, viz. :—3·789.

For comparison I refer to the following analyses made by Genth, and published in Watt's "Dictionary of Chemistry," 1879, Vol. VIII., Pt. II.)

	I.	II.	III.	IV.
Ferric Oxide ...	0·56	1·26	0·32	14·38
Lead Oxide ...	0·39	...	...	...
Cupric Oxide ...	...	1·04	1·08	...
Bismuth Oxide ...	66·78	68·78	71·90	50·68
Tellurous Oxide ...	26·83	25·45	23·90	27·65
Water	5·74	3·47	2·86	6·16

This dark brownish red mineral is as the analysis shews a new variety of montanite and I think without doubt pseudomorphous after iron pyrites.

As the methods used in the analysis may be of some value I give them.

The mineral was fused in a covered porcelain crucible with three parts of dry sodium-carbonate and three parts of sulphur, and the mass digested when cold with water. The metals remain as insoluble sulphides separated by filtration from the soluble.

From this solution the tellurium was precipitated as sulphide by the addition of dilute hydrochloric acid, filtered, oxydised with hydrochloric and nitric acids, and evaporated to dryness on the water bath The salt was taken up by hydrochloric acid and the tellurium precipitated as metal (?) by sulphite of sodium filtered into a tared filter and dried until the weight remained constant and then weighed.

The bismuth was estimated as $Bi_2 O_3$ by precipitation with ammonia and carbonate of ammonia.

The other method consisted in bringing all the metals into solution by means of an acid, and precipitating the bismuth and tellurium as sulphides by means of sulphuretted hydrogen, and separating the bismuth from the tellurium by means of ammonium-sulphide in the ordinary way. The first method however was found to be the best.

I have made careful inquiries and can find no uses for tellurium in the arts or otherwise, therefore it is of little or no commercial value, but more so in consequence of the rarity and scarcity of the element. The value purified is about 27s. per ounce.

Professor Liversidge in his valuable work—entitled "The

Minerals of New South Wales," under the heading of "Native Tellurium" states—"a rare element; reported to occur at Bingera, co. Murchison."

I have examined several samples of bismuth ore from various parts of the colony, and in one or two cases, notably, in one sample obtained from the Kingsgate Mine, near Glen Innes, a strong trace of tellurium was found.

This ore consisted of sulphide of bismuth with molybdenite and metallic bismuth, it also contained a few ounces of silver to the ton.

3.—NOTES ON SILVER SMELTING.

By Edgar Hall, F.C.S.

Note 1.—On the separation of silver in smelting rich ores so as to obtain slags free from silver.

In the extraction of silver from ores by smelting, whether the precious metal be obtained in alloy with metallic lead, as in reducing lead ores, or concentrated into a regulus of copper, iron and lead, as in reducing mixed sulphides, the main efforts of the smelter are directed towards obtaining "clean" slags, that is, slags as free as possible from silver, absolute freedom being a practical impossibility. Little is known as to the cause of slags carrying large or small amounts of silver. In a valuable paper on "Lead Slags" which appeared in the *Chemical News* (Vol. LVII., pp. 4-7, 18-19, 37-38, 43-45, 57-58), M. W. Iles says—"Why should one slag be good and another bad?" "The dissemination of matte globules does not to my mind satisfactorily explain the silver-losses, since I have detached perfectly pure crystals from the very heart of the pot from slags of all of the above types, and as a general thing these crystals were found to contain a larger amount of silver than the main body of the slags; the lead contents will usually be less." In Percy's "Metallurgy" (Silver and Gold, Part I., p. 532) it is stated that when running matte is of greater value than 80-100 ozs. silver per ton, it is not practicable to make "clean" slags.

It is well known that silver will concentrate in the last liquid portions of its alloy with lead, and Pattinson's process depends upon this fact, although it is usually explained differently. Some observations of the writer have led him to conclude that silver has the property of passing from the already solidified or solidifying portion of a body, into the composition of which it enters, into the last remaining liquid portion, and that perhaps high silver slags may be due to some extent to this movement.

Upon a recent occasion, when smelting a large quantity of rich silver-bearing material, the following notes were made, and they are presented with the hope that they may induce other smelters to make observations in this direction.

In furnacing the material, matte, averaging 200 ozs. silver per ton and 30 per cent. of copper, together with lead carrying over 600 ozs. of silver per ton, was produced. The proportion of lead to matte was as 1 is to 2. The furnaces worked well; an excellent slag was made (of type closely approaching type D, of Iles), and the daily assay of samples taken in the usual manner (by drawing samples from the molten slag on a iron rod, and plunging into cold water) showed a fairly low loss of silver, averaging from 2 to 3 ozs. per ton. A calculation of results however, revealed a great loss of silver, and in searching for the cause, the slag dump was sampled and assayed, with a result shewing a much larger silver content than the daily assays had shewn. At first it was thought that the slag-breakers had been careless in throwing away matte with the rejected slags, but examination proved this not to be the case, and the clean crystallized slag assayed as high as the bulk. At the same time a similar material was being smelted in reverberatory furnaces, producing matte only, but of an equally high grade, and the slags from them were remarkably clean, in fact much cleaner than those from furnaces producing a lower grade matte. In blast furnaces, as is well known, the matte often runs out with the slag, and is found at the bottom of the pot forming a cake separated when cold by a marked division from the slag above it. In reverberatory furnaces the slag is skimmed from the molten matte in a liquid state into beds to cool, while the matte is tapped into other and separate beds. The writer was led to think that possibly the blast furnace slag assays were correct, and that although when hot and liquid the slag might contain little silver, yet by cooling in contact with the rich matte, silver might pass into it from the matte.

For some days assays were made of the slags both hot and cold with the view of testing this surmise, and the following figures were obtained:—

Furnace.	Slags sampled liquid. Silver per ton.									Sampled when cold. Silver per ton.			
	ozs.	dwt	grs.	ozs	dwt	grs.	ozs.	dwt	grs.	ozs.	dwt	grs.	
Furnace A ...	3	2	0	2	4	0	3	9	0	} 11	0	0	Experiment No. 1.
,, B ...	2	1	0	3	17	0	1	8	0				
Furnace A ...	3	10	0	3	4	0	2	14	0	} 8	15	0	Experiment No. 2.
,, B ...	3	5	0	2	14	0	5	3	0				
Furnace A ...	2	9	0	2	2	0	2	7	0	} 5	12	0	Experiment No. 3.
,, B ...	2	9	0	3	4	0	2	17	0				
Top of Pot ...	..	...	..	...	..	..	...	..	..	5	14	0	Sample pot taken at same time as Experiment No. 1 above.
Bottom of Pot	..	..	..	..	...	...	..	..	..	6	1	0	

The samples were taken hot in the usual manner at frequent intervals; each assay represents eight hours work; the slags for twenty-four hours were sampled next day in bulk when cold, care being taken to secure only "clean" specimens.

These assays seemed conclusive, but for confimation some pots of slag, also containing matte, were sampled hot, then placed aside to cool, and samples taken again when cold. The result given in the next table, while to a certain extent confirmatory, was not altogether satisfactory.

Slag Pot.	Sampled hot, liquid.	Sampled cold.
	Silver per ton.	Silver per ton.
No. I.	3 ozs. 4 dwts. 0 grs.	3 ozs. 15 dwts. 0 grs.
,, II.	2 ,, 11 ,, 0 ,,	4 ,, 1 ,, 0 ,,
,, III.	2 ,, 17 ,, 0 ,,	5 ,, 7 ,, 0 ,,
,, IV.	3 ,, 2 ,, 0 ,	3 ,, 1 ,, 0 ,,

No opportunity occurred for making other experiments but upon retreating the rich slags their average silver contents were found to be 6 ozs. 5 dwts. per ton, against a general average for the run, according to the ordinary system of hot sampling, of 3 ozs. 4 dwts. per ton.

Note 2.— On the distribution of silver in iron and copper mattes.

In Percy's "Metallurgy" (Silver and Gold, Part I., p. 509) it is stated that, in the process there described, the last liquid portion of the matte is found to be richer in silver than the removed solid cakes. The writer has recently had occasion to run large quantities of matte into moulds, and has noticed that upon breaking the blocks when cold, a curious cannon-ball like mass of a crystalline character separates from the outer part which comes off like a shell. These cores upon assay are found to contain a much larger proportion of silver and copper than the shells, and the accurate sampling of large parcels of matte has been a matter of considerable difficulty owing to this cause. The following assays shew the difference in value :—

		Outer Shell.	Central Core.
I.	Silver	124 ozs. 8 dwts. 20 grs. per ton.	335 ozs. 1 dwt. 10 grs. per ton.
	Gold	1 oz. 2 dwts. 20 grs. per ton.	1 oz. 19 dwts. 9 grs.
	Copper	12 per cent.	26 per cent.
II.	Silver	128 ozs. 14 dwts. 3 grs. per ton.	380 ozs. 4 dwts. 10 grs. per ton.
	Gold	13 dwts. 1 gr. per ton.	1 oz. 19 dwts. 4 grs. per ton.
	Copper	14 per cent.	25 per cent.

NOTE 3.—ON KERNEL ROASTING.

The phenomenon of "kernel" roasting is well known to all metallurgists, but it does not appear to have been recorded whether silver follows the copper into the kernels.

During the open-air roasting of very large quantities of sulphides, consisting of intimate mixtures of pyrites, copper pyrites, blende and galena, careful watch was kept for good kernels. These were not very plentiful, the galena and blende apparently preventing their formation.

However, a number of good kernels of varying sizes were collected, and, the separation in most cases being imperfect, all the kernels were mixed together, and all the shells, and assays carefully made of the average. The result was :—

KERNELS	Silver, 42 ozs. 3 dwts. per ton. Copper, 13.1 per cent.
SHELLS	Silver, 20 ozs. 8 dwts. per ton. Copper, 2.7 per cent.

which proves that silver does concentrate in the kernels but to a less marked extent than copper.

[Drs. Rennie, Leibius, and Messrs. J. A. Pond and W. M. Hamlet took part in the discussion on these papers.]

THURSDAY, AUGUST 30TH.

The President, Mr. J. G. Black, M.A., DSc., Professor of Chemistry and Mineralogy, University of Otago, New Zealand, in the Chair.

The President delivered an addre:ss "On Chemistry in relation to Education."

The following papers were read :—

1.—SOME CONSIDERATIONS IN REGARD TO THE FORMATION OF COAL AND CARBONACEOUS MINERALS.

BY W. A. DIXON, F.I.C., F.C.S., Lecturer on Chemistry, Sydney Technical College.

IN most chemical manuals the production of coal, and similar carbonaceous minerals, from cellulose is assumed and equations are given shewing its transformation into coal, of different varieties, by the elimination of oxygen and hydrogen as water, carbon and oxygen as carbon dioxide, and carbon and hydrogen as methane. These are known to be evolved during the decomposition of vegetable matter and are assumed to be given off by cellulose, and as this has a high molecular weight and as any acquired number of molecules may be used the equations look very pretty. One can substract any acquired number of molecules of CO_2 H_2 O and CH_4 from C_6 H_{10} O_5 or a multiple of it and obtain a residue corresponding to anything from free carbon to cellulose itself. These views are again set forth in one of the latest chemical works bearing on the subject, viz. "Wanklyn's Gas Engineers' Chemical Manual." In connection with this I would point out that in most coals the woody fibre, which contains the greater portion of the cellulose in modern plants, is represented by almost pure carbon forming the so-called "mother of coal" or mineral charcoal. As cellulose was so converted it is an untenable position that other portions of the *same* substance should under the *same* conditions be converted into bituminous matter.

On the other hand mineralogists and geologists generally, lay great stress on the conditions under which the deposit of coal was formed and refer particular varieties to different horizons as a reason for their different composition and properties. This can be made to agree with the chemical hypothesis mentioned as it may be said that different quantities of the products would be formed under varying conditions.

There are others who acknowledge that there are at least three conditions which modify the compositon of the mineral. Thus Percy recognises the fact that difference in the composition of vegetable matter due to resinous bodies, etc., may by increasing resistance to decomposition tend to preserve vegetable structure (Fuel, p. 270.) Dana says "Coals were once beds of vegetation, analogous in most respects to the peat beds of modern times" (Mineralogy, p. 758), and on the succeeding page, "between excluded air and imperfectly excluded, and of pressure from heavy superincumbent earthy beds and little or no pressure lie the conditions which attended the origin of the various kinds of coal and determined, in *connection with the nature of the vegetation itself,* their transformation in progress." From various observations the writer has come to the conclusion that the words put in italics by himself are of more importance than is usually assumed and that this idea is probably the most important of all. This condition is placed first in a sentence in Ronalds and Richardson's "Knapp's Technology," (I., p. 765), where it says—"The varieties of coal may depend on the nature of the plants that composed it, the varied circumstances attending their deposit, or the varied conditions under which the beds have subsequently been placed."

My thoughts were first directed to the probable comparatively great importance of the original composition of the plants through examining a number of brown coals from New Zealand, Victoria, Western Australia, and New South Wales, and which I found could be divided into four classes.

1st.—Those containing fossil resin (retinite) distributed through them in grains from the size of pin heads to that of marbles, and amounting sometimes to 20 or 25 per cent. of the mass.

2nd.—Those containing iron pyrites but no retinite.

3rd.—Those containing neither retinite nor pyrites but having much sulphur in organic combination.

4th.—Those without retinite, pyrites, or much sulphur.

Subjected to distillation the first and last evolved but little sulphuretted hydrogen, the second evolved much of this gas under the conditions of high temperature, the third both at high and low temperature.

If we consider these varieties of imperfect coal it appears probable that, had they been subjected to conditions such as would convert them into coal, the results would be very different for each although the conditions were the same. The first is evidently produced from highly resinous vegetation, and would probably yield bituminous coal, and the resin gives an aromatic odoured distillate on quickly heating, but the amount of resin available was too small to go into the matter of the products. The second from non-resinous vegetation, the pyrites being formed by infiltration, would yield a coal like the stinking coal of Lancashire or the brassy coal of some of the Scotch mines. The third it seems probable was produced from vegetation containing much sulphur, such as we find in our modern Cruciferæ and to this I know of no corresponding true coals. The fourth would correspond to the splint, cherry, and other less bituminous coals.

Again, the deposit of kerosene shale or torbanite at Joadja Creek consists of three distinct layers, separated by almost imperceptible partings and yet everywhere perfectly distinct. The seam is composed of first, a layer of splint coal containing a rather large proportion of ash, second a layer of shale, covered third, by a layer of bituminous coal of fair quality. In this case it appears that the three layers were deposited in orderly succession and that all must have been subjected to the same conditions since deposition, and yet the ultimate products are entirely different. It may be observed in passing that these deposits of torbanite, both in New South Wales and Scotland, where one only has been found, seem to have been originally laid down in irregularly lenticular depressions, and observation has indicated that they have never been subjected to excessive pressure, as wherever the "cover" exceeds two or three hundred feet the torbanite is found changed into a carbonaceous slaty mass. It is evident that the differences in the three layers in this seam cannot be ascribed to any other causes than an orginally radical difference in the vegetation forming them. Torbanite, Boghead, or kerosene shale, has been legally classed as coal, and it is usually classed with cannels although it is very different. Thus Wanklyn (*loc. cit.*) says—"The following is an analysis of one of the richest cannels, viz. Boghead," (the original torbanite of

Scotland.) "The large proportion of mineral matter (21-22 per cent.) will not escape notice; and it will be perceived that Boghead consists of mineral matter saturated with a hydrocarbon containing a larger proportion of hydrogen than there is in benzine $C_6 H_6$." At Joadja Creek the mineral matter falls as low as six per cent., and it is difficult, I should say impossible, to think of six parts of mineral matter "saturated" with ninety-four parts of hydrocarbon, whilst the overlying coal and sandstone, and the underlying coal and sandstone are absolutely free from it.

The old alchemists used to subject everything organic to distinctive distillation and divide it into water, phlegm, and caput mortuum, and perhaps some information may be gleaned from this industry as now carried out on a large scale. This information is, however, not very direct owing to the effect of varying temperatures in process, so that the subject is divided into two, namely, high temperature distillation, *i.e.* gas making, and low temperature, *i.e.* oil making. In the first the liquid and solid hydrocarbons obtained are mostly composed of the aromatic series, whilst those of the latter belong to the fatty series. The gaseous products may be disregarded in both cases, as they are similar, being hydrogen, methane, and some of the lower olefines, and mixed, in the case of high temperature work, with the vapours of aromatic hydrocarbons held in gaseous solution.

In all high temperature work, more gas is produced, than in low, and carbon is deposited whilst aromatic hydrocarbons are formed, as benzol from polymerisation of acetelene below a red heat and its conversion by elimination of hydrogen into napthalene at a red heat, whatever the source of the original hydrocarbon. If, however, we look at what is done commercially with various coals and shales we shall find they are not used indiscriminately, but some for one purpose, some for another, according to the value of the products. The statements sometimes found in books are often rather confusing, thus Knapp says—"When submitted to destructive distillation all varieties of coal yield the same solid, liquid, and gaseous products, consisting of coke, tar, ammoniacal liquor, benzole, naphtha, naphthaline, paraffin, paraffin oil, and illuminating gas, the proportions of which vary with the quality of the coal and the temperature employed" (Ronalds and Richardson's "Knapp's Technology," Vol. I., p. 273.) Later writers recognise some difference, thus Mills says—"Cannel tars are poorer in aromatic compounds than are bituminous tars" ("Manualette of Destructive Distillation") and Lunge,—"We may say generally that the tars from peat, brown coal, and bituminous shale consist principally of hydrocarbons of the 'fatty series,' wood tar of phenols and their derivatives, coal tar of aromatic hydrocarbons ("Distillation of Coal Tar," p. 3.) Again—"Brown coal tar as well as that obtained from peat and bituminous shale (and formerly from the Torbane Hill mineral) is manufactured for its own sake as a principal product, and forms the basis of the West European manufacture of mineral oils and paraffin. The other products of the destructive distillation of such more recent fossils possess very little or no value, except in the case of some very dense, coal-like, brown coals, which furnish good coke and good gas but no mineral oil."

These quotations shew the general drift of opinion amongst those intimately connected with the subject of distillation, as I have also been more or less for thirty years. There is a radical difference in the substances submitted to retorting, and although the fatty hydrocarbons are more or less converted into gas and aromatic hydrocarbons by a high temperature, the transformation is always incomplete, and I believe that the difference in products arises chiefly from the original differences of the vegetation of which the coal or shale was formed. Of the various mineral fuels, some, as anthracite, and splint and cherry coals, are never distilled, the products being of no value. Cokeing coals (in contradistinction to gas coals which are used for making both gas and coke) are distilled for the sake of the coke, and a few years since it was anticipated that great results would be obtained by the use of Simon Carvés and other improved ovens by which the tar could be collected, but valuable aromatic hydrocarbons were present in such small proportion that the anticipations were not realised. Bituminous gas coal yields tar rich in benzine, anthracene, and other valuable aromatic hydrocarbons and practically none of the fatty series, and tar distillers object to the use of shale along with it, as they introduce these.

Cannel used alone in gas making, as in Edinburgh and Glasgow, gives a tar yielding less benzine and its homologues than that from bituminous coal, and these are mixed with a noteable proportion of fatty hydrocarbons. From this tar olefins and paraffins boiling from 20° to 100° C are obtainable, and of the liquid obtained at the boiling point of benzine, only about two-thirds consist of that substance which crystalises out when the mixture is placed in ice and salt. On distilling cannel tar only about ten per cent. of oils are obtained which are lighter than water, about thirty-five per cent. on the tar being heavier, and although the lower fractions contain noteable quantities of fatty hydrocarbons these gradually decrease until the heavy pitch oil contains mere traces of paraffins. I speak here of the low heats used in gas making thirty years since, with the high heats employed now-a-days, the quantity of light hydrocarbons is much smaller, not above four to five per cent. On the other hand cannel has been little used for low temperature work, (except Leeswood cannel (which was what we would call here kerosene shale), although the amount of volatile hydrocarbons it contains ranges from forty to forty-five per cent., and even higher in Scotch cannels, where shales yielding thirteen per cent. of oil are worked.

Cannel oil in my experience is troublesome to purify, yielding much tar (poliminerized acetelenes, etc.) to sulphuric acid.

Shale is very rarely used alone for making gas, but it is so used for the gas for the railway carriages on our Government railways. I tried to procure a sample of the tar but found that unfortunately it could not be kept separate from the tar from bituminous coal, from which gas is also made. The mixed tar was just heavier than water and particularly mobile for a tar. Subjected to distillation, the process being carried so far that the residue in the retort set to a rather hard pitch on cooling, it gave a distillate wholly lighter than water. This distillate treated by reagents gave the following percentages by bulk :—

8.5 per cent to concentrated sulphuric acid—basic bodies and polyminerized acetelins.
31.9 per cent. sodium hydrate—phenols—and conjugate acid bodies formed by previous treatment with acid.
46.7 per cent. to nitric acid—aromatic hydrocarbons and olefins—
12.7 per cent. unattacked—paraffins.

99.8

As the shale used gives on low temperature distillation a refined product containing paraffins to olefins in the ratio of 3 to 7, the 12.7 per cent above would give 29.6 per cent. of olefins which added to 12.7 gives 42.3 per cent. of fatty hydrocarbons, and substracted from 46.7 gives 17.1 per cent. of aromatic. If we consider that the amount of phenols extracted by soda from coal tar is about 6 per cent., and this added at the same rate to the 17.1 per cent of aromatic hydrocarbon, would give 18.2 per cent of coal tar hydrocarbons, and we would then have 18.2 coal hydrocarbons to 42.3 of fatty or shale hydrocarbons, which is in the ratio of 1 to 2.32. I am informed by Mr. Inspector Mitchell that the quantities of material used in the gas works are $9\frac{1}{3}$ tons of Newcastle coal and $7\frac{2}{3}$ tons shale per week, and as coal gives approximately 10 gallons of tar per ton, whilst shale averages about 27 gallons, this would give the following ratios :—

Coal to shale as ...	1 : 0.82
Coal tar to shale tar as	1 : 2.29

which shews a tolerably close approach to the ratio of hydrocarbons actually found. In this only the more stable hydrocarbons which have been taken into consideration, but, look at the matter how we may, there seems no doubt that the fatty hydrocarbons remain true to their type, and are much less readily converted into the higher carbon aromatics than is usually assumed, under the conditions of high temperature distillation as carried out on a large scale. This is further shewn in the fact that although numbers of inventors have proposed processes, and have taken out patents for the conversion of the comparatively low value fatty hydrocarbons into the higher value aromatic ones by passing the vapours through heated tubes and otherwise, none of these have been commercially successful in consequence of the loss being great in the form of lower fatty hydrocarbons, and the yield of aromatic therefore small.

The C_6 formula of celulose has been thought to connect it with the aromatic series, but all transformations convert it into hydrocarbons, alcohols, and acids of the fatty series. On the other hand ligno-cellulose as found in jute, and other bast fibres with a higher percentage of carbon and a lower of oxygen does yield aromatic compounds—as hippuric acid during its digestion by herbivorea—and by its giving pyrocatechuic acid by chlorination, and subsequent treatment of the chlorinated product by fusion with potash. Ligno-cellulose, however, treated with nitric and sulphuric acids yields no aromatic nitro-derivatives, so that the benzine nucleus must be absent. This seems to connect ligno-cellulose with these coals which do not yield valuable aromatics during distillation, that is cokeing, steam, and splint. I do not enter further into the consideration of those coals at present.

Suberose, cutose, or adipo-cellulose, the principal constituent of cork and the cuticular envelopes of plant tissues, differs widely from ordinary cellulose and yields by all treatments substances belonging to the fatty series, and it seems probable that if transformed into mineral coal it would retain its fatty character.

Published analyses of these three celluloses shew the following numbers :—

	Cellulose.		*Ligno-cellulose.*		*Adipo-cellulose.*
Carbon	44.6	...	47.0	...	73.66
Hydrogen	6.3	...	6.0	...	11.37
Oxygen	49.7	...	47.0	...	14.97

I shall now refer to the three varieties of coal usually subjected to distillation for their products and shall take first, bituminous coal, used for gas making and yielding valuable aromatic hydrocarbons as a bye-product. The published analyses of coals are of little value for comparison for the purpose in hand, as these analyses have been made from average samples of different seams to determine their commercial value, and so do not take into account the fact that almost every coal is made up of a mixture of heterogeneous materials varying from nearly pure carbon to substances containing large percentages of hydrogen and oxygen. Even in the different bands, into which coal seams are divided by partings, the average of each band may differ very considerably from the average of the whole. Thus in the six bands of a coal seam which I recently examined, the ratio of volatile hydrocarbon to fixed carbon was in each band—

No. 1	... ...	1 : 1.977
„ 2	... ...	1 : 2.750
„ 3	... ...	1 : 2.349
„ 4	... ...	1 : 3.075
„ 5	... ...	1 : 2.260
„ 6	... ...	1 : 1.122

It appears doubtful whether much information could be got from making ultimate analyses of the separated constituents of any coal (except in the case of the substance No. 1 below, which I shall examine further), and I have confined myself to determining the hydrocarbons driven off at a cherry red heat from different materials in the same block of coal.

In some Newcastle coal, colliery unknown, a piece was separated into jet black bituminous matter which broke easily into more or less cubical fragments, and a dense hard coal with a rather pale lustre. Subjected to heat the bituminous portion fused together forming a swollen bright coke, whilst the other did not fuse but shrank slightly, and gave a coke of the same shape as the original, or nearly so, and silvery. The ratio of volatile matters to fixed carbon was—

	Volatile.		*Fixed Carbon.*	*Ash.*
In No. 1 ...	1	:	2.012 ...	0.52 per cent.
„ 2 ...	1	:	3.455 ...	9.81 per cent.

The ash in No. 1 was composed almost entirely of ferric oxide, that of No. 2 was greyish.

A piece of Stockton coal, which is considered one of the best of our Newcastle coals for gas making, similar in appearance to the first, gave—

	Volatile.		*Fixed Carbon.*	*Ash.*
No. 3 ...	1	:	1.870 ...	1.12 per cent.

In this case also the ash was almost entirely composed of oxide of iron. This coal is bituminous to such an extent that I could not get enough non-bituminous to examine by itself.

The coals of our Western districts are much less bituminous than in the Northern, and the bituminous matter is in very thin layers. From No. 4, the bright black portion of a piece of Lithgow Valley coal, and from No. 5 the contiguous dull portion I got—

	Volatile.		*Fixed Carbon.*	*Ash.*
No. 4 ...	1	:	1.889 ...	1.07 per cent.
No. 5 ...	1	:	2.248 ...	5.63 per cent.

No. 4 swelled up and united into a single mass, but did not so entirely loose its original outline as in the case of No. 1, and it was lustrous black, not silvery. The ash consisted chiefly of alumina with a little oxide of iron and some traces of silica.

In No. 5 the coke was shrunk, and of the same shape as the coal. There were some bright black thread-like bands in No. 5 which it was impossible to remove and these probably raised the percentage of volatile matter. I could not avoid this as I wished to have the portions of coal immediately contiguous.

Those results seem to indicate that the bituminous part arises from altered resin, from the low ratio of fixed carbon and the low percentage of ash—in the case of those from Newcastle, oxide of iron, which could be introduced by infiltration, as could also be the case with the alumina in the Lithgow Valley, as the water of the overlying Hawkesbury Sandstone generally contains sulphate of alumina in solution.

In connection with a coal from Mittagong, the analysis of which was published in the "Annual Report of the Department of Mines" in 1878, I made the following remark, which has been reproduced in Professor Liversidge's "Minerals of New South Wales":—

"The bright lines of fracture were marked by numerous lense-shaped cavities 00.5 to 0.10 inch in greater diameter, generally filled with a brownish pulverulent carbonaceous matter. These were apparently the impressions and remains of seeds, and they shewed traces of a dense cortical layer. The bituminous matter on heating, glowed, emitted a smoky odour and burned away completely." These seeds were quite absent except in the bright layers. Now if the seeds fell and were enclosed in resin, germination would be prevented and they would be preserved, whilst if they fell in decaying vegetable matter all traces of them would be lost.

I conclude therefore that the bituminous coals yielding low and valuable hydrocarbons on distillatiion are originally derived from aromatic resin bearing plants, the resinous ligno-cellulose of which contributed to the result, whilst the cambium or more cellulosic portions were mostly lost by decay, a little being converted into mineral charcoal. We can see the preservation of resin in retinite and also in the more recent Kauri and grass tree gums where the cellulose has often disappeared.

Cannel.—I have no analysis of my own of this mineral but give below the ratio of volatile matter and fixed carbons from two analyses given in Percy's "Fuel" and one from "Watt's Dictionary." In nearly all books, analyses of true cannels are mixed up with those of torbanite, or kerosene shale from Bathgate and elsewhere. The Lesmahago is a true typical cannel from the middle ward of Lanarkshire and there called candle coal (pronounced caun'l) where it was first used to give light in the farmhouse kitchens, a lump being put on the red fire in the evening.

	Volatile.		Fixed Carbon.		Ash.
Lesmahago ...	1	:	1.495	...	6.03 per cent.
Wiggan ...	1	:	1.304	...	2.40 per cent.
Mold	1	:	1.188	...	... ...

Cannel differs from bituminous coal in being of a nearly uniform texture, in which it resembles torbanite, but differs from the latter in every other way. From the character of the hydrocarbons it yields on distillation, it seems probably derived from adipo-cellulose and ligno-cellulose, the latter having considerable development in plants, which, form the comparative uniformity of the mineral, were probably of small size.

Torbanite or Kerosene Shale —In the coals and cannels the volatile hydrocarbons are always less than the fixed carbon, whilst in the shales, this ratio is always reversed and that irrespective of the amount of ash present. The following are five recent determinations of mine, the carbon being the smaller is taken as No. 1, not the volatile matter as in the coals :—

		Carbon.		Volatile Hydrocarbon.		Ash.
No. 1	Joadja Creek ...	1	:	16.908	...	6.17
,, 2	Source unknown	1	:	12.500	...	6.20
,, 3	Murrurundi ...	1	:	8.625	...	21.32
" 4	,, ...	1	:	6.041	...	40.88
,, 5	United States ...	1	:	2.561	...	7.95

Nos. 1 and 2 were beautiful, fine grained shales, with a velvety lustre and pale streak.

No. 3. Fine grained brownish, scarcely velvety.

,, 4. Coarse-grained brownish, dull.

,, 5. Black, dull—streak dark brown, almost black.

It will be observed that the ratios in these shales differ widely, and also that the percentage of ash has a great range, but the value of the shale for distillation, either for oil or gas, appears to depend more on the ratio of hydrocarbons to fixed carbon than upon the quantity of ash. Thus, No. 3 is a shale much superior, whilst No. 4 is very little inferior, to No. 5, although it contains more than five times as much ash. I refer to the quantity of gas or oil yielded. If distilled for oil, No. 5 would yield a very bad quality, the distillate containing much tar. This shale approaches in appearance the outlying portions of the better shales where they have been pinched under heavy cover.

Looking at the ultimate composition of shale in conjunction with the yield of fatty hydrocarbons, I was at first inclined to consider it as a product of adipo-cellulose. The following are analyses—first, of torbanite from Bathgate given in "Watt's Dictionary."—second, of shale from Hartley, by Professor Liversidge, which I have calculated free from ash, and for comparison I repeat that of adipo-celluloses in the third column.

	I.	II.	III.
Carbon	79.6	79.67	73.66
Hydrogen	11.2	12.92	11.37
Oxygen, Nitrogen, and Sulphur*	9.1	7.41	14.97
	99.9	100.00	100.00

I subjected some carefully selected cork in thin shavings, as the nearest substitute for adipo-cellulose to a rapid red heat and also pure cellulose and obtained the following ratios :—

	Fixed Carbon.		*Volatile matter.*
Ash	1	:	5.245
Cellulose ...	1	:	7.916

As under no conceivable conditions could the ratio of volatile matter be increased during the conversion into mineral the similarity in composition goes for nothing.

It has been suggested by someone that the shales are the products of resinous spores of some plant. From the persistent fatty products of distillation I think resin must be abandoned as resins pass more to aromatics. It appears to me more probable that shale comes from some oil or wax producing plant, more likely the latter, in view of the considerable yield of solid paraffin.

The shale at Joadja Creek is very uniform in texture, there is here and there a starlike speck of so called jet, and rarely a ribbon-like piece of the same running through a block, perhaps an inch or so wide and barely an eight of an inch thick. As there is bituminous coal above, these may represent resinous roots, but I could not get any for examination in time for this paper. At Joadja there is a ligno-cellulose coal below—a wax shale in the middle, and a resinous ligno-cellulose coal above.

Several other points have occurred to me since I promised this paper for the meeting of the Association, but pressure of other work has prevented me going into them.

Addendum, September 29th.—Since writing the above paper I have found in my notes an analysis of the best Joadja Creek shale for which I had before looked in vain. In the first column is given the analysis, in the second the carbon, hydrogen and oxygen only, eliminating the other ingredients as extraneous—in the third the numbers for the formula C_{34} H_{64} O_2, that is a paraffin with 4 H replaced by 2 O (calculated).

*The sulphur and nitrogen are very small in these shales. The only difference is an increase of carbon and a decrease of oxygen in the shales.

	I.	II.		III.
Carbon ...	75.32	81.10	C_{34}	80.95
Hydrogen	12.05	12.97	H_{64}	12.69
Oxygen ...	5.49	5.93	O_2	6.33
Nitrogen...	0.28	...		...
Sulphur ...	0.31	...		...
Ash ...	6.55	...		...
	100.00	100.00		

Pyrites was observed in the shale and was probably the source of the sulphur.

I do not attach much importance to the formula obtained, as the organic matter of shale is not a pure substance, though I think an approach thereto. For comparison there are given below some analyses of waxes. First, myricin or myricyl-palmatate (calculated.) Second, ceroxylin or palm wax, the average of three analysis by Boussingault, Lewy, and Teschemacher. ("Watt's Dictionary," I, 837), Third, Carnabau wax by Lewy, ("Watt's Dictionary," I., 805). Fourth, Occuba wax, by Lewy, ("Watt's Dictionary," IV., 173), and fifth, tristearin (calculated.)

	I.	II.	III	IV.	V.
Carbon ...	79.31	80.74	80.30	74.0	76.8
Hydrogen	13.22	13.26	13.00	11.3	12.3
Oxygen ...	7.47	7.00	6.70	14.7	10.9

Occuba wax (No. 4), the product of a plant growing in marshy places in South America, is not a true wax but a mixture of solid fats.

It seems evident that the organic matter of shale, if produced, as I think probable, from a vegetable secretion, must nave been so produced by the elimination of hydrogen and oxygen in the form of water, with probably elimination of hydrogen also by atmospheric oxygen, and could not arise from either of the last two which contain less hydrogen, and still less could it arise from fats of lower molecular weight than tristearin, whilst it is possible from the waxes. This is more clearly seen if in Nos. 4 and 5 the hydrogen and oxygen are calculated for a quantity of carbon equal to that in the shale, thus :—

	IV.	V.
Carbon (as in shale) ...	81.10	81.10
Hydrogen	12.39	12.98
Oxygen	16.11	11.52

The first shews less hydrogen than the shale, the last an equal quantity, but in both there is a large percentage of oxygen to remove hydrogen, which is not the case with the waxes, in which indeed the oxygen is rather deficient, which deficiency could be supplied by atmospheric oxygen.

The objection to derivation from fats apply with even greater force to the derivation from amber (succinite) and similar mineral resins, probably little altered in constitution, a connection claimed by Dana in Bathvillite (" Mineralogy," p. 742), as amber contains much less hydrogen than Bathvillite or shale.

The organic matter of the shale of this country is evidently a very stable body. It is almost absolutely insoluble in naphtha, carbon bisulphide and similar menstruæ. It is scarcely acted on by exposure to the weather, as for years subjected to fierce sun in summer, frost in winter, and rain at all times, it only becomes slightly brown on the immediate surface. Long continued boiling with caustic alkali dissolves from the powder, only a trace of humus like matter, and fusion with caustic potash for two hours gives a similar result, whilst amber is soluble in alkalis. The bituminous matter of coal is insoluble in solution of caustic potash, but fusion with potassium hydrate renders it largely soluble in water. In this respect it is different from the "jet" mentioned above which is insoluble in such menstruæ as carbon bisulphide, etc., in caustic potash solution, and long fusion with caustic potash gives no more soluble matter than is obtained from the shale itself.

This "jet" subjected quickly to a cherry red heat gives—

Volatile matter	41.12
Carbon*	55.80
Ash	3.08

The ash was reddish coloured from the presence of oxide of iron. The immediately adjacent shale gave 9.16 per cent. of white ash, whilst the volatile matter was 83.62 per cent., and the fixed carbon 7.21, indicating a radically different original constitution from the jet, although in some respects that was different from the bituminous matter of coal.

2.—ON SOME MEANS OF POPULARISING THE STUDY OF CRYSTALLOGRAPHY.

By F. Ratte, Mineralogist, Australian Museum, Sydney.

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*The carbon was left as a highly intumesced bright coke.

MONDAY, SEPTEMBER 3.

The President, Mr. J. G. Black, M.A., DSc., Professor of Chemistry and Mineralogy, University of Otago., New Zealand. in the Chair.

The following papers were read :—

1.—ON THE DISSOLVED MATTER CONTAINED IN RAIN-WATER COLLECTED AT LINCOLN, CANTERBURY, NEW ZEALAND.

BY GEORGE GRAY, F.C.S., Lecturer on Chemistry, School of Chemistry, Lincoln, New Zealand.

FOR the past four and a half years samples of the rain-water, collected at the School of Agriculture, Lincoln, have been analysed, and the results published in the reports of the school issued from time to time. The investigation is being still continued ; in the present paper the results, so far obtained, are collated and averages deduced.

In the collection of the samples of rain-water as much care as possible is exercised in order to prevent contamination. The collecting vessels, which are stationed at the Meteorological Observatory of the School, consist of glass funnels eight inches in diameter, the stems of these are inserted into the necks of "Winchester" quart bottles so that the rain as received comes only into contact with glass. These collectors, of which there are three, are cleansed from adhering impurities occasionally. The rain-water as collected is stored in other stoppered bottles until the end of each month, when the whole is thoroughly mixed and portions taken for analysis, There exists considerable difficulty in collecting samples perfectly free from extraneous matter, as dust, pollen, insects, etc., will find their way into the vessels in spite of all care. In removing such matters, which is always done as early as possible, decantation is resorted to, since it is found that filter paper always contained sufficient ammonia to vitiate the results, unless washed thoroughly five or six times with specially prepared distilled water.

With the exception of the water collected during the year 1887 the analysis was made as soon as possible after the month in which the rain was received. When the investigation was commenced it was intended only to analyse the monthly rainfall extending over three years, and afterwards to analyse the mixed annual rainfall, but in consequence of the abnormal rainfalls of 1886 and 1887 and the interesting nature of the results, it was thought better to continue the monthly analyses for a few years longer. In consequence of this, the samples collected during 1887 were not examined until the beginning of the present year. The effect produced on the nitrogenous compounds, by keeping the water, will be referred to when the results are considered.

The position of Lincoln with regard to the sea has considerable influence on the results obtained in the case of chlorine and sulphuric anhydride. It is situated about five miles to the westward of the hills forming Banks' Peninsula, at an elevation of about sixty-two feet above sea level, and is nearly midway between the sea coasts north and south of the Peninsula. A line drawn in a north-east direction, would meet the sea at a distance of about eighteen miles, while one drawn towards the south-west would reach it in about twenty miles, and in doing so would pass over Lake Ellesmere and its adjoining flats.

The greater portion of the rain received at Lincoln is accompanied by winds blowing from one or the other of these points, and is consequently liable to contamination from sea spray, which, as is well known, is often carried for a considerable distance inland.

The rainfall of Lincoln recorded since the establishment of the School, together with that of Christchurch, which is about fourteen miles distant, is shewn hereunder:—

TABLE I.—RAINFALL OF CANTERBURY.

Year.	Lincoln.	Christchurch.
1881	28.071	21.78
1882	25.391	20.84
1883	30.336	29.71
1884	28.415	26.92
1885	22.130	23.01
1886	35.287	41.81
1887	32.890	30.01
Mean.	28.931	27.726

For the Christchurch results we are indebted to Mr. J. B. Stansell, late Government Meteorological Observer, who gives the average annual rainfall for twenty-four years, 1864 to 1887 inclusive, as 25.288 inches, with a maximum annual fall in 1886 of 41.81 inches, and a minimum in 1878 of 13.540 inches. Generally speaking, therefore, as far as the results at present shew, the rainfall of Lincoln is above that of Christchurch.

It is advisable here perhaps to give a brief outline of the analytical methods employed, although they are all such as are in general use in water analysis, A small room is devoted exclusively to the work, so as to avoid the fumes of ammonia and hydrochloric acid prevalent in the general laboratory.

The total dissolved matter are estimated by evaporating 500 c.c. of the water in a platinum dish on an iron hot-plate, dust, etc., being prevented from entering by covering the dish with a large funnel. The final drying is effected in a water bath at 100°C.

Nitrogen existing as ammonia compounds is determined by placing 500 c.c. of the water, with a few drops of sodic carbonate, in a retort connected with a Liebig condenser, the same having been previously freed from ammonia by the steam from distilled water ; 150 c.c. are distilled over, and the ammonia determined by Nessler's well known colorimetric test. The Nessler solution is frequently sensitised with mercuric chloride, so as to give an indication with .2 c.c. of standard ammonic chloride solution, equivalent to .002 milligrammes of nitrogen. The distilled water used in the testing is specially prepared in a large copper still, by distilling over two-fifths and collecting the next fifth part which is found to be practically free from ammonia,

The albuminoid nitrogen is determined in the water left after the removal of the ammonia, by distilling with 50 c.c. of an alkaline solution of potassic permanganate, which has been previously boiled, collecting the first 150 c.c. and applying Nessler's test as before.

Nitric acid is estimated by converting it into ammonia by means of a copper-zinc couple and determining the ammonia evolved with Nessler's test, 250 c.c. of the water being used for the purpose. The copper-zinc couple consists of a cylinder of perforated zinc 3 × $\frac{3}{4}$ inch, which has been immersed in a five per cent. solution of cupric sulphate until a firm coating of copper is obtained. The action is allowed to continue for twelve hours at a temperature of about 80° F.

For testing the presence of nitrous acid an acid solution of metaphenyldiamine is employed.

Chlorine is determined volumetrically by a standard solution of silver nitrate, 1 c.c. of which is equivalent to .005 grms. of chlorine, potassic chromate being used as an indicator. The water used, 250 c.c., is reduced by evaporation to about 50 c.c.

Sulphuric anhydride is estimated in the water, concentrated to about 50 c.c., by precipitating with baric chloride in the presence of hydrchloric acid. The quantity employed varies with the amount of the rainfall, 500 c.c. being the minimum. In order to avoid error with the small precipitates obtained, acid extracted filter paper only is employed.

For ascertaining the reaction of the water rosolic acid is used.

Rain being formed by the condensation of the moisture evaporated from the surface of the earth, would, at the time that it passed into the condition of vapour, be comparatively pure, although it is very doubtful whether under any condition it would be possible, even if it suffered no further contamination to obtain vapour water perfectly pure from rain. The surface from which the water is formed, whether land or water, always contains more or less combined nitrogen, which when the water evaporates, passes away with it. The troublesome operation of preparing distilled water, that will have no effect on a sensitised Nessler solution, is one well known to all conversant with water analysis. The opinion generally accepted is that water vapour is made up of minute spheres of liquid and that it is the coalescence of these spheres which forms rain. We know that in the process of evaporation that a considerable portion of the dissolved substances in the liquid are left behind, but in the case of gases there seems to be a limit, especially in the case of those like ammonia and carbonic anhydride.

The greater part of the dissolved matters in rain is derived from the air through which the rain passes, and these may have quite a different source from that of the water vapour itself. This view is supported by the fact that the first rain falling after a dry period is always found to be richer in dissolved matters than that which falls subsequently, the proportion present gradually diminishing as the shower proceeds. The rain thus washes, as it were, the air, and any interval between two rainfalls allows the air, more or less according to the time, to become again contaminated, so that several falls of short duration, might contain, comparatively, more impurlties than when the rain is continuous for a longer period. This is well shown in our results by the different quantities of rain falling in the several months.

The combined nitrogen contained in rain is derived from three sources; the ammonia compounds derived from tho decay of animal and vegetable substances and from the combustion of fuel; the organic matter existing in the air; and lastly the nitric acid resulting either from the oxidation of ammonia, and probably some of the organic matter, or, from the direct union of atmospheric oxygen and nitrogen under the influence of the electrical discharges taking place in the atmosphere.

In the decay of animal and vegetable substances, and also in combustion, the nitrogen present is evolved in the form of ammonia, and the carbon as carbonic anhydride, these two gases pass into the atmosphere and unite, forming carbonate of ammonium, which being volatile at the ordinary temperature of the air, is held as it were in suspension, until removed by the rain.

The organised nitrogen exists in the air in the form of germs and minute organisms and possibly of minute particles of disintegrated organic matter. Being generally in the form of albuminoids the term albuminoid nitrogen has been applied to it.

Sulphuric acid in rain indicates contamination of the air, either by the decomposition products of organic substances, or by the sea spray brought inland by winds. The combustion of coal appears to be particularly a source of sulphuric acid, the air of towns containing sufficient to give an acid reaction to the rain.

Chlorine also is derived from the combustion of fuel, but the greater part is obtained, at any rate at Lincoln, from sea spray.

The extent of the impurities therefore in rain water is dependent mainly on the population of the district and its proximity to the sea,

The following table (Table II.) will shew the analytical results obtained during the past four and a half years from the rain collected at Lincoln.

Table II.—Analysis of Rain-water.

Results expressed in parts per million.

1884.

Month.	Total rainfall.	Dissolved solids.	Nitrogen as			Total Nitrogen.	Oxygen required to oxidize organic matter.	Sulphuric anhydride.	Chlorine.	Reaction.
			Albuminoid Nitrogen.	Ammonia.	Nitric acid.					
	inches									
January ...	4.450	15.0	.0329	.1112	.0987	.2428	.062	—	—	
February	1.780	18.2	.1359	.1208	.1854	.4121	.041	—	3.00	
March ...	1.460	28.7	.1359	.1421	.2655	.5435	.104	3.29	4.60	
April ...	1.720	17.6	.0741	.0824	.1236	.2801	.008	1.54	6.20	Alkaline.
May... ...	1.280	37.6	.1359	.1030	.1991	.4380	.104	1.71	14.20	
June ...	1.477	21.6	.0865	.1867	.3901	.6633	.144	1.37	7.40	
July	3.880	13.4	.0247	.0576	.0906	.1729	.072	2.19	6.20	
August ...	1.928	25.2	.1359	.1771	.0947	.4077	2.132	2.30	6.40	s. Acid
September	1.985	17.8	.0988	.1598	.0584	.3170	.088	2.74	6.75	
October ...	2.236	19.2	.2348	.2636	.0453	.5437	.162	1.23	7.25	Alkaline
November	3.259	21.8	.1030	.0597	.0948	.2575	.017	2.05	8.20	
December	2.996	11.4	.0927	.0432	.0855	.2214	.196	.48	2.80	
Total ...	28.454	247.5	1.2911	1.5072	1.7317	4.5300	3.130	18.90	73.00	
Monthly mean.	2.371	20.62	.1076	.1256	.1443	.3775	.261	1.89	6.63	

1885.

Month.	Total rainfall.	Dissolved solids.	Nitrogen as			Total Nitrogen.	Oxygen required to oxidise organic matter.	Sulphuric anhydride.	Chlorine.	Reactian.
			Albuminoid Nitrogen.	Ammonia.	Nitric acid.					
	inches									
January ...	1.687	23-4	.1483	.0885	.1133	.3501	.524	1.71	7.60	Alkaline.
February	1.264	45.8	.0988	.1401	.1236	.3625	.900	4.66	9.00	
March ...	5.101	17.0	.0495	.0796	.1017	.2308	.040	1.30	5.20	
April ...	.546	54.0	.1483	.3515	.1044	.6042	.476	.61	18,60	
May... ...	1.552	38.0	.1112	.0467	.0796	.2375	.227	3.08	13.20	
June ...	1.396	14.4	.0371	.0618	.0988	.1977	.072	1.09	2.60	
July... ...	3.026	12.8	.0741	.0432	.2287	.3460	.072	1.37	2.80	
August ...	2.903	16.0	.0742	.1854	.0494	.3090	.184	1.20	8.40	
September	.566	101.6	.1854	.6921	1.1001	1.9776	1.040	8.44	36.40	
October ...	1.395	81.0	.0927	.2224	.0866	.4017	.104	5.62	33.20	
November	2.142	23.6	.0865	.1112	.2719	.4696	.034	1.73	8.40	
December	.552	89.0	.1395	.5562	.1854	.8775	.888	5.42	35.00	
Total ...	22.130	516.6	1.2420	2.5787	2.5435	6.3642	4.561	36.22	180.4	
Monthly mean	1.844	43.05	.1035	.2148	.2119	5.303	.380	3.01	15.03	

1886.

Month.	Total rainfall.	Dissolved solids.	Nitrogen as			Total Nitrogen.	Sulphuric anhydride.	Chlorine.	
			Albuminoid Nitrogen.	Ammonia.	Nitric acid.				
	inches								
January	.621	68.2	.3708	.5190	1.0260	1.9158	6.31	24.8	Alkaline.
February ...	1.354	54.6	.0494	.1236	.0412	.2142	1.64	7.0	
March	2.594	24.0	.0123	.0494	.0742	.1359	2.47	10.4	
April	4.208	31.0	.0185	.0309	.2575	.3069	1.99	12.6	
May	5.860	28.4	.0185	.0062	.1792	.2039	3.15	9.0	
June	5.065	19.0	.0741	.0247	.0557	.1545	1.71	10,2	
July	.331	112.0	.4326	.5622	.9828	1.9776	7.54	21.0	
August	8.429	18.4	.0309	.0123	.0907	.1339	1.37	5.0	
September ...	2.094	24.0	.0432	.0803	.2287	.3522	4.39	11.2	
October	2.222	16.0	.1359	.1730	.3832	.6921	1.51	7.0	
November ...	.767	36.0	.0988	.0371	.2101	.3460	3.43	13.5	
December ...	1.742	20.8	.0865	.2472	.0412	.3749	2.32	8.7	
Total	35.287	452.4	1.3715	1.8659	3.5705	6.8079	37.83	140.4	
Monthly mean ...	2.940	37.7	.1143	.1555	.2975	.5673	3.15	11.7	

1887.

Month.	Total rainfall.	Dissolved solids	Nitrogen as			Total Nitrogen.	Sulphuric anhydride.	Chlorine.	Reaction.
			Albuminoid Nitrogen.	Ammonia.	Nitric acid.				
	Inches								
January	1.414	50.4	.2966	.0988	.7664	1.1618	4.04	16.4	Slightly acid.
February ...	1.828	36.8	.1112	.0123	.3791	.5026	3.15	10.2	Alkaline.
March... ...	1.021	70.2	.0556	.0618	.1854	.3028	9.05	24.0	
April	1.713	40.2	.0185	.0247	.4491	.4923	6.99	15.2	
May	2.658	34.4	.0309	.0123	.1113	.1545	2.67	12.2	
June	5.983	26.6	.0185	.0124	.0906	.1215	.89	8.0	
July	5.021	25.4	.0246	.0124	.1318	.1688	1.92	5.8	
August	2.553	45.6	.0247	.0062	.1998	.2307	2.60	15.8	
September ...	1.621	29.4	.0309	.0124	.6056	.6489	1.98	8.8	
October	3.772	31.6	.0186	.0185	.3111	.3482	1.78	12.8	
November ...	4.319	27.4	.0370	.0123	.2555	.3048	1.71	6.8	
December ...	.987	52.2	.0494	.0185	.3317	.3996	3.63	23.0	
Total	32.890	470.2	.7165	.3026	3.8174	4.8365	40.41	159.0	
Monthly mean ...	2.741	39.18	.0597	.0252	.3181	.4030	3.36	13.25	

1888.

Month.	Total rainfall.	Dissolved solids.	Nitrogen as			Total Nitrogen.	Sulphuric anhydride.	Chlorine.	Reaction.
			Albuminoid Nitrogen.	Ammonia	Nitric acid.				
	Inches								
January	1.961	26.6	.0988	.0123	.0114	.1225	2.19	9.6	Alkaline.
February ...	2.355	25.2	.0741	.0309	.1339	.2389	2 53	12.2	
March	2.060	83.4	.0803	.2348	.1978	.5129	5.07	35.4	
April	3 255	23.2	.0742	.0185	.0433	.1360	2.19	6.0	
May	3.421	11.4	.0247	.0556	.0268	.1071	2.40	3.8	
June	.652	62.8	.0185	.1360	.4820	.6365	6.17	21.0	

The results of 1887 in the above table as regards nitrogen are somewhat abnormal. The proportion existing as ammonia is less than that of the other years, while that in the form of nitric acid is higher. As before stated, the specimens were somewhat old before being analysed, and it might with justice be assumed that nitrification of the ammonia had taken place and that much of it had been converted into nitric acid. The condition under which the samples were stored as regards light were favourable to nitrification, the room facing south and being not very well lighted. Messrs. Lawes, Gilbert, and Warrington, in their experiments, found that with the rain-water collected at Rothamsted that the ammonia in rain-water was fairly permanent, but it is also suggested that this might be due to lead in solution derived from the guage in which it was collected, this being detrimental to the existence of the organisms by which nitrification is effected. Experiments have been started with a view to ascertaining whether nitrification does take place in the Lincoln rain-water, and at what rate it proceeds. If the ammonia has become nitrified it will not affect the results of the total nitrogen, but only its condition. If we consider the ratio existing between the ammonia and nitric acid in the rain of the several years the difference of composition is very apparent. In the following table in which the results have been computed from the quantity of nitrogen as ammonia and nitric acid received annually in lbs. per acre of land, the ratio existing between the nitrogen in the two substances is shewn.

TABLE III.—Shewing ratio between the nitrogen in ammonia and nitric acid contained in rain-water.

YEAR		N as NH_3		N as NH_3
1884	... ...	1	—	1.2
1885	... ...	1	—	1.1
1886	... ...	1	—	2.6
1887	... ...	1	—	13.8
1888 (to June)	...	1	—	1.4

The differences is also evident from the table of curves appended to this paper.

The results contained in the table of analyses shew the proportion of the several constituents per 1,000,000 parts of rain, and the means shew merely the average composition, assuming that this amount of each monthly rainfall were taken. But the rainfall of each month varies and the amount of dissolved matter varies with it, but in an inverse ratio, and consequently the results will be better understood when the absolute quantity of the several constituents received over a given area are calculated. From the numbers so obtained the real average composition of the water can be deduced.

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TABLE IV.—Shewing the amount of rain and dissolved matters received by an acre of land in pounds per annum.

1884.

Month.	Rain.	Dissolved matters.	Nitrogen as			Total Nitrogen.	Sulphuric anhydride.	Chlorine.
			Albuminoid Nitrogen.	Ammonia.	Nitric acid.			
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
January ...	1,006,706	15.352	.033	.114	.101	.248	.935	3.197
February	402,682	7.451	.056	.049	.076	.181	.935	1.228
March ...	330,290	9.637	.045	.048	.089	.182	1.104	1.544
April ...	389,109	6.870	.029	.032	.049	.110	.610	2.452
May ...	289,569	11.069	.040	.030	.058	.128	.504	4.180
June ...	334,136	8.337	.029	.063	.133	.225	.465	2.513
July... ...	877,757	11.598	.022	.051	.081	.154	1.954	5.532
August ...	436,164	11.174	.060	.078	.042	.180	1.019	2.838
September	449,059	8.126	.045	.073	.026	.144	1.250	3.058
October ...	505,841	9.874	.121	.135	.023	.279	.632	3.754
November	737,270	16.340	.077	.045	.071	.193	1.536	6.146
December	677,773	7.855	.064	.029	.059	.152	.281	1.929
Total ...	6,436,356	123.683	.621	.747	.808	2.176	11.225	38.371

1885.

Month.	Rain.	Dissolved matters.	Nitrogen as			Total Nitrogen.	Sulphuric anhydride.	Chlorine.
			Albuminoid Nitrogen.	Ammonia.	Nitric acid.			
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
January ...	381,643	8.921	.055	.034	.043	.132	.652	2.897
February ...	285,949	13.096	.028	.040	.035	.103	1.332	2.573
March ...	1,153,978	19.617	.057	.092	.117	.266	1.500	6.000
April	123,519	6.670	.018	.043	.013	.074	.762	2.297
May	351,102	13.341	.039	.016	.028	.083	1.081	4.634
June	315,811	4.547	.012	.019	.031	.062	.344	.821
July	684,559	8.762	.051	.029	.156	.236	.937	1.916
August ...	656,734	10.507	.049	.122	.032	.203	.788	5.516
September ...	128,043	13.009	.024	.088	.141	.253	1.080	4.660
October ...	315,585	25.652	.029	.070	.027	.126	1.773	10.477
November ...	484,576	11.435	.042	.054	.131	.227	.838	4.070
December ...	124,876	11.113	.017	.069	.023	.109	.676	4.370
Total ...	5,006,375	146.670	.421	.676	.777	1.874	11.763	50.231

1886.

Month.	Rain.	Dissolved matters.	Nitrogen as Albuminoid Nitrogen.	Nitrogen as Ammonia.	Nitrogen as Nitric acid.	Total Nitrogen.	Sulphuric anhydride.	Chlorine.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
January ...	140,486	9.581	.052	.072	.144	.268	.886	3.483
February ...	306,310	16.724	.015	.037	.012	,064	.502	2.144
March ...	586,830	14.083	.007	.029	.043	.079	.1449	6.103
April	951,959	29.510	.017	.029	.245	.291	1.904	11.994
May	1,245,684	35.377	.023	.007	.223	.253	3.923	11.211
June	1,145,834	21.770	.085	.028	.063	.176	1.959	11.687
July	74,880	8.386	.032	.042	.073	.147	.564	1.572
August ...	1,906,858	35.086	.074	.023	.172	.269	2.612	9.534
September ...	473,717	11.369	.020	.038	.108	.166	2.079	5.305
October ...	502,674	8.042	.068	.087	.192	.347	.759	3.518
November ...	173,515	6.246	.017	.006	.036	.059	.595	2.342
December ...	394,085	8.197	.034	.097	.016	.147	.914	3.428
Total ..	7,902,832	204.371	.444	.495	1.327	2.266	18.146	72.321

1887.

Month.	Rain.	Dissolved matters.	Nitrogen as Albuminoid Nitrogen.	Nitrogen as Ammonia.	Nitrogen as Nitric acid.	Total Nitrogen.	Sulphuric anhydride.	Chlorine.
	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.
January ...	319,883	16.122	.095	.031	.245	.371	1.292	5.246
February ...	413,541	15.218	.046	.005	.156	.207	1.302	4.218
March ...	230,976	16,214	·013	.014	.042	.069	2.090	5.543
April ...	387,525	15.578	.007	.009	.174	.190	2.708	2.015
May ...	601,308	20.684	.019	.007	.067	.093	1.605	7.335
June ...	1,353,510	36.003	.025	.017	.122	.164	1.204	10.828
July ...	1,135 880	28.841	.028	.014	.149	.191	2.180	6.588
August ...	577,554	26.336	.014	.003	.115	.132	1.501	9.125
September ...	366,712	10.781	.011	.004	.222	.237	.726	3.227
October ...	853,324	26.965	.016	.016	.265	.297	1.518	10.922
November ...	977,070	26.771	.036	.012	.249	.297	1.670	6.644
December ...	223,285	11.655	.011	.004	.074	.089	.810	5.135
Total ...	7,440.568	251,168	.321	.136	1.880	.2337	18.606	76.826

1888.

Month.	Rain.	Dissolved matters.	Nitrogen as Albuminoid Nitrogen,	Nitrogen as Ammonia.	Nitrogen as Nitric acid,	Total Nitrogen.	Sulphuric anhydride	Chorine.
	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.
January ...	444,362	11.820	.044	.005	.005	.054	.973	4.265
February ...	533,643	13.447	.040	.016	.071	.127	1.350	6.510
March ...	466,796	38.930	.037	.110	.092	.239	2.366	16.524
April ...	737,583	17.111	.055	.013	.032	.100	1.615	4.425
May ...	775,198	8.837	.019	.043	.021	.083	1.860	2.945
June ...	143,211	8.993	.003	.019	.069	.091	.883	3.007

The information given in the above table is also represented by the charts. (Plates III. and IV.)

Taking the mean of the above results we find that an acre of land at Lincoln receives annually about 179 lbs. of dissolved solids, of these 60.5 lbs. consist of chlorine equivalent to 133 lbs. of chloride of sodium; about 15 lbs. of sulphuric anhydride equal to about 26.5 lbs. of sodic sulphate; and a little over 2 lbs. of nitrogen, one half of which exists as nitric acid and the remainder is made up of nearly equal parts of nitrogen in the form of ammonium compound and organic matter.

It has been previously stated that the quantity of solids received does not depend entirely on the total amount of rain, but more on the quantity and frequency or otherwise of the separate rainfalls. If we group our results in lbs. per acre according to season as in Table V., several interesting points are brought out. We see that although the mean maximum rainfall occurs in the winter months, yet the amount of solids is about the same as that received in the autumn months with only about three-fourths of the rainfall.

The maximum amount of chlorine and sulphuric anhydride are, according to the means in this table, received in the autumn, whereas nitrogen in all its forms attains its maximum in the spring.

TABLE V.—Shewing quantity of dissolved matters in lbs. per acre received in different seasons.

Months.		Mean maximum Solar radiation.	Rain.	Total dissolved solids.	Nitrogen as Albuminoid Nitrogen.	Nitrogen as Ammonia.	Nitrogen as Nitric acid.	Total Nitrogen.	Sulphuric anhydride.	Chloride.
Spring Months, Sept. to Nov.	1884	114.1	1,692,170	34.340	.243	.253	.120	.616	3.418	12.958
	1885	127.3	928,204	50.096	.095	.212	.299	.606	3.691	19.207
	1886	123.7	1,149,906	25.657	.105	.131	.336	.572	3.433	11.165
	1887	123.9	2,197,106	64.517	.063	.032	.736	.831	3.914	20.793
Total ...		489.0	5,967,386	174.610	.506	.628	1.491	2.625	14.456	64.123
Mean ...		122.2	1,491,846	43.654	.126	.157	.372	.656	3.614	16.031
Summer Months, December to February.	1884	129.0	1,409,388	22.803	.089	.163	.177	.429	1.870	4.425
	1884-5	123.0	1,345,365	29.872	.147	.103	.137	.387	2.265	7.399
	1885-6	136.8	571,672	37.418	.084	.178	.179	.441	2.064	9.997
	1886-7	138.6	1,127,509	39.537	.175	.133	.417	.725	3.508	12 892
	1887-8	140.1	1,201,290	36.922	.095	.025	.150	.270	3.133	15,910
Total ...		667.5	5,655,224	166.552	.590	.602	1.060	2.252	12.840	50.623
Mean ...		133.5	1,131,045	33.310	.118	.120	.212	.450	2.568	10.125
Autumn Months, March to May	1884	102.1	1,008,968	27.576	.114	.110	.196	.420	2.218	8.176
	1885	115.6	1,628,599	39.628	.114	.151	.158	.423	3.343	13.931
	1886	109.7	2,784,473	78.970	.047	.068	.511	.623	7.276	29.308
	1887	111.3	1,219,809	52.476	.039	.030	.283	.352	6.403	14.893
	1888	114.6	1,979,577	64.878	.111	.166	.145	.422	5.841	23.894
Total ...		553.3	8,621,426	263 528	.425	.522	1.293	2.240	25.081	90.202
Mean ...		110.6	1,724,285	52.705	.085	.104	.258	.448	5.016	18.040
Winter Months, June to August.	1884	85.7	1,648,057	31.109	.111	.192	.256	.559	3.438	10.883
	1885	93.0	1,657,104	23.816	.112	.170	.219	.501	2.069	7.253
	1886	91.7	3,127,572	65.242	.191	.093	.308	.592	3.135	22.793
	1887	92.9	3,066,944	91.180	.067	.034	.386	.487	4.885	26.541
Total ...		363.3	9,499,677	211.347	.481	.489	1.169	2.139	15.527	67.470
Mean ...		90.8	2,374,919	52.836	.120	.122	.292	.535	3.882	16.867

Attention has been called to the fact that the ratio of sulphuric anhydride to chlorine is always higher in rain-water than that existing in sea-water, shewing that a proportion of the sulphuric anhydride is derived from other sources than sea-water. In two samples of sea-water, collected outside the bar at Lake Forsyth, and at Sumner, sulphuric anhydride and chlorine were found as follows:

	Lake Forsyth.	Sumner.
Chlorine ...	19276.5 per million	18815.0 per million.
Sulphuric anhydride	2191.5 „	2126.6 „
Ratio of chlorine to sulphuric anhydride	100 to 11.36	100 to 11.30

If we assume that the whole of the chlorine in rain is derived from sea spray and compare these figures with those representing the ratio of chlorine to sulphuric anhydride in the different seasons, we find that one half at least of the sulphuric anhydride is obtained from other sources than sea water.

Ratio of chlorine to sulphuric anhydride in rain-water at different seasons.

	Cl.		SO_3
Spring	100	...	22.5
Summer	100	...	25.3
Autumn	100	...	27.8
Winter	100	...	23.0
Mean of whole year ...	100	...	24.9

The increased amount is probably due to volatile compounds of sulphur disengaged in the decomposition of organic substances, which proceeds more rapidly during the warmer months.

The influence of winds from different quarters probably affect the results, but in what way it is difficult to ascertain. Our results have been compared with the prevailing direction of the wind, but as yet without shewing any decided influence. The characteristic hot "nor-westers" experienced here, probably affect the results most, but rain is seldom received in any quantity from this quarter, and several attempts to secure samples have proved fruitless. Indications might be given in the rain-water falling in the "sou'-westers" which frequently follow the former wind, such however as yet have not been examined.

The results in Table VI, shew the true average composition of rain-water in the several seasons in parts per million. The numbers are obtained by dividing the numbers of pounds of rain per acre into the weight of each constituent, and multiplying the result by 1,000,000. The richness of the rain in solids during spring, summer, and autumn seems to be fairly constant, but there is a considerable fall in the winter season. The albuminoid nitrogen is greatest in summer, due probably to the increased vigour of all forms of life during this period. The nitrogen as ammonium compounds appears to be about equal in spring and summer, while the nitrogen present as nitric acid is more abundant in the spring. It is curious to note that the total nitrogen decreases in the successive seasons.

TABLE VI.—Shewing true average composition of rain-water received in different seasons. Results expressed in parts per million.

	Dissolved solids.	Nirtogen as			Total Nitrogen.	Sulphuric anhydride.	Chlorine.
		Albuminoid Nitrogen.	Ammonia.	Nitric acid.			
Spring months mean of four seasons—September to November.	29.26	.084	.105	.250	.439	2.42	10.70
Summer months mean of five seasons—December to February.	29.45	.104	.106	.187	.397	2.27	8.95
Autumn months mean of five seasons—March to May.	30.56	.049	.060	.150	.259	2.91	10.46
Winter months mean of four seasons—June to August.	22.24	.050	.051	.123	.224	1.63	7.10
Mean of $4\frac{1}{2}$ years ...	27.4	.067	.075	.168	.310	2.28	9.15

Before concluding it is advisable to notice the work of other investigators, that has come under our notice.

First among the researches on the constituents of rain-water stand those of Messrs. Lawes, Gilbert, and Warington, of Rothamsted, Herts, England.

Experiments have been carried on since 1853 and results are published in the "Journal of the Royal Agricultural Society of England," (Vol. XVII, 1881, p. 241, and Vol. XIX., 1883, p. 313.) The summary of results contained in the latter paper are here inserted for comparison.

"(1) One hundred and fifty-two analyses of rain, snow, dew, and hoar frost, representing the daily collections from June 22, 1881, to January 5, 1882, gave an average of 0.248 of nitrogen as ammonia per million of water; the extremes observed were 5.491 and .043, The variations are dependent on the richness of the atmosphere in ammonia and on the quantity of the rainfall, the smaller deposits containing the larger proportion of ammonia.

(2) Analyses during two years of fresh monthly mixtures of rain gave an average of 0.316 of nitrogen as ammonia per million. Analyses of fifty monthly mixtures, a considerable number of them old, gave a mean of 0.340. The rain collected in the leaden gauge at Rothamsted generally tends to increase in ammonia by keeping The rainfall of summer is generally richer in ammonia than that of winter.

(3) The nitrogen as ammonia annually supplied by rain per acre reckoned from the daily determinations of six months is 2.374 lbs.; from the analysis during two years of fresh monthly mixtures 2.466 lbs; from the analyses of fifty monthly mixtures, many of them old, 2.662 lbs. The nitrogen as nitric acid is apparently, from Frankland and Ways' results,

about 1 lb. per acre and the nitrogen as organic matter a similar quantity. The total combined nitrogen in the annual rainfall at Rothamsted would thus be about 4.5 lbs. per acre.

(4) Six years' determinations of chlorine in monthly mixtures of rain give an average of 1.99 per million of water, or 14.92 lbs. per acre equal to 24.59 lbs. of pure common salt. Two thirds of the chlorides fall in the six winter months, October to March. The minimum quantity falls in July; the maximum in October and November.

(5) Determinations of sulphuric acid in the rain of two years have given a mean of 2 41 per million (reckoned as anhydride). or 18.5 lbs. per acre per annum. The sulphuric acid occurs in nearly equal quantity in summer and winter."

Many analyses of interest are contained in the work of the late Dr. Angus Smith "Air and Rain," but the results given cannot be used for comparison with our own, in consequence of their not representing the rainfall of definite periods.

At the Royal Agricultural College, Cirencester, determinations of chlorine have been made for sixteen years in the mixed half-yearly rainfalls. The results are reported by Professor E. Kinch in a paper read before the Chemical Society of London, and published in the Journal of the Society for January, 1887. The mean results of twelve years are stated as follows:—

	Rainfall in inches.	Chlorine per million.	Equivalent to sodic chloride, lbs. per acre.
Mean of 12 summer periods to 1885	17.04	3.14	19.91
Mean of 12 winter periods to 1885-86	17.65	3.58	23.56
Yearly average for 12 years ...	34.69	3.36	43.47

Comparing the mean results obtained at Lincoln with those above we notice that the total nitrogen received in rain is less than one half of that received at Rothamsted. The nitric acid is approximately the same but the nitrogen existing as ammonia is especially low, only about one fifth the quantity, while the organic nitrogen amounts to one half. It should be mentioned here, however, that the method adopted by Frankland in the estimation of organic nitrogen was probably the combustion process, and as it is an open question whether the whole of the nitrogen contained in the organic matter of rain-water is evolved by the "ammonia process" our results might be, in this case, below the truth.

The amount of sulphuric anhydride is also less, but the chlorine is considerably above that of Rothamsted, and also of Cirencester. If we take into consideration, however, the excess of sulphuric anhydride above that corresponding to the chlorine, according to the ratio in sea-water, we find the quantity at Lincoln to be only about one-ninth that of Rothamsted.

The deficiency of nitrogen and sulphuric anhydride in the Lincoln rain-water is probably due to the less populated nature of the country, while the excess of chlorine is due to the position of the district with regard to the sea.

Nitrous acid has not been detected in any of the samples of rain-water examined.

2.—NOTES ON THE COMPOSITION OF FAHLERZ AND EMBOLITE, FROM NEW SOUTH WALES.

By G. S. Mackenzie, Ph.D., F.I.C.

I.—Fahlerz.

A crystalized specimen of this mineral, from the Webb Mine, near Emmaville, district of New England, was submitted to analysis with the following result :—

	I.	II.	Average.	
Antimony ...	26.14	25.96	26.06	
Copper ...	36.02	34.48	35.25	
Silver ...	4.14	4.48	4.31	
Iron ...	6.09	5.94	6.01	
Zinc ...	3.29	3.26	3.27	
Sulphur ...	24.03	24.17	24.17	(Highest).
	99.71	98.29	99.07	

Calculating a formula from above figures, we have—

Sb = 26.06	120	0.2171	5.43	
Cu = 35.25	63	0.5595	13.99	18.95
Ag = 4.31	107.66	0.0400	1.00	
Fe = 6,01	55.9	0.1075	2.69	
Zn = 3.27	64.9	0.0507	1.27	
S = 24.17	31.98	0.7558	18.895	

Or a composition most nearly corresponding to $(R'' S_4) Sb_2 S_3 = R'' Sb_2 S_7$, where $R'' =$ (Cu. Ag. Fe. Zn).

Finding R'' for the various metals, silver being taken as 0.5, we have—

$$\left(\frac{140}{190}\text{Cu.}\ \frac{10}{190}\text{Ag.}\frac{27}{190}\text{Fe.}\ \frac{13}{190}\text{Zn}\right)_7 S_4, + Sb_2 S_3$$

This corresponds closely to an analysis of Fahlerz, from Germany, by Kühlemann (vide Dana, "Mineralogy," p. 102. Analysis No. 22).

It therefore contains considerably less sulphur than that demanded by the general formula given in Dana's "Mineralogy" $RS_4\ Sb_2\ S_7$. This may, possibly, be accounted for by impurity or mechanical mixture of another mineral. The specimen analysed was a carefully selected, fully crystallised, twin tethrahedron crystal.

The mineral occurs closely associated with galena, arsenical pyrites, and a little zinc-blende, in a felstone and quartz matrix.

Diallogite (carbonate of manganese and iron) occasionally accompanies it with quartz in vughs, in the felstone.

II.—Embolite from Silverton.

This was a massive specimen of the mineral, enclosed in a siliceous and ferric oxide gangue, handed me by Professor Liversidge. It contained, in addition to chlorine and bromine, a trace of iodine.

To obtain the chlorobromide free of impurity, several portions were fused with sodium carbonate. and the sodium bromochloride reconverted into the silver salt.

The silver buttons obtained from these fusions were weighed and percentage calculated.

	I.	II.
Silver	59.43 %	58.29 %

From the difference in weight between the total chlorobromide thus obtained, and the original weight of mineral taken for fusion, the quantity of impurity was determined.

Two determinations yielded—

	I.	II.
Impurity	7.75 %	7.62 %

Various portions of the chlorobromide of silver prepared as above, were fused in a bulb tube in a stream of dry chlorine gas, and the resulting chlorides weighed, and fusions repeated until the weights were constant. From the difference in weight between the chlorobromide of silver taken, and weight obtained of silver chloride, the amount of bromine and bromide of silver contained was calculated. To check results, the chloride of silver in one instance was reduced to metallic silver in a hydrogen stream, and the resulting silver carefully weighed.

Three determinations yielded—

	I.	II.	III.	Mean.
Chloride of silver...	66.39%	66.31%	66.19%	66.29%
Bromide of silver...	33.61%	33.69%	33.81%	33.70%
	100.00%	100.00%	100.00%	99.99%

3.—ON GOLD: ITS FORMATION IN OUR REEFS AND NOTES OF SOME NEWLY DISCOVERED REACTIONS.

By William Skey, F.C.S., Analyst to the Geological Survey of New Zealand, Wellington, New Zealand.

I seek in this paper to discuss shortly the various prevailing theories in explanation of the origin of gold in our reefs in order that my own theory may be fairly considered.

I have divided my subject into two parts:—

I.—Details of the evidence that I have gathered and experimentally produced in the laboratory relative to the deposition of gold in reefs.

II.—The various discoveries I have made relating to the reactions of gold and the other noble metals when subject only to ordinary atmospheric and terrestrial agencies.

I.—Referring now to the first, it has been pretty conclusively established that the material forming our reefs and also the gold have been deposited from aqueous solutions. The most important question, therefore, that now remains to be determined is, how was its deposition accomplished?

Among the different theories that have been advocated, it will be necessary to refer to the following:—

a—That the reducing agent is one or other of the proto-salts of iron.

b—That it is organic matter.

c—That it is organic matter in conjunction with metallic sulphides.

d—That it is metallic sulphides alone.

a. That the reducing agent is one or other of the proto-salts of iron. In regard to this hypothesis it cannot be doubted, that they have at times, especially the sulphates and bicarbonates, been concerned in the reduction of a part of our natural gold. Gold reduced by these agencies would be finely granular, possibly crystalline, but never so far as can be judged from laboratory reactions, massive or even in nuggety grains. The bulk of our gold is of a massive character, and we have still to find an agent competent to depost it in this form.

b. That it is organic matter. Organic matters easily decompose the ordinary salts of gold, liberating it in the form of thin laminæ or minute crystals, hence the popularity of the theory that it is organic matter in a state of decay to which must be ascribed the deposition of a large proportion of our gold. That some gold has been reduced by this means is beyond dispute.

As already stated, gold deposited by organic matters is filmy or finely granular, the tendency of such an agency being the same as that of the ferrous salts, namely, to disperse in grains rather than aggregate in masses, and it appears certain that to whatever extent the auriferous deposit had formed therein, a vegetable structure would be apparent in the metallic mass. As little of our gold has this structure, but little of it could have been formed in this way. If, however, organic matters have not been the nuclei for gold, they might still be the main reducers of gold from its solutions, and to other substances we must look for the nuclei to aggregate the gold so reduced.

Impressed with this idea, and by facts respecting the differences in composition of reef and alluvial gold, Dr. A. R. C. Selwyn, now Director-General of the Geological Survey of Canada, proposed the following theory :—

"That nuggets may be formed and that particles of gold may increase in size through the deposition of metallic gold from the meteoric waters percolating the drifts, and which must have been during the time of our extensive basaltic eruptions of a thermal and probably highly saline character favourable to their carrying gold in solution."

The means by which the gold was to be precipitated from these solutions is not stated, except it be inferred that the nuclei were to perform this office also. However, the late Mr. R. Daintree came forward to assist the theory of Dr. Selwyn, with a description of certain phenomena he had observed, showing according to his interpretation, that a fragment of gold is a nucleus to itself *as deposited from a solution of its chloride by organic matter.*

As this had a new and important bearing on the question as to how gold nuggets have been formed, I attempted at the time to reproduce Mr. Daintree's results in the laboratory. For this purpose experiments were made by taking a curved disc of thinly hammered gold of known weight, and placing the same in gold solution under varying conditions.

In the first experiment, pieces of cork and glass were employed as nuclei, light being excluded, and the gold deposited found by simple weighing.

The quantity deposited upon the gold disc was found by numerical calculation to be not more, in proportion, relatively to the surface of a disc, than that which the remainder of the gold bore to the extent of the surfaces upon which it had affixed itself.

Second.—The same experiment repeated, but vessel and contents not darkened.

Third.—Gold solution reduced to half its strength. Diffused sunlight admitted.

Fourth.—Soluble organic matter used in place of wood; sunlight excluded.

In these three experiments there was no discernible difference in results to those obtained in experiment No. 1.

So far, therefore, as is shown by these results gold reduced from a solution of its chloride, by aid of such kinds of organic matter as cork or wood, does not in the manner of its deposition exhibit such a notable selective power for metallic gold as the description of Mr. Daintree's results would lead us to suppose. It does not, indeed, show any selective process at all, that is to a greater extent than can be attributed to the action of surfaces generally, regardless of their nature; and in support of this, I believe I am correct in stating that the whole sum of our experiences (omitting those of Mr. Daintree) is directly against this theory, as to the rapid and marked deposition of gold on gold in the manner stated; indeed, so far as I am aware, we only produce by these means fine incoherent powder—minute crystals, or films of exceeding thinness—nothing nuggety. We get a certain size of grain or crystal, or a certain thickness of film, which our efforts have hitherto failed to enlarge.

The correctness of my results have been corroborated by Mr. Cosmo Newbery.

c. That it is organic matter in conjunction with metallic sulphides. In 1868, Mr. C. S. Wilkinson, Government Geologist of New South Wales, sought for other substances besides gold that would attract to themselves gold as liberated from soluble salts by organic matter. In this he appears to have been very successful, for shortly afterwards he read a paper "On the formation of Nuggets," in which he gave the results of his experiments. He stated that in solutions of chloride of gold, metallic sulphides were in a short time beautifully gilded. At the same time he exhibited specimens of several sulphides to illustrate this property of gold as liberated by organic matter.

d. That it is metallic sulphides alone. I had found that the metallic sulphides were very fair conductors of electricity, that in fact they can be used in a voltaic circuit as the negative pole with zinc. The kind of phenomena appears to have some relation to the formation and decomposition of metallic lodes. Also that "it is pretty certain analogically considered that these sulphides should be able among themselves to form voltaic pairs in presence of sea-water as they differ from each other in respect to their affinities for oxygen."

With these facts in my mind, I was therefore prepared to see Mr. Wilkinson's results in a different light to that in which he saw them, so I repeated his experiments in every detail *except using organic matter.*

The case, therefore, as far as these results of Mr. Wilkinson are concerned, is reduced to one in which there only remains to consider the metallic sulphides and arsenides—minerals both chemically and mineralogically related to each other.

In respect to sulphides, it is distinctly stated by Mr. Newbery, that in even weak solutions of terchloride of gold (the salt used in his experiments), they decompose but so slowly as not to "interfere with the deposit taking place regularly." Having corroborated this statement, and also proved that the arsenides are similarly affected, it occurred to me, that in reality, the commencement of metallic deposit was affected, not by the interaction of organic matter as supposed, but by that of the several nuclei themselves, with the salt of gold.

I therefore agitated a little finely-powdered galena with a weak solution of terchloride of gold, omitting the addition of organic matter, and taking every precaution against its presence accidentally, when I found, after a little while, that the gold solution had become colourless, and on testing it, not a trace of this metal could be found; a careful inspection of the galena showed it to be feebly gilded.

Small cubes of galena simply immersed for a few hours in weak solutions of the gold salt, without organic matter, were so thoroughly gilded over the greater part of their surfaces, that in certain positions they could not be distinguished by the eye from gold.

Chloride of gold was also found to be reduced by contact with the following sulphides,—including those mentioned by Mr. Wilkinson:—sulphides of iron (proto and bi-sulphide), sulphides of copper (ferros-sulphide and sub-sulphide), and the sulphides of zinc, tin, molybdenum, lead, mercury, silver, antimony, bismuth, arsenic, platinum and gold; and among the arsenides, mispickel, and arsenide of silver, Cubical iron pyrites is rather slow in its action upon this solution of gold, while sulphide of antimony scarcely affects it at all at first, but after some hours contact with it, reduction goes on rapidly, perhaps by aid of some voltaic action. All these effects were produced at common temperatures (with the exception of that with sulphide of bismuth), and other experiments with iron and copper pyrites prove that similar effects are produced when all light is excluded, so there is no reason to suppose that light has been concerned in any of these re-actions.

In the case of some of the highly-coloured minerals, such as cinnabar and arsenide of silver for instance, it is necessary to operate upon their *streak*, in order to obtain a visible deposit upon them.

A portion of the metal of the sulphide operated upon was uniformly found in the solution afterwards, and also a little sulphuric acid; the mode, therefore, in which these effects were produced, was evidently by the oxidation of both the constituents of the nucleus employed, at the expense of the chloride, or rather the hydrochlorate of oxide of gold, supposing as seems probable, an equivalent of water combined with it as administered.

We have thus removed this anomaly of gold in the act of precipitating, selecting as nuclei substances so diverse from it, while refusing others which differ no more from such non-metallic nuclei than do these from gold; it appears from these results that whatever gold has been reduced by organic matter in the experiments quoted, would never deposit on these non-metallic nuclei, surface to surface, but only upon gold already occupying such surfaces, reduced by the exercise of affinities far superior and swifter in their action than those involved in the decay of wood or other organic substances, used by Mr. Wilkinson in the experiments alluded to.

The great deoxydizing power of sulphides generally upon most gold, silver or platina salts, as manifested by the experiments just described, renders them so absorbent of these metals, that any solutions traversing even a very thin vein or reef of the common metallic sulphides, would, in all probability, be completely divested of these metals.

I would state, that in regard to silver, the nitrate is but little affected by iron pyrites; but the chloride in alkaline chlorides, as also the carbonate in carbonate of soda, is decomposed with liberation of silver. This metal is easily reduced from all its solutions (except the ammonical) by galena, copper pyrites, and the inferior sulphides of iron and copper. From its solutions in carbonate of soda, potash, or ammonia, gold is also reduced by the sulphides, but not from its solutions in alkaline sulphides.

The gold or silver, deposited upon these sulphides, is coherent and smooth if the solution is weak. It bears all the signs of being electro-deposited, a true voltaic pair having been formed.

I said, in a former paper, the knowledge that metallic sulphides and arsenides are capable of reducing several metals from their solutions, should be taken into consideration when we attempt to explain the origin of these metals in the forms they have taken, and in the rocks or veins they have selected.

As yet, most of the theories explaining the occurence of such deposits in these matrices, are based upon the reducing power of organic matter; when the fact is, that most or all of these sulphides are much superior in this respect to such matters, being far more rapid in their effects, and capable of reducing, weight for weight, more metal; a single grain of iron pyrites being sufficient to reduce $8\frac{1}{6}$ grains of gold,

Organic matter could scarcely exist in such quantity among our older and more altered rocks, or be carried there in such quantity as to effect the reduction of gold in such quantity, and in such confined spaces as it is occasionally discovered in.

While allowing that organic matter may have had a share in the reduction of this and other metals, I cannot but think that by far the greater portion of these deposits—especially those deeper-seated ones—have been due to the "deoxydizing effects of pyritous minerals."

I shall now pass on to a consideration of the objections that may be raised to my theory, that the metallic sulphides are commonly the reducers of our native gold.

Mr. Newbery remarks that were this theory correct, we should have gilded pyrites occurring naturally, whereas this is not the case.

Salts of gold are not the only oxidizers of our sulphides, nor must it be supposed that they have advanced to the attack singlehanded.

I conceive that the oxidizing agents which must necessarily accompany gold salts, and that too in proportionately large quantities, would eat into pyritous nuclei and thus undermine most of the gold which had deposited thereon; in fact isolate the bulk of it as fine spangles, so that everything like a complete coating or film of gold over any mass of sulphide would be impossible. The fine particles thus released would, of course, be out of electric circuit, and therefore subject to the solvent power of the surrounding liquid, and would thus be re-dissolved, perchance to be re-deposited upon some piece of gold which, having preserved contact, has remained nuclear as being the negative element of a voltaic pair.

Grains of gold might lodge upon the upper surface of the sulphide, and by outside pressure, or by their own weight, keep up electric contact, and thus form by accretion the coarser or more nuggety gold which has to be accounted for.

Again, pyrites is never equally exposed to the flow of aqueous currents on all sides; frequently but one side is exposed to the action of the auriferous solution.

There is another and still more serious objection to be encountered. It is held by many scientists that the gold and metallic sulphides were deposited simultaneously, and if this theory be correct, I know of no process of deposition that would satisfy such a condition.

There is one important consideration which should always be kept in view before giving our adhesion to any theory. It is this—our native gold is always alloyed with silver, sometimes with copper, bismuth and platinum; allowing, however, that the three latter require exceptional circumstances to favour their deposition with gold, there still remains silver to be considered.

Any theory then must be such that it will satisfactorily explain the constant association of silver with gold, or at any rate gold derived from reefs.

It might fairly be asked, is *organic matter* as competent, as *metallic sulphides*, to precipitate and concentrate silver along with gold? I think it will be generally admitted that it is not.

As regards the metal copper in native gold, I own that my theory cannot account for it. I have tried to get such a combination by means of metallic sulphides, but have entirely failed as yet. On the other hand, silver alloys are easily formed.

I have thought that in some of the analysis of cupreous gold nuggets, the copper was probably derived from a core of cupreous sulphide, but this can hardly be so in all instances, as, in one case which came under my notice, I found a speck of very dark gold in the centre of a mass of native copper, which must have contained at least 10 per cent. of copper, judging by the colour of its clean surfaces. I also found several specks of brighter gold in the same body of copper.

THE ORIGIN OF THE GOLD.

Admitting the reducing property of the metallic sulphides, and their power to aggregate gold in massive forms the first question suggests itself, is—what is the source of the gold?

Sonstadt has shown that every ton of sea-water contains one grain of gold. Now we know that by far the greater portion of the country rock, forming our continents, is of marine origin; it does not require a great stretch of the imagination, to believe, that during the formation or deposition of the strata, now forming dry land, the strata became saturated with sea-water. Supposing these rocks retained only three per cent. of their weight of sea-water, even at this low estimate, every cubic mile of rock would contain nearly 1,000,000 ounces of gold.

Besides this, we can no doubt draw upon the gold existing in the rocks in a native state.

Some chemists have laid much stress upon the solvent power of free chlorine, but we must consider that our rock masses are, for the most part, alkaline, and hardly in a favourable condition for the existence of free chlorine, but rather for hypo-chlorous acid, a substance which has no solvent powers on gold.

Clearly then, it is by other agents that this, gold has been attacked and dissolved; that is, if our reefs have been supplied with gold so derived. I shall endeavour, in the second part, to show what these are.

II..—Dealing with the various discoveries I have made relative to the re-actions of gold and the other noble metals when subject only to ordinary atmospheric or terrestrial agencies.

For convenience of reference I have divided my obsevations and remarks under this heading into the following divisions:—

a.—Sulphurization of gold.
b.—Oxidation of gold.
c.—The agencies which have brought the gold into the reefs.

a. Sulphurization of gold. It is the opinion of chemists generally, that gold is not amenable to those simple though feeble agencies which are sufficient for the satisfaction and removal of the so-called base metals. Prior to my investigations in 1870 there was no reason for believing otherwise than that gold, remained as gold, "pure and undefiled," through all the mutations which the other metals have undergone at the earth's surface.

It is now many years since I first published my discovery that gold, like the so-called base metals, becomes tarnished under ordinary, everyday conditions.

Anyone can readily satisfy himself of the truth of my assumptions by a simple and easy test.

When clean gold is plunged into clean mercury it instantaneously alloys with the mercury forming a white amalgam; but if the gold is not quite clean the amalgamation is retarded or altogether prevented.

The above is my principal test to discover the actual condition of gold surfaces.

With a little clean mercury and a few threads of gold any one may easily prove for himself the fact that gold is subject to the influences which affect the base metals.

It was while personally investigating into the great loss of gold at the Thames Gold-field, in Auckland, that I became aware that a notable portion of it could not be properly referred to the causes which were then generally supposed to account for it.

The gold there is, as a rule, highly argentiferous, sometimes assaying as high as thirty per cent. of silver, and I thought that the alloy was possibly sulphurized, that is, as regards its surface. I therefore cleaned some of the more argentiferous of this gold and afterwards exposed it to a jet of sulphuretted hydrogen for a considerable time. I expected it to darken somewhat from the formation of sulphide of silver, but I was unable to detect any change in its colour. As a further test I plunged it into mercury and found that it would not amalgamate in the least.

I was greatly surprised that gold, containing so high a percentage of silver, did not sensibly darken, though highly sulphurized as proved by the mercury test.

I exposed a sample of pure gold to a current of sulphuretted hydrogen and then plunged it into mercury, and found that it also refused to amalgamate. I afterwards found that a few seconds in the gas jet was sufficient to render any gold neutral to mercury, and that gold was similarly affected when brought into contact, for a short time, with hot water in which sulphur was present, or aqueous solutions of alkaline sulphides.

Pure gold, after treatment with sulphuretted hydrogen gas, gave a good reaction of sulphur, but could be readily brought back to an amalgamable condition by a short contact with cyanide of potassium, chromic acid, and nitric acid.

The gold had most certainly absorbed sulphur, and the important question to decide was—What is the nature of this absorption? Is it mechanical as in the case of gaseous absorption by platina, or is it chemical?

If this absorption is mechanical, the sulphur must be in one of the two following conditions:—

1. As free sulphur.
2. Combined with hydrogen, as sulphuretted hydrogen.

1.—That it is not as free sulphur is evidenced by the fact that boiling ether, or bi-sulphide of carbon—two liquids having considerable affinities for sulphur—would not remove it from the gold; for, after long contact with these solvents, and an after thorough washing, the gold still refused to amalgamate.

Neither of these liquids had any effect upon clean gold in regard to its behaviour with mercury.

2.—That it is not combined with hydrogen, and thus condensed on the gold surface as sulphuretted hydrogen, appeared from the circumstance that sulpurous acid effected no apparent change on it.

Not appearing to be in either of these forms, I therefore assume it to exist in chemical union with the metal as a sulphide of gold.

Independent of the proof derived from experiment, it may be expected that sulphur brought into close contact with a metal which we know does form chemical union with it in a wet way, and at common temperatures, would then be in an extremely favourable condition for the exercise of chemical affinities; and the same argument applies for absorption being generally chemical wherever there are affinities existing at the temperatures we employ between the absorbants and the absorbed substances.

Indeed so far as these experiments and arguments are deemed conclusive in favour of the absorption of sulphur by gold being chemical, by so much are we compelled to diverge from the received opinion that the absorption of the common gases by platina is always a mechanical one, and are compelled to distinguish varieties of absorption.

The affinities of sulphur, also oxygen, for platina, are superior to their affinity for gold; why not therefore suppose sub-sulphides, or sub-oxides, to form, when these substances are respectively absorbed; but the whole question of these minute actions of metallic surfaces requires rigorous investigation.

As I have already said, there is no visible change upon the surfaces of gold treated with sulphuretted hydrogen, not even upon richly argentiferous gold. Still the sulphur is there, and as my tests reveal, in chemical combination with the metal; but some farther confirmation may be considered necessary. Professor Eglinton, of the New York School of Mines, records the fact that he has found gold soluble in cold sodic-sulphide. It will be remembered that I have already stated that gold should be soluble in alkaline sulphides, as it is sulphurized by them, and gold sulphide is soluble in them.

But a more complete confirmation of the correctness of my discovery, that the absorption of sulphur by gold is chemical, has just been obtained experimentally.

I find that if gold is digested for about eighteen hours in a weak solution of sodic and ammonia sulphide, it becomes very perceptibly darkened, and this is rendered more apparent by comparing it with gold not sulphurized. Occasionally I have succeeded in giving an irridescent appearance to it by this means.

Gold thus treated affords a good reaction of sulphur, and is not brought back to its original colour by hot hydrochloric acid, from which I conclude that the dark film is composed of anhydrous sulphide of gold.

I should state that strips of platinum were digested alongside these pieces of gold, and for an equally long time, but did not manifest any change of colour.

In this connection I may mention that although platinum does not darken in sulphide solutions, it is, however, affected by them as well as by sulphuretted hydrogen, becoming non-amalgamable. Like gold, it is rendered amalgamable by a short contact with nascent hydrogen; but unlike gold, it is rendered amalgamable by cyanide of potassium.

Platinum, however, becomes readily amalgamable on being raised to a temperature of 400° to 600° F., also by a short contact with any of the followiug substances:—Chromic acid, nitric acid, or chlorine, but sulphuric and hydrochloric acid do not have this effect.

It further appears that platinum is also brought into a non-amalgamable condition by a short contact with an aqueous solution of potash or ammonia; in these cases, however, the application of hydrochloric or sulphuric acid renders it readily amalgamable. In none of these cases did the metal appear to sustain any visible change upon its surfaces.

The results thus stated tend to show:—

First.—That platinum, like gold, is capable of absorbing sulphur at common temperature, either from a solid or gaseous compound,

Second.—That this absorption is chemical.

Third.—That this metal is superficially oxydized in alkaline solutions.

These results, as I have said, appear to impugn the correctness of the opinion, that gaseous absorption by platinum is, in every case, simply mechanical.

There is another and suggestive fact to record here, namely—that dry sulphuretted hydrogen does not affect platinum, water being necessary to assist the reaction. It is probable, therefore, that in the cases where I sulphurized gold, water was also necessary. What part it plays in the reaction does not readily appear from what is known of the properties of gold. My observations in the next section of this paper may throw some light on this subject.

I think I have furnished sufficient evidence to show that the absorption of sulphur by gold is chemical, but as I am desirous of getting all the evidence possible, I have endeavoured to get those electrical manifestations which are always the concomitants of chemical action.

Taking two plates of gold, chemically pure, I placed one of them in a cell charged with sea-water, and the other in a porous cell charged with sulphide of ammonium, which cell I partially immersed in the first. These gold plates I connected voltaically at points quite clear of the liquid, and inserted a delicate galvanometer in the circuit. when I found the needle was vigorously deflected over an arc of 20° to 30°, indicating, of course, that a strong current of electricity was being generated. The direction of this current, as shown by the needle, was from the inner to the outer cell. The gold in the sulphide solution, therefore, was the positive element of the pair.

Electric currents of equal strength were also developed by charging both cells with sea-water, or with a solution of potash or ammonia, and administering sulphuretted hydrogen to the gold plate in either cell. The direction of these currents was constantly from the cell to which the gas was supplied. By charging one of the cells with potash or ammonia, and the other with sea-water, a current of electricity was also produced, but this was of very feeble intensity, and might well be owing to traces of sulphur in the alkaline solutions.

The currents thus developed by gold, and in the same manner by platinum, in sulphide solutions soon ceased, but they were so well marked, and had such an apparent intensity, that I was induced to try if they had any effect upon certain metallic solutions, and on trial, I found that, in the case of that obtained by the use of gold plates in contiguous solutions of potash and sulphide of potassium, a degree of intensity was reached sufficient to decompose solutions of copper, silver and gold, and to deposit these several metals in adherent films upon proper electrodes. The same results were afterwards obtained with platinum.

This capability of gold and platinum to generate electrical currents under these circumstances—currents of such intensity as to exhibit true electrolytic effects—when taken along with the results of my former experiments on this subject, appear conclusive evidence in favour of the sulphurization of these metals being, as has been already urged, the result of chemical action.

OXIDATION OF GOLD.

I shall now proceed to a description and explanation of the phenomena, which I have discovered, when gold and silver are allowed contact with air and water, and which I was partly prepared for, by the results described above.

I shall treat, first of all, with silver. Placing a slip of silver, thoroughly cleaned, in ordinary spring water, and a second in distilled water, I kept them therein for twelve hours, and then dipped both in clean mercury. The clip from the distilled water refused to amalgamate, while that from the spring water completely amalgamated in a second. It was, however, remarked at the time, that even the silver from the spring water, tested by the side of a clip that had been kept dry, manifested a slight hesitation, as it were, to the process. Evidently before amalgamation could take place, some chemical combination had to be overturned by the mercury.

I found that silver which had been kept in distilled water until it became non-amalgamable, was rendered readily amalgamable by immersing it for a short time in spring-water. The same effect was also produced on the silver by ferrous sulphate, acetic acid, and alkaline chlorides, or by heating it to a temperature of about 500° F.

These results taken conjointly, signify, I think, that silver is a metal which oxidizes with far greater facility than we have hitherto considered possible.

Thus in the distilled water the silver appears to have oxidized, and afterwards, or simultaneously with this process, combined with carbonic acid to form a carbonate, which I have found by actual experiment, is only decomposed by mercury very slowly indeed, so that the silver coated in this way is practically non-amalgamable.

That amalgamation in the case of the clip from the spring-water not being *quite instantaneous*, shows that it had become coated with a film.

In dry air, silver remains clean, that is amalgamable; and I could not observe that sunlight exerted any effect in regard to these reactions.

The knowledge that silver is easily oxidizable in air and moisture, led me to extend my investigations to gold, the question arising, might not even it be affected by the same agencies?

The results of my experiments with gold may be briefly summarised as follows:—

1.—That gold immersed in spring-water for a few hours, or in water charged with neutral salt, refuses for a long time to amalgamate with mercury.

2.—That it is also passed to this condition by contact for about eighteen hours with distilled water.

3.—That it is also thus affected by being placed in contact, for a short time, with an aqueous solution of caustic or carbonated alkali or ammonia, at their boiling points respectively, or for a somewhat longer time, when the solution used is at a common temperature; also when ignited with carbonate of soda.

4.—That when put into this condition, as to its surface, it becomes readily amalgamable by a short contact with either weak acetic or hydrochloric acid; also by ignition.

5.—That it becomes non-amalgamable when allowed contact with weak sulphuric acid; also when fused beneath bisulphate of potash and borax.

These facts prove that gold is chemically acted upon when in contact with water or neutral saline solutions charged with air, and that this action is facilitated by the presence of alkaline substances, and especially when these are used hot instead of cold. It seems to me, therefore, there can be little doubt but that gold thus acted upon has been oxidized, and has afterwards combined with carbonic acid to form a carbonate of gold, which, having a yellow colour, would thus remain invisible.

THE AGENCIES WHICH HAVE BROUGHT THE GOLD INTO THE REEFS.

Having shown in the preceeding pages the reduction of gold from its acid or alkaline solutions by metallic sulphides, and its sulphurization and oxidation by ordinary agencies of air and water, we may now speak of the nature of those substances which are likely to have brought auriferous compounds into solution, and thus to put them in a condition favourable for their translation from the country rock into the reefs.

In regard to the sulphide of gold, Bischof has long since proved it to be soluble in alkaline sulphides; and since then Professor Eglinton has indirectly proved this for the sodic sulphide, by showing, as already stated, that even the metal itself is soluble in this salt.

The carbonate and oxide of gold are, I find, readily soluble in bicarbonates of the alkalies.

In testing I use thinly electro-gilded platinum or pyrites, according as to whether I wish for a minute quantity of gold—fixed or detached. By this means I can detect a disappearance of gold in sealed vessels, at common temperatures, containing carbonate of soda and free carbonic acid. The disappearance is, however, very slow, occupying about two years.

By this means, I found that hot solutions of carbonate of soda showed a marked solvent power on gold in twenty-four hours.

Sea-water, aqueous solutions of caustic potash, and strong solutions of sodic chloride, even after digesting gold for many hours, do not appear to have any effect upon it, nor does the addition of hydrochlorine acid to the salt alter the result.

Thus it is probable, that, in the alkaline sulphides, carbonate of soda, and carbonic acid, all very common in our rocks, we have the agencies necessary to dissolve the gold they contain, so that it can be transported to the reefs by those aqueous currents which are ever setting in that direction.

CONCLUSION.

In the foregoing pages I have set forth and discussed my own theory relating to the formation of gold in reefs, comparing it with the other popular theories on this subject.

I have shewn the very energetic decomposing power of metallic sulphides upon certain of the soluble salts of gold and silver; also the fact that the metal reduced in this way is electro-deposited, and that in a coherent form, upon the decomposing body itself. From these facts I have drawn the conclusion that these metallic sulphides are probably largely concerned in the production of native gold.

I have also proved that gold like the base metals is rapidly affected, in a chemical way, by certain of the constituents of air in conjunction with water, by which it becomes minutely corroded and as minutely enfilmed; and I have proved by direct experiment and legitimate deduction, therefrom, that the greater portion of the surfaces of natural gold are varnished over in this manner.

Thus I have marked down those invisible, but none the less formidable and real foes that we have to encounter, lurking neither in the mercury, nor in the sulphides, but upon the gold itself; foes that have to be destroyed before amalgamation can be thoroughly performed.

In mitigation of any errors that may have crept into my paper I may state that it was hurriedly prepared, at very short notice, and that many of the experimental results detailed therein have only just been obtained.

4.—THE PROPOSED CHEMICAL LABORATORY, AT THE UNIVERSITY OF SYDNEY.

By A. Liversidge, M.A., F.R.S., Professor of Chemistry and Mineralogy in the University of Sydney.

The need for proper accommodation for the Chemical Department of this University is one of very long standing, and it has been under the consideration of the Senate on many occasions for the past fifteen years. As far back as 1873, it was almost as near being an accomplished fact, as at the present time, and the buildings would doubtless have been put up long ago, had it not unfortunately been found that certain extra and temporary accommodation could be provided. This led to a series of makeshifts from year to year, of a very inconvenient character; fortunately no more are possible, so that there is now a chance of this department being suitably housed in a plain and unpretending building, but one which, I trust, will be internally adapted to the work to be carried on in it.

I have drawn many different plans to suit the various sites which have from time to time been chosen, and although the last selected site is not the best of them, it is very well adapted for the purpose, and, morever, has the advantage of being near to the physical, engineering and biological laboratories. This grouping of the scientific work and lecture-rooms will be a great convenience to the students, and prevent much loss of time, in passing from place to place.

The plans placed before you are the preliminary ones, intended for the use of the Colonial Architect in preparing working drawings, hence they may undergo some slight modifications, but no very material change is likely to be made. With the elevation I have not concerned myself, except in so far as regards the position of the windows and doors, since they have to be arranged in such a way as to suit the internal fittings, and the uses to which the rooms are to be placed.

The elevation is exceedingly plain, but as the money available for the building is comparatively small, it has been necessary to sacrifice external appearance. A far more pleasing and attractive building could, of course, easily have been designed by the architect., but architectural effects have had to give way to economy.

Particular attention has been paid to the fittings and small details, since in a chemical laboratory much inconvenience and loss of time is often entailed, by not paying sufficient attention to what might be considered as trifles. When absent on leave in 1878, and during last year, I took the opportunity to visit many of the principal European and American laboratories, as well as those in Japan; in this last there are some very good and well arranged laboratories, especially the new one in Tôkyô. The newer English laboratories are equal to the best I saw in any country, although not the largest; but it is by no means an unmixed advantage for a laboratory to be of great size.

GENERAL PLANS.—PLATE V.

The building is a plain rectangular one of brick and cement. All the principal accommodation for chemistry is on the ground floor, the mineralogy and metallurgy rooms being in the basement.

The main laboratory is a room seventy-two by thirty-six feet, with height of twenty-two feet in the central part. In this room all, except the very junior (principally medical) and research students, will be accommodated. At first it was intended to have separate rooms for qualitative and quantitative work, but the recollection of the advantages which I experienced myself at the old College of Chemistry in London, from being amongst students doing work of various kinds decided me to throw the two rooms into one, and, moreover, this arrangement has the further advantage that it is very much easier to instruct and superintend in one large room than in two or more separate ones, and fewer assistants are required.

A portion of the roof is left flat, for photographic and other experiments requiring direct solar light; a place of this kind is convenient too for experiments which are likely to give rise to explosions, or the emission of offensive smells or fumes. Connected with this flat roof it is proposed to have a small gallery to overlook the main laboratory for supervision during examinations.

Ordinary fire places are omitted, thus causing a considerable saving of space and expense, since it is intended to warm the rooms when necessary by moveable gas stoves placed in the recess under the draught cupboards. In this climate artificial warming is only required for a few days in the year, and then only to a very slight extent. In European laboratories it is necessary for almost the whole of the nine months or so that they are open.

For cheapness the walls are plastered instead of being covered with glazed tiles, as is now the practice in most of the new English laboratories. At the Central Institute, South Kensington, the staircase is built of glazed terra cotta, and the pillars are of the same, and at the Liverpool College of Chemistry the walls are lined with cream and gold coloured glazed bricks; certainly very clean, effective and artistic, but the cost is out of the question for a chemical laboratory in Sydney.

A small asphalted yard is provided at the south-west end for outdoor experiments, this will contain a large sink, and a good water supply for washing apparatus, and especially sulphuretted hydrogen generators. It is also intended to place the sulphuretted hydrogen gas-holder in this yard.

The east and west corridor is made wide, so that when any extension of the building is necessary it may be placed at this end, connected directly with the main building or indirectly by a light bridge; meanwhile it is intended to use the corridor for the reception of glass cases to hold apparatus and collections. A drain pipe runs down this and the other corridors, partly in case it should be necessary to fit them with working benches.

The floors are intended to be of wood, except where otherwise specified, as in the gas analysis and furnace rooms, and for neatness and cleanliness it is intended to have them varnished round the walls and benches. The ceilings throughout are to be of zinc, galvanised iron, or other incombustible material, plaster being unsuitable for a chemical laboratory. There is to be a small lavatory and hat room in the entrance porch.

It is intended to have all the interior woodwork varnished or polished, since paint, in a chemical laboratory, unless free from lead, is liable to be blackened by sulphuretted hydrogen.

A large cistern is to be provided in the roof, or if the funds will permit of it, in a turret or upper room, not only for a supply of water under pressure, but as a precaution against fire, fire hoses connected with this will be placed in the corridors and in all the principal rooms. All the gas and water pipes, speaking tubes, battery, telephone and electric light wires are arranged in channels along the floors, and down the angles of the rooms in such a way as to be readily accessible at all times; the covering boards, where such are necessary, being arranged to open on hinges; but wherever possible all pipes and wires will be left exposed as in the temporary chemical laboratory. It is proposed to take them from the ground floor to the basement down by the dust shoot, which will form a well passing from the turret to the basement. This well can also be utilized for the aspirator and compressed air tubes. It is proposed to use speaking tubes for communication between the different parts of the chemical laboratory, and the telephone for the same purpose to other parts of the University.

The gas and water pipes are to be so arranged and provided with shut off taps that repairs and alterations can be made in one part of the building without stopping the supply in all the other rooms. These taps will not be placed in the floor, as is often the case, but at a convenient height on the wall.

LIGHTING.

In some places it will be necessary to have roof lights, but in such cases the skylights are designed to receive their light as much as possible from the south, so as to exclude the direct rays of the sun and to keep the place as cool as possible in the summer; the skylights will also be utilized as ventilators. In the lecture room arrangements are made for readily darkening them, and in such a way as to be under the easy control of the lecturer.

Some of the windows are utilised as draught cupboards by enclosing the outer side of the lower sash, and the space underneath is intended for gas stoves, furnaces, etc. The flues connected with the window draught cupboards are carried down to below the floor level so that horizontal flues from the tables can be connected with them.

The windows are designed as free from obstructions as possible, so that they can be used with microscopes and other optical instruments. The lower part of the windows open with ordinary sashes, and the upper part on hinges to enable the rooms to be quickly cleared of noxious fumes. The window sills are of flat slate or stone slabs, so that a heliostat or other instrument can be placed outside the window.

In the Mineralogy rooms the doors and windows are, as far as possible, placed opposite to one another to allow a beam of light to be reflected through from room to room according to the position of the sun. The window sills are arranged to come down to an uniform height of three feet from the floor, *i.e.* at about the level of the top of the benches. Outer venetian blinds or inner shutters are to be provided for all the windows facing north and west and inner blinds for the other windows. The spaces under the lecture room galleries are lighted by the side windows and by thick-ribbed glass placed in front of the gallery tiers.

GENERAL LABORATORY

Along the west wall of the laboratory is a long slate bench forty-eight feet long. (Plates XI. and XII.) At one end is a Doulton-ware sink with the edge projected by wood and india-rubber, and a drying slope, with perforated drying rack over. Next to this is a self-feeding still for distilled water to supply about ten gallons a day. This is placed on a strong and firmly supported slate slab, inserted in the wall and raised some four feet above the bench so as to allow the distilled water to be conducted by gravitation through tin or glass pipes along the whole length of the laboratory, from a large glass receiver or plate glass cistern. (Plate XI.) The still is to be self-feeding, from the hot water overflow of the condensing or worm tub. As shown in the sketch (Plate XI.), the inlet tube is curved downwards; this is to prevent steam forcing its way into the condenser tub, as sometimes happens with a straight tube. The supply of water from the cistern is to be regulated by a ball tap or other suitable arrangement. To economise gas it is proposed to have a Fletcher's corrugated base to the still, and to enclose it in an iron casing or jacket as usual. The opening of the still head is made large for readily cleaning, and made to fit steam tight, by an outer screw collar or cap. The next part of the bench, about eight feet in length, is merely covered with a hood for use with gas furnaces for melting, combustion, and other purposes. Beyond the hood is an ordinary draught cupboard five feet six inches long by twenty-one inches broad, followed by two similar cupboards, one of which is fitted with five copper water ovens and baths combined, the space between the oven being packed with asbestos to prevent loss of heat. Each oven is provided with two sets of perforated covers and rings, so that they can be used for either large or small evaporating basins. (Plate XII.)

The water ovens are provided with large ventilators. As usually made the ventilation is quite insufficient, and the escape tube or flue, is far too small as well as too short. The doors contain a glass panel so that they can be looked into without opening the door, and thus unnecessarily lowering the temperature.

The third draught cupboard is fitted with a hot plate, and large water bath. Beyond this is a hood, similar to the first, for distillation and combustions. (Plate XII.) By this arrangement no student will have to go far from his place to fetch distilled water, or for the use of the water ovens, gas furnaces, etc.

The special re-agent shelves, etc., are placed between the draught cup-boards, so as to be readily accessible to all.

LECTURE ROOM.

The principal lecture-room is thirty-four by forty-seven feet, and has a height of twenty-two feet in the central part, the wall being sixteen feet high. The seats are arranged for one hundred and eighty students, but, if necessary, nearly two hundred can be accommodated. It is partly lighted by three windows at the side, and by a skylight facing south in the roof over the lecture table. The principal entrance is from the corridor, but in case it should be necessary to empty the room quickly, there is a second door on the opposite side. The two doors at the other end are to give access to the space under the gallery, which will be used as a preparation room or store for lecture apparatus. A direct entrance into this space is by a trap door and flight of steps from one of the middle tiers of steps. The upper portions of the windows open on hinges, so that ample ventilation should be obtained, and no other artificial ventilation will probably be necessary, beyond gas jets in the side flues. If the funds permit, it is intended to light this room by incandescent electric lamps, or by the Clammond or other incandescent gas burner. The Bower ventilating light is being much used in English laboratories, and may be substituted for one of the others.

The diagram screens of red baize are large and can be readily lowered. Other diagram frames, in the form of light iron gallows (Plate VII.), are provided for extra diagrams which do not require to be exposed during the whole of the lecture, as well as an easel stand, for heavy diagrams or pictures that cannot be hung.

The lecture table (Plate VIII.), of polished pine with teak top, is twenty-seven feet long and three broad, and is provided with an ample supply of gas and water, with leads for the electric light, also aspirators, air blasts, together wiih oxygen, hydrogen, and coal gas under water pressure from the cistern in the roof, thus doing away with the need for gas bags, and their inconvenient pressure boards. There are also six-inch down draught flues, provided with moveable trumpet-shaped cowls, so arranged that an experiment can be performed either in front of the hoods or under a glass hood, over the flues themselves. In the table there is also a glass pneumatic trough, which can be lighted at the back with gas at night, so that the students can see all the details of the experiment as readily as in the day time. On the opposite side of the centre of the table, and corresponding in position, is a mercury trough and tray.

Instead of using cane chairs, as at present, it is proposed to have the seats in the lecture rooms made of stout wire gauze, covered with Brussels carpet (Plate XIII.) as it is thought this will be more comfortable than the usual hard wood bench. It is true that lectures as a rule only last one hour, but then in the aggregate they may extend over three to four successive hours. The seats are numbered and separated by iron arms, the space allotted to each being twenty-one by thirty-six inches.

In many of the American University and College lecture rooms I noticed that each student had a separate wooden or cane-seated arm chair, with a writing board attached to the right arm; these, although very comfortable and convenient in many respects, take up rather more space than can be spared in the proposed building here.

The table in the draught closet at the back of the lecturer is moveable and runs on rails, so that it can be moved out into the lecture room or lecture preparation room. The top is of slate so that it can be used with gas furnaces for experiments upon combustions, cupellation, fusions, &c. Dropping down in front of this niche, or draught cupboard, is a large blackboard suspended by a heavy weight and levers so that it can be readily lowered, The one at Finsbury (fourteen feet by six feet six inches) is said to be so well hung that it can be moved by the little finger or even by the pressure of the chalk.

In front of the black board is a white screen for experiments with the electric lamp; this is to be suspended from copper-plated steel tapes running over large pulleys.

To obtain the benefit of the greater height, and to avoid the noise of the falling water in the lecture-room, the pump and aspirator tubes from the lecture-room will be taken down the well of either the rubbish-shoot or lift.

To the left of the black board is a small drying closet and sand bath, and on the other side a water oven and bath; these are let into the thickness of the wall with glazed sashes on both sides. In addition to the ordinary black board it is proposed to have a "roll up" black writing screen made of flexible material. All the windows have double blinds for darkening the rooms, the rollers of which are connected by a rod passing from window to window, so that one person can draw the three blinds simultaneously. If possible, the blinds to darken the skylights will also be connected by copper covered steel tapes with the same roller.

THE LECTURE PREPARATION ROOM.

This is intended to combine the conveniences of a special experimental laboratory for lecture purposes, and a workshop, as far as is requisite for chemical purposes. All the rougher chemical apparatus will be kept in it, and the collections which do not require extra care. In it will be placed the glass-blowers' table, lathe, carpenters' bench, and similar appliances, so that any repairs can be effected without loss of time—when things have to be sent away to a distant part of the building, delay often takes place and the repairs are apt to be left for a more convenient season, and too often are not ready when wanted, Also the storage cylinders for compressed hydrogen, oxygen, coal gas, and sulphuretted hydrogen and an extra deep sink.

Ample space is provided for washing and drying apparatus for distillations and similar operations.

COLLECTION ROOM AND MUSEUM.

The finer apparatus and collections of rarer chemicals are to be kept in the collection-room opening out of the lecture preparation room. And in this will be placed the diagram table and cabinet.

To avoid interfering, as far as possible, with the museum or students' collections it is proposed to have one case set apart for the specimens and special appliances required for each lecture, arranged in trays, ready to place out on the lecture table, The collections of carbon compounds will be arranged so as to show their derivation from the hydro-carbons and their relationship to one another.

CLASS ROOM.

This is a smaller lecture room to seat one hundred and thirty students for special courses of lectures and tutorial classes, it is arranged and fitted in a somewhat similar way to the large or principal lecture-room.

DEMONSTRATION ROOM FOR JUNIORS.

This room is thirty-six by thirty-four feet, and contains forty benches, each three feet nine inches by two feet (Plate IX.), arranged so that the whole face the demonstration table. Each bench is amply supplied with gas and water, and with an aspirator, The sulphuretted hydrogen supply is laid on to the large window draught cupboards, as well as to the benches; any escape of gas into the room will be prevented as far as posiible by connecting the exit tube with the aspirator or draught hood on each bench.

The draught cupboards in this room have already been described. When full, this class-room will probably want two demonstrators, one to illustrate and describe the experiments, and the second to assist those students who have not kept pace with the lecturer's experiments.

BALANCE ROOMS, AND LIBRARIES.

To ensure stability, and to avoid vibration from the floors, the balances are to be placed on slate slabs let into the walls. In each balance-room one or more glass cases are provided for books and apparatus ; the smaller and more delicate pieces being kept in cases arranged on the walls over the balances, There are also reading and writing tables provided, since these rooms will also have to serve as libraries for the various departments.

GAS ANALYSIS, SPECTROSCOPE, AND POLARISCOPE ROOM.

This room will have to be used for several different purposes, but to fit it for gas work, the floor is to be of asphalt with grooves sloping to one corner, so as to collect any mercury that may be spilt.

The tables in this room will all be grooved round the edges for the same purpose.

This room will also be used for photographic, photometric, and similar work, and will be fitted with blinds and shutters (with suitable openings) for darkening. Also with gas and water, a draught cupboard, and with a low work bench, so that the observer can be seated at his work.

METALLURGICAL LABORATORY.

In this room there is a group of two nine-inch and two twelve-inch wind furnaces, and of two muffle furnaces, (Plate X.) built according to the plans given in Percy's "Metallurgy" of Silver, except that they are cased completely with iron, and a hood is placed over to carry off the hot air and fumes which may arise. The iron casing allows the fire brick lining to be thinner, consequently the space occupied by the furnaces is reduced.

At the end of the room a slate bench, with hood over, is arranged for use with gas furnaces. It is proposed to have the gas engine, and crushing and grinding apparatus in this or in an adjoining room not shown in the plan. The other fittings are the ordinary character and require no special comment.

Opposite is the metallurgical laboratory and balance room; on this floor there is also a small metallurgical lecture-room, and a store for coarser chemical and metallurgical apparatus, acids, and re-agents. The coke, coal, wood, &c., for this department are kept in iron wheeled trucks so that they can be run out for filling. Ashes will also be removed in a similar iron truck.

STORE ROOMS.

These rooms are fitted with the necessary shelves and drawers for apparatus. There is also a sink and lead covered table for mixing acids, &c., in each. In the centre of each is a group of skeleton shelves for light and bulky apparatus.

MINERALOGY.

For this subject there is a small lecture room and a mineralogical laboratory off the mineralogy museum, The museum is intended to be simply a teaching collection, and not a general one, as it is thought unnecessary to have another, there being already one in the Australian Museum in College-street, and special mineral collections at the Technological Museum and in the Mining and Geological Museum at the Department of Mines.

PRIVATE LABORATORY.

There is nothing very special in this room, excepting that an effort has been made to make the most of a limited space—it provides accommodation for three or four workers.

The glass hood between the windows is unprovided with sashes and uprights, so as to leave the bench as clear as possible. The draught cupboard, eighteen feet long facing the windows (Plate XIV.) is supported on slate slabs, and is fitted with water-ovens, water-baths, hot plates, &c.

WORKING BENCHES.

Efforts have been made to combine the best features of those in use in other laboratories, and where possible to improve upon them. Shelves for re-agents are omitted altogether from the benches (Plate IX.) in the junior students' laboratory, and their place is supplied by moveable rack-trays, saturated with paraffin wax to prevent the action of acids. The shelves, as ordinarily arranged, obstruct the view of the laboratory, and they not only hide the students from the instructors, but what is of more importance, they hide the instructors from the students. It is most desirable that the students should be able to see the instructors from all parts of the room, so that they may be able to go to them for information at once, and without any unnecessary expenditure of time. There is, moreover, the additional advantage that fewer instructors are required.

The moveable racks for re-agents are less obstructive in other ways and occupy less space, since, when not required, they can be put away in the cupboard under the benches, thus leaving all the table top free for bulky apparatus—an important matter in the student's early work—when engaged upon experiments with the gases, afterwards when testing, the space occupied by the racks can easily be spared. At night they can be placed in the cupboard under lock and key.

The benches in the general laboratory (Plate VII.) are made fairly complete and convenient without being luxurious. Each student has the usual gas and water supply for working and distillation, and the use of one aspirator tap on the bench, and often of two. The sulphuretted hydrogen supply is to be brought to each bench from a gas-holder out of doors through ordinary small composition gas-piping, and in the draught cupboard this is finished off with a piece of three-quarter inch copper tubing for the insertion of a glass or ebonite tap (of small bore, one-eighth inch to one-twelfth inch, to prevent waste) through a perforated cork. By this means all permanently fixed metal taps are done away with—metal ones are objectionable from their liability to corrode and become fast. If an I.R. pinch-tap be used, the wide copper end is unnecessary. Although the central water-taps and sink are liable to be a source of splash and wet on the bench, they have been retained, but to prevent splashing as much as possible, a small inverted flower-pot, without a bottom, is placed in the sink, and an inward projecting rim of sheet indiarubber is placed round the basin's edge; this also tends to prevent breakage against the earthenware basin.

The lower end of the inverted flower-pot, *i.e.*, the real top, is closed by a perforated wooden or lead disc, so that the flower-pot can be used as a receptacle for matches, filter paper, &c. The ordinary earthenware rubbish receptacle is too large, takes up too much space, and is the cause of much broken apparatus in washing up.

The space in front of the basin is utilized as a cupboard for the two students in common.

Each student's table-top space is five feet by two feet three inches in the main laboratory, and if the laboratory is not full he can have a space ten feet long. For every four students there is a double draught cupboard on the working benches, two feet nine inches square, divided down the centre (Plates XV. and XVI.), affording sufficient space for all the ordinary operations of boiling, evaporation, &c., so that he has no need to leave his bench for such purposes. These draught cupboards are glazed at top and sides, and have draught flues leading downwards. But it will probably be found more convenient to use the upcast flue as in Plate VII.

The plan shows down draught tubes from the bench draught closets, as well as the upcast ones, so that the alternative arrangements may be fully considered before the final selection is made, and the fittings proceeded with.

Where these draught cupboards have moveable sashes, the weights are attached by copper-covered steel tapes, passing over pulleys down into tubes in the central longitudinal space, between the two halves of the cupboards left for the draught flue, gas and and water pipes, thus avoiding the necessity of reducing the openings of the cupboards by having weight boxes in the front. The front framing can thus be made solid and correspondingly narrower.

Attached to each bench is a small leather-covered iron seat, or rest, like a bicycle seat. This is supported on a strong iron bracket, moveable so that it can be turned on one side out of the way. The drawers are reduced to two, with suitable subdivisions, for it is found that the average student does not want more, and if he has more drawer space he does not properly use it, his apparatus is too scattered, and he wastes much time searching through all the drawers for some small article. The drawers are subdivided for corks, tubes, &c., and there is one provided with a moveable tray for blowpipes, files, and similar small articles, which can, if necessary, be taken out and placed on the bench. By this means the two drawers afford nearly as much real accommodation as the half-dozen usually provided.

A toe-space is left in front of the bench instead of giving it an overhanging top. The gas used for lighting the benches is made use of for ventilation also, the heated products of combustion passing into the ventilating flues from the bench draught cupboards. When not lighted there is a valve which can be closed to prevent the draught in the cupboards being spoilt; an advantage of the upcast draught is that the heat from operations carried on in the draught cupboard assists the draught, which is not the case when the draught is a down one. All the gas and simple water taps are made with lever handles, since they are more readily turned, and serve as guides to show how far the supply is turned on.

In the main laboratory every bench is provided with the following fixtures:—Two cupboards for each student, two drawers, subdivided, and with a tray; one draught cupboard for each pair of students, one basin for each pair of students, one sulphuretted hydrogen tap for each pair of students, an aspirator, water, and distillation water tap for each, adjustable book rest adjustable desk slope for note book, bicycle seat or rest, matchbox holder, ink well, name plate, shelves for re-agents, cast iron heating plate, three retort rings, three filtering rings to fit into slots in uprights of the draught cupboards (Plate XVII.), or to run on iron rods fitting into the bench top.

The draught in the flues is maintained by gas jets, impinging upon fire-clay domes.

It is intended to line the sheet-iron flues with asbestos board, well saturated with tar or other impervious substance, to preserve the iron from acid fumes as much as possible. The top of the benches are to be of teak, if possible, and grooved underneath like drawing boards to prevent warping from the damp of spilt liquids and the heat of the lamps; they are also to be saturated with paraffin wax.

A low rose burner (Fletcher's) with stand for sand plate, iron plate and asbestos, or evaporating basin, is placed for each student in the draught closets, so that he is not so much tempted to evaporate acid liquids outside, and thus fill the room with fumes. The gas jets in the draught closets for ventilation are to be made of steatite or fire clay, to prevent corrosion from acid fumes.

A cover is provided for the sink in the centre, in case a student should want a broad and open space to work upon. The receivers below the basins are of earthenware, since lead is apt to corrode very quickly. The overflow of these is arranged to be at least three inches from the top, otherwise any sudden flow of water into the basin causes an overflow in the basins below, and a consequent flooding of the floor (Plate VII.). If leaden basins should have to be used, they will be dished to prevent acid liquids remaining and causing corrosion. For the same reason it is intended to give all leaden gutters and drain pipes a good fall. If an open gutter be employed, one overflow receptacle to catch paper, matches, etc., will suffice. The drain pipes are disconnected from all soil pipes.

A master key is retained for all the benches. One lock does for each, since the drawers are fastened underneath by buttons and the sliding door is caught by the lock, so that the student has to use only one key. The retort rings, filtering rings, book rests, and writing slope, are attached to the draught cupboard by slots in metal plates attached to the uprights, the former inside as well as outside, these go nearly through the two-and-a-half inches of wood, so as to give firm and untwisting support. The draught cupboards are floored with white tiles.

DRAUGHT CUPBOARDS.

To save space in the width of the room, the large draught cupboards are built out from the windows. These are about four feet in height, and twenty-one inches deep from front to back. The window is divided into three, the lower sash rises as usual, the middle is fixed, and the upper part opens for ventilation. As each window is about four feet eight inches wide, good roomy draught places are obtained.

The draught is obtained by a gas jet in the flue by the side, each vertical flue ventilates two cupboards. The side walls are lined with white tiles, and the slate slab or floor forms a roof for a lower niche, serving for heating gas stoves, furnaces, etc., which discharge into a separate flue. This flue, in common with the others, when not in use can be closed by an iron door or damper.

It is proposed to hang the sash from copper-plated steel tapes working through stuffing boxes containing glass, wool, and paraffin, or vaseline, to prevent oxidation. Cords are an endless source of trouble, since the hemp or flax is rapidly acted upon by the acid fumes. All the gas taps are outside, and to each chamber there are two half-inch and two three-quarter-inch taps, with quadrant handles. Sulphuretted hydrogen is laid on to each, as in the case of the bench draught cupboard, and the draught is obtained by a Bunsen burner, with perforated fire-clay cylinder over it. These draught cupboards are large enough to serve as combustion niches, so that special ones for this purpose are unnecessary.

The flues from the draught cupboards are built out as pilasters, and form an ornamental architectural feature in the building both inside and outside. The flues from the draught cupboards are six inches by nine inches and fourteen inches by nine inches.

Those from the tables and lecture tables are six inches diameter in the clear, or about six and a-half inches outside, since the sheet-iron pipes are lined with asbestos cardboard saturated with sodium silicate, pitch or otherwise treated, to prevent corrosion of the iron.

To prevent leakage of fumes into the rooms from the window draught cupboards the sash is provided with felt cushions. India-rubber was tried by Dr. Armstrong at South Kensington, but found to be unsuitable for this purpose, as there was too much friction, and moreover the indiarubber became hard and decayed. All the wood work is thickly varnished, to prevent its being destroyed by acid fumes.

For the benches in the practical class room it is proposed to have six-inch flues proceeding downwards, with small moveable hoods or cowls with trumpet-shaped mouths, and arranged in such a way that evaporations can be carried on under them without much fume finding its way into the room. The cowls do not rise high enough to materially obstruct the view; they and the pipes leading from them will be made either of earthenware or of sheet-iron lined with asbestos board. The form (Plate IX.) is so arranged that the student will be able to see into the evaporating basin, even when it is under the hood.

Artificial draught by furnaces has been relinquished in England and on the Continents of Europe and America ventilating furnaces do well enough, since artificial warming is necessary for most of the year, but in Sydney this is not required.

Small openings are provided in the draught closets for admitting fresh air, so that it is not always necessary to raise the sash for that purpose.

It does not do to have the draught cupboards too large, otherwise the air is not changed quickly enough, and the fumes hang about inside. To facilitate their removal the upper part is made to slope inwards on all sides in the draught closets on the benches, and from the back in the window draught cupboards. The roof of the closets always presents more or less difficulty—wood is liable to warp, char, or catch fire, plaster falls down and slate cracks, iron rusts and scales off—but if not too low glass answers well enough.

At Strasbourg coarse iron-wire gauze, coated with cement, fixed in iron frames, is used. At the Finsbury Technical College galvanized iron thickly varnished is employed, but here I intend to try asbestos board.

The draught exit is made with a flattened trumpet mouth at a height of about twelve inches from the floor of the bench draught cupboards, so that an evaporating basin may be placed directly opposite to it. The minor openings into the draught-closets are made in front as usual, to keep the fumes away from the operator as much as possible.

SULPHURETTED HYDROGEN.

A gas-holder for the supply of this gas is placed outside. It is to be five feet in diameter by seven feet high, made of lead or stout sheet-iron, coated with well baked bitumen. The taps are all of ebonite or glass, let into one inch iron gas pipes, so that no galvanic action should be set up, as there would be between brass taps and the iron, where practicable indiarubber pinch taps will be used. The usual water space is reduced to a minimum, by an inner core or cylinder, and the liquid used is heavy kerosene oil. A drain is arranged from it to take off emptyings, &c.

FITTINGS.

A master key is to be provided for all doors as well as for all the bench locks. A centrally placed key cupboard will be provided for the keys of students' benches, to which they will be required to return their keys on leaving for the day. Amongst the fittings it is proposed to have a six-horse-power gas-engine to provide electric light, to drive the crushing and grinding apparatus, Chilian mill, blower, and exhaust, also to work the gas-liquifying and freezing apparatus, centrifugal dryer, and similar appliances now necessary in a modern laboratory.

Steam chambers supplied from a large boiler are not provided, on account of the little use there is for a steam boiler, the power required for grinding, dynamos, &c., being obtained from a gas-engine, but small moveable boilers or digesters will be supplied.

A small lift is provided to avoid carrying apparatus up and down stairs. All the principal doors are in two leaves, and four feet wide and nine feet high, to allow glass cases and large pieces of apparatus to be taken through readily. To keep out dust and dirt from the corrider swing doors are placed at the ends.

As many flues as possible have been arranged, since they are all sure to be required sooner or later, and they have been so arranged as pilasters as to form an essential feature in the architecture, especially in the long corridors. Between the pilasters in the corridors and lecture-rooms are placed brackets, upon which it is intended to have busts of some of the more distinguished founders of chemistry and the allied science, such as :—Avogadro, Berthollet, Berzelius, Bunsen, Brodie, Boyle, Black, Cavendish, Davy, Dumas, Dalton, Dulong, Faraday, Frankland, Graham, Gay, Lussac, Hales, Hofmann, Laurent, Lavoisier, Liebig, Margraff, Mitscherlich, Petit, Priestly, Roscoe, Stahl, Stas, Scheele, Thénard, Wollaston, Wöhler, &c.

5.—NOTES ON SOME AUSTRALIAN MINERALS.

6.—NOTES ON THE THUNDA METEORITE, QUEENSLAND.

By A. Liversidge, M.A., F.R.S., Professor of Chemistry and Mineralogy in the University of Sydney.

7.—BIBLIOGRAPHY OF THE CHEMISTRY OF INDIGENOUS AUSTRALIAN VEGETABLE PRODUCTS.

By J. H. MAIDEN, F.L.S., F.C.S., Curator of the Technological Museum, Sydney.

INTRODUCTORY NOTES.

THE genera have been arranged as in the "Census of Australian Plants," by Baron von Mueller, but differences of synonymy between that work and the "Flora Australiensis" have been noted. The New Zealand species have been placed in the same classification.

A few references to chemical researches on non-Australian species belonging to well-known Australian genera have been given, as they may prove suggestive. Such references are marked with an asterisk, and no attempt has been made to give a complete bibliography of them.

ABBREVIATIONS.

Wittstein.—"The Organic Constituents of Plants and Vegetable Substances and their Chemical Analysis," by Dr. G. S. Wittstein. Translation from the German by Baron von Mueller. Melbourne, 1878.

Gmelin.—"Handbook of Chemistry," by Leopold Gmelin. Watts, Cavendish Society.

Eucalyptographia.—"Eucalyptographia: a Descriptive Atlas of the Eucalypts of Australia," by Baron von Mueller. The numbers refer to the decades.

NYMPHEACEÆ.

*1. *Nymphœa alba*, Linn. (Water-lily).
*1. *Nuphar lutea*, Sm. (Water-lily).

Chemistry of the Nympheæceæ. W. Grüning, *Arch. Pharm.* [3] xx. 582-605, and 736-761; *Journ. Chem. Soc.* xliv. 369. [We have one *Nymphœa* and one *Nelumbium.*]

MONIMIEÆ.

1. *Atherosperma moschata*, Labill. (Victorian and Tasmanian "Sassafras.")

Resin of, Zeyer, *Pharm. Viertelj.* x. 517 ; *Gmelin*, xvii. 447.
2. Atherospermine (alkaloid). Zeyer, *loc. cit.* 513 ; *Wittstein*, 20 ; *Watts' Dict.*, vi. 231.
3. Atherospermatannic acid. Zeyer, *loc. cit.* 511 ; *Gmelin*, xv., 514 ; *Wittstein*, 21.
4. "On Essential Oils," J. H. Gladstone.
Part I., *Journ. Chem. Soc.* xvii. 1.
Part II., *op. cit.* xxv. 1, includes *Atherosperma moschata*, *Eucalyptus amygdalina*, *Eucalyptus oleosa*, *Melaleuca ericifolia*, *Melaleuca linariifolia.*
Part II. in abstr. *Pharm. Journ.* [3] ii. 687, 704, 745.
See also *Watts' Dict.*, vii, 871.

VIOLACEÆ.

*1. *Viola, spp.*
Occurrence of Salicylic acid in the Violaceæ. K. Mandelin, *Pharm. Journ. Trans.* xii. 627-8 ; *Journ. Chem. Soc.* xlii. 548.

PITTOSPOREÆ.

Pittosporum undulatum, Andr. ("Mock orange.")
1. Pittosporin. Glucoside of the bark and fruits. *Wittstein*, 175.

DROSERACEÆ.

*1. *Drosera intermedia*, (Sun-dew). The acid of. G. Stein, *Berichte*, xii. 1603 ; *Journ. Chem. Soc.* xxxviii. 36.
1. *Drosera Whittakeri*, Planch. (Sun-dew). E. H. Rennie, *Journ. Chem. Soc.* li.
2. E. H. Rennie, *Proc. R. S., S. A.* x. 72.

GUTTIFERÆ.

1. *Calophyllum inophyllum*, Linn. ("Ndilo tree"). Oil from the seeds of. *Gmelin*, xvii. 94.
2. Tacamahac resin obtained from. *Gmelin*, xvii. 430.

MELIACEÆ.

Melia azedarach, Linn. (White Cedar).
1. J. Jacobs, *Amer. Journ. Pharm. Sept.* 1879 ; *Journ. Pharm.* [3] x. 245.
1 *Cedrela febrifuga*,* Bl. (from Java). Bark of. W. Lindau, *Jahresb.* 1861, 768 ; *Watts' Dict.* vi. 418.

RUTACEÆ.

Murraya exotica, Kōen. ("China Box").
1. Glucoside, etc. *Watts' Dict.*, vi. 841. Also, De Vrij, *J hresb.* 1876, 850 ; *Watts' Dict.*, viii. (2.) 1343.
Xanthoxylon senegalense, alkaloids from the bark of Giacosa and Monari, *Gazzetta Chemica Italiana*, xvii. 362-7 ; *Journ. Chem. Soc.* liv. 167.

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* A synonym of *C. toona*, Roxb, a tree stated by Bentham to be identical with our Red Cedar (*C. australis*, F. v. M.)

MALVACEÆ.

1. *Adansonia Gregorii*, F. v. M. ("Cream of Tartar tree.") Adansonin. The bitter principle of the bark of, and *A. digitata*, Linn. *Wittstein*, p. 6.

STERCULIACEÆ.

Sterculia fœtida, Linn.

* 1. Oil of the seeds of, Lepine. *Gmelin*, xvii. 99.

EUPHORBIACEÆ.

1. *Petalostigma quadriloculare*, F. v. M. ("Crab-tree," "Native Quince.") Falco. *Chem. Cent.* 1867, 142; *Watts' Dict.*, Suppl. i. 904.
1. *Aleurites triloba*, Forst. ("Candle-nut"). Composition of. G. Nallino, *Gazzetta Chemica Italiana*, ii. 257-262; *Journ. Chem. Soc.* xxvi. 85; *Watts' Dict.*, vii. 239.

[This species is best known from India and the Pacific Islands, but it is also indigenous in Queensland. Several researches have been published on this plant.]

Mallotus phillipinensis, Muell., Arg., Syn. *Rottlera tinctoria*. Roxb. ("Kamala" of India). *Watts' Dict.*, v. 118, under *Rottlera*.

URTICEÆ.

1. *Ficus rubiginosa*, Desf. ("Port Jackson fig.")

On the resin of *Ficus rubiginosa*, and a new homologue of Benzylic alcohol. Warren de la Rue and Hugo Müller, *Phil. Trans.* 1860, 43; *Journ. Chem. Soc.* xv. 62; *Watts' Dict.*, ii. 646, and v. 645 (*Sycocerylic acid*, etc.).

See *Gmelin*, xvii. 43, for fuller bibliography.

CORIARIEÆ.

1. *Coriaria ruscifolia*, Linn. "The extraction of the poisonous principle of the Tutu plant." W. Skey. *Trans. N.Z. Inst.* ii. 153; *Pharm. Journ.* [3] i. 565; *Watts' Dict.*, vii. 391.
2. "Certain properties of the Tutu plant." H. G. Hughes, *Trans. N.Z. Inst.* iii. 237; *Pharm. Journ.* [3] ii. 282 and 302.
3. Cf. also "Note on Tutu." T. H. Hustwick, *Pharm. Journ.* [3] xv. 22.

SALSOLACEÆ (CHENOPODIACEÆ.)

1. *Atriplex nummularium*, Lindl.
1. *A. campanulatum*, Benth.
1. *Kochia pyramidata*, Benth.

Chenolea bicornis ? = Bassia bicornis.

"On Salt-bush and Native Fodder Plants of New South Wales. W. A. Dixon, *Proc. R.S., N.S.W.* 1880, 133.

*1. *Chenopodium ambrosioides*, Linn. Mexico. Oil of. *Gmelin*, xiv. 366., where see Bibliography; *Watts' Dict.*, i. 867, for this and other species.

1. *Salsola Kali*, Linn., and other species. Ash analysis. *Watts' Dict.*, v. 176.

FICOIDEÆ.

Mesembryanthemum crystallinum, Linn. (in B. Fl., not in Cens.) ("Pig's-face.")

1. "On the watery secretion of the leaves and stems." A. Völcker, *Phil. Mag.* xxxvi. 377.
2. H. Mangon, *Compt. Rend.* xcvi. 80-3; *Journ. Chem. Soc.* xliv. 499.
3. E. Heckel, *Compt. Rend.* xcvi. 592-4; *Journ. Chem. Soc.* xliv. 680.

POLYGONACEÆ.

Muehlenbeckia Cunninghamii, F. v. M. ("Polygonum.")

1. Tannin in. Tate, *Proc. R.S.,S.A.* vi. 175.

LEGUMINOSÆ.

Acacia, spp.

Tannic acid in the barks of several species. J. H. Maiden, *Proc. R.S., N.S.W.*, 1887. Analyses of barks and leaves belonging to numerous other genera, appertaining to various natural orders, *loc. cit.*

MYRTACEÆ.

1. *Melaleuca linariifolia*, Smith (A "Tea-tree").
   See *Atherosperma moschata.*
1. *Melaleuca ericifolia*, Smith (A "Tea-tree").
   See *Atherosperma moschata.*
   Cajeput oil is yielded by an Asiatic species of *Melaleuca.*
1. *Eucalyptus amygdalina*, Labill.
   See *Atherosperma moschata.*
   See also *E. globulus.* (Oils.)
1. *Eucalyptus doratoxylon*, F. v. M. ("Spear-wood.)
   Leaves. *Eucalyptographia*, iv.
1. *Eucalyptus dumosa*, A. Cunn. (A "Mallee.")
   Lerp manna. 13.8 % Inulin from the same. Th. Anderson, *Journ. für prackt. Chemie.*, xlvii. 449; *Edin. N. Phil. Journ.* vii. 136.
   Gmelin, xv. 113-4.
2. Flückiger, *Arch. Pharm.* [2] 146, 543; *Watts' Dict.*, vii. 733.
1. *Eucalyptus globulus*, Labill. ("Blue Gum" of Tasmania and Victoria).
   Examination of the leaves.
   A. Rabuteau, *Compt. Rend.* lxxv. 1431; *Journ. Chem. Soc.* xxvi. 403; *Pharm. Journ.* [3] iii. 463. Proving that they contain no basic principle analogous to the alkaloids.
2. Report of Mr. Broughton, Government Quinologist at Ootacamund, India, to Government. Quoted in *Pharm. Journ.* [3] iv. 150. Same result as Rabuteau.

3. Resinous extract of the old leaves. P. A. Hurtzer, *Deuts. Chem. Ges. Ber.* ix. 314-316 : *Journ. Chem. Soc.* xxix. 942 : *Watts' Dict.*, viii. (1) 762.
4. F. A. de Hartzen, *Compt. Rend.* lxxxi. 1248-9 ; *Journ. Chem. Soc.* xxix. 615.
5. Analysis of wood and leaves. *Eucalyptographia*, vi.
   See also *E. rostrata.*
6. "Chlorophyll from *E. globulus.*"
   E. Schunck, *Chem. News*, xxxi. 32 ; *Journ. Chem. Soc.* xxxviii. 894.

The following researches on Eucalyptus oil are, in some cases, but doubtfully referred to *E. globulus* (in spite of the nomenclature of the authors), as the name "globulus" has become quite generic in some quarters. Some of the papers refer to the oils of more than one species, but they are placed here for convenience.

7. Eucalyptol.
   Clöez, *Ann. Ch. Pharm.* cliv. 372 ; *Watts' Dict.*, vii. 493.
8. Eucalyptol.
   Faust and Homeyer. Proving the Eucalyptol of Clöez to consist of a terpene mixed with cymene. *Deuts. Chem. Ges. Ber.* vii. 63-6 ; *Journ. Chem. Soc.* xxvii. 475 ; *Watts' Dict.*, viii. (1) 761.
9. Eucalyptus Oil. Faust and Homeyer, *Deuts. Chem. Ges. Ber.* vii. 1429-30 ; *Journ. Chem. Soc.* xxviii. 371 ; *Watts' Dict.*, viii.(1) 761.
10. Oil of *E. globulus.*
    I. Homeyer. *Arch. Pharm.* [3] v. 293 ; *Journ. Chem. Soc.* xxix. 244 ; *Pharm. Journ.* [3] vi. 786.
11. Preservative properties of Eucalypts. Thomas Taylor, *U. S. Agriculture Report*, 1876-82 ; *Pharm. Journ.* [3] viii. 545.
12. Eucalyptol. E. Jahns, *Berichte*, xvii. 2941-4 ; *Journ. Chem. Soc.* xlviii. 394.
13. Oil of *E. globulus.* R. Voiry, *Compt. Rend.* cvi. 1419-21 ; *Journ. Soc. Chem. Ind.* vii. 516 and 585 ; *Journ. Chem. Soc.*, liv. 961 ; *Bull. Soc. Chim.* l. 106 ; *Journ. Soc. Chem. Ind.* vii. 764,
14. Eucalyptus Oils. P. MacEwan, *Pharm. Journ.* [3] xvi. 272.
15. Oil of *E. globulus and E. amagdalina.* O. Wallach and E. Gildmeister, *Annalle.* ccxlvi. 265 ; *Journ. Chem. Soc.* liv. 1205.

1. *Eucalyptus maculata.* Kino of. E. N. Grimwade, *Pharm. Journ.* [3] xvi. 1102.

1. *Eucalyptus oleosa*, F. v. M. (A "Mallee.") See *Atherosperma moschata.*

1. *Eucalyptus Planchoniana*, F. v. M. Kino of. *Eucalyptographia*, iv. *Eucalyptus rostrata*, Schlecht. ("Red Gum.")

1. "Analyses of the ash of the wood of two varieties of the Eucalyptus." The two *species* are *E. rostrata* and *E. globulus*. *Journ. Chem. Soc.* xxxvii. 416.
2. Wood, leaves, bark (analyses). *Eucalyptographia*, iv.
1. *Eucalyptus viminalis*, Labill. Manna. Copious bibliography under *E. viminalis*. *Eucalyptographia*, x.
2. Melitose, first recognised as a distinct substance by Johnston in some manna from Tasmania. *Mem. Chem. Soc.* i. 159; *Phil. Mag.* xxiii. 14; *Journ. für prackt. Chem.* xxix. 485; *Gmelin*, xv. 296-7; *Watts' Dict.* ,iii. 869.
3. Melitose (Berthelot). *Ann. Ch. Phys.* [3] xlvi. 66.
4. Eucalyn (Berthelot). *N. Ann. Chim. Phys.* xlvi. 72; *Chim. Org.* Paris 1860, ii. 250; *Gmelin*, xv. 298; *Watts' Dict.* ii. 601.
1. *Eucalyptus, spp. div.* Kinos. Dr. Wiesner, *Zeitsch. d. Allg. Oesterr. Apotheker. Vereines.* 1871; Abstr. *Pharm. Journ.* [3] ii. 102.
2. Miscellaneous analyses of tannic acid in kino, bark, and leaves, scattered throughout *Eucalyptographia.*
3. Essential Oils. Report on Class iii (Vegetable substances), *Victorian Exhibition*, 1861.
4. Tannic acid in the leaves and bark of several species. J. H. Maiden, *Proc. R. S., N.S.W.*, 1887.
1. *Eugenia australis*, Wendl, (a syn. of *E. myrtifolia*, Sims). De Luca a Ubaldini, *Journ. Pharm.* [4] iii. 44; *Watts' Dict.*, vi. 608.

UMBELLIFERÆ.

Hydrocotyle asiatica, Linn.

1. Contains bitter principle (Vellarin). Lepine, *Journ. Pharm.* [3] xxviii. 47; *Gmelin*, xviii. 243, where a fuller bibliography is given.

SANTALACEÆ.

Leptomeria acida, R. Br.

1. "On the acids of the Native Currant." E. H. Rennie, *Proc. R. S., N.S.W.*, 1880, 119.

PROTEACEÆ.

Grevillea robusta, A. Cunn. ("Silky Oak.")

1. Gum-resin. G. Fleury, *Journ. Pharm.*, [5] ix. 479-80; *Journ. Chem. Soc.* xlviii. 238.

RUBIACEÆ.

Morinda citrifolia, Linn.

1. "On the colouring matter of *M. citrifolia*." Th. Anderson., *Edin. Phil. Trans.* xvi. 335.
2. Morindin. Yellow dye of the root. *Wittstein*, 132.

*1. *Galium aparine*, Swartz, and
1. *G. verum*, Linn. ("Goosegrass.") Rubichloric acid in. *Gmelin*, xvi. 66.

COMPOSITÆ.

1. *Brachyglottis repanda*, Forst.
1. *B. rangiora.**
   "On a search for the poisonous principle of." W. Skey, *Trans. N.Z. Inst.* xiv. 400.

GENTIANEÆ.

*1. *Erythræa centaurium*, Pers. Ferment oil of. Büchner, *Repert.* liii. 299; *Gmelin* xiv. 405.

MYRSINEÆ.

1. *Corynocarpus lævigata*, Forst.
   "Preliminary notice on the isolation of the bitter substance of the nut of the Karaka tree." W. Skey, *Chem. News.* xxvii. 190; *Trans. N. Z. Inst.* iv. 316. See also *Trans. N.Z. Inst.* ii. 155.

APOCYNEÆ.

* *Alyxia Reinwardtii*, Blume, from Java. A camphor from the inner surface of the bark of. *Gmelin*, xiv. 337.

* *A. aromatica*, in *Watts' Dict.*, 1. 113.
(I cannot trace this specific name).

Alstonia constricta, F. v. M. ("Bitter-bark.")

1. Alkaloids of, Palm. *Jahresb.* 1863, 615; Wittstein's *Viertel. Jahresb. f. pr. Pharm.* xii. 161; *Gmelin*, xviii. 214.; *Watts' Dict.*, vi. 101.
2. Alkaloids of, Oberlin and Schlagdenhauffen. *Pharm. Journ.* [3] x. 1059-60; *Journ. Chem. Soc.* xxxviii. 127.
3. Alkaloids of, O. Hesse. *Annalen der Chemie.* ccv. 360-371; *Journ. Chem. Soc.* xl. 623; *Pharm. Journ.* [3] xi.775.
4. Alkaloids of, O. Hesse. *Deuts. Chem. Ges. Ber.* xi. 1546, and 1753-4; *Journ. Chem. Soc.* xxxvi. 269, also *Berichte*, xi. 2234-5; *Journ. Chem. Soc.* xxxvi. 332.
5. Alkaloid of, (Alstonin). *Wittstein*, p. 330.
6. See also *Pharm. Journ.* [3] ix. 1059.
7. Alstonine (Chlorogenine) Merck's *Bulletin* i. (5). 1888; *Journ. Soc. Chem. Ind.* vii. 866.

* *Alstonia spectabilis.* O. Hesse, *Annalen der Chemie*, cciii., 170; *Pharm. Journ.* [3] xi. 369.

*1. *Alstonia scholaris*, *R. Br.* ("Dita" bark.) J. Jobst and O. Hesse, *Annalen der Chemie*, clxxviii. 49-79; *Journ. Chem. Soc.* xxix. 276; *Pharm. Journ.* [3] vi. 142; *Watts' Dict.*, viii. (1) 688.

[An exhaustive research on a bark, which, although indigenous in Queensland, is best known in India and the Archipelago, It has been examined by many other chemists, the following investigation being the most important:—

* This name is not in the *Handbook of N.Z. Flora* of Hooker.

*2. O. Hesse, *Annalen der Chemie.* cciii. 144; *Pharm. Journ.* [3] xi. 331. (A farther bibliography is also given, *loc. cit.*)

SOLANACEÆ.

Duboisia myoporoides, R. Br. (A "Corkwood.")

1. Duboisin (Alkaloid). *Wittstein*, 331.
2. Duboisine. A. Ladenberg, *Beriehte*, xiii. 257-58; *Journ. Chem. Soc.* xxxviii. 675.
3. "Alkaloid of *Duboisia myoporoides.*" A. W. Gerrard, *Journ. Pharm.* [3] viii. 787-90.
4. Crystallised Duboisine. A. W. Gerrard, *Pharm. Journ.* [3] xi. 383.

Duboisia Hopwoodii, F. v. M.

1. "Preliminary Examination of Pituri or Pitchere." A. W. Gerrard, *Pharm. Journ.* [3] ix. 251.
2. "The Alkaloid of Pituri. A. Petit, *Pharm. Journ.* [3] ix. 819.
3. "The Alkaloid from Piturie." A. Liversidge, *Proc. R S., N.S.W.* 1880, 123; *Pharm. Journ.* [3] xi. 815.

SCROPHULARINEÆ.

Gratiola officinalis, Linn.

*1. On the proximate principles of the Water-hyssop (*G. officinalis.*). G. F. Walz, *N. Repert. Pharm.* vii. 543; *Journ. Pha rm.* [3] xxxv. 231; *Watts' Dict.*, ii. 942.

EPACRIDEÆ.

1. *Epacris, sp.* "Alcoholic extract of leaves of a species of *Epacris* from Australia." Rochleder a. Tonner, *Jahresb.* 1861, 773, 1866, 694; *Watts' Dict.*, vi. 580.

1. *Coprosma grandiflora* (*? grandifolia.*), Hook. f.
"On the examination of the bark of *Coprosma grandiflora* for alkaloids." W. Skey, *Trans. N.Z. Inst.* ii. 152.

CONIFERÆ.

Dammara australis, Lamb.

1. "Kauri gum." R. D. Thomson, *Ann. Ch. Phys.* [3] ix. 499; *Watts' Dict.*, ii. 301.
2. "Note on New Zealand Kauri Gum." M. M. Pattison Muir, *Journ. Chem. Soc.* xxvii. 733; *Watts' Dict.*, viii. (1). 625.
3. "On New Zealand Kauri Gum." E. H. Rennie, *Journ. Chem.* Soc. xxxix 240.
4. "Kauri Resin." Julius Morel, *Pharm. Journ.* [3] ix. 714.
5. "Australian or New Zealand Dammar Resin. *Gmelin*, xvii. 335-6.

*1. *Dammara alba.* Rumph. ("Dammar.") Indian Archipelago. *Gmelin*, xvii. 334, where see excellent bibliography. This and the last resin are dealt with together in *Gmelin.*

*2. See also *Pharm. Journ.* [3] ix. 714; and *Watts' Dict.*, ii. 301.

*1. *Araucaria brasiliensis.* A. Rich, Resin, and products therefrom. Peckholt, *N. Br. Arch.* cxxii. 225; *Gmelin*, xviii. 19 and 20; *Watts' Dict.*, vi. 190

*1. *Podocarpus cupressinæ*, var. *imbricata*. Bl., Resin. Oudemans, *Berichte*, vii. 1122, 1125 ; *Liebig's Annalen*, clxx. 213 ; *Watts' Dict.*, viii. [2] 1657.

CYCADEÆ.

Macrozamia spiralis. Miq. (Syn. "*Encephalartos spiralis* Lehm.) (" Burrawang.")

1. " On *Macrozamia spiralis*, with figs. F. Milford, *Proc. R.S., N.S.W.*, 1876, 295.

ORCHIDEÆ.

1. *Sturmia* (*Liparis*) *reflexa*, F. v. M.
1. *Dendrobium Kingianum*, Bidwill.
1. *D. linguæforme*, Swartz.
1. *D. Hillii*. (I do not know what plant is intended by this obsolete name. *D. Hillii*, F. v. M. = *Sarcochilus Hillii*, F. v. M., while *D. Hillii*. Hook, is a slight var. of *D. speciosum*, Sm., the "Rock-lily." The present is a suitable occasion to point out the unwisdom of omitting authors' names with specific names. The author's name is, in fact, part and parcel of the species name.)

"On the Ashes of some Epiphytic Orchids." W. A. Dixon, *Proc. R.S., N.S.W.* 1882, 175.

DIOSCORIDEÆ.

Dioscorea sativa. Linn. "Yam."

In *Watts' Dict.*, ii. 335, 23 per cent. of starch is given for this species, while *D. bulbifera*, Forst. (merged in this species) is only credited with 10 per cent. *Pharm. Journ.* vi. 23. In *Watts' Dict.* (loc. cit.) full analyses of *D. batatas* are given.

LILIACEÆ.

Smilax glycyphylla, Smith. ("Native Sarsaparilla.")

1. Glycyphyllin. Glucoside of the leaves. *Wittstein*, 230.
2. " Note on the sweet principle of *Smilax glycyphylla*." C. R. Alder Wright, and E. H. Rennie, *Journ. Chem. Soc.* xxxix. 237 ; *Pharm. Journ.* [3] xi. 808.
3. "Glycyphyllin, the sweet principle of *Smilax glycyphylla*." E. H. Rennie, *Journ. Chem. Soc.* xlix. Dec. 1886.
4. Notes on the sweet principle of *Smilax glycyphylla*." E. H. Rennie, *Proc R.S., N.S.W.* xx. 211.

*1. *Smilax glauca*. Walt. Constituents of the rhizome. John Blankenhorn, *Amer. Journ. Pharm.* May, 1879 ; *Journ. Pharm.* [3] x. 204.

Phormium tenax, Forst. ("New Zealand Flax.")

1. Further report on the chemistry of. A. H. Church, *Trans. N.Z. Inst.* vi. 260.
2. Difference between New Zealand flax and flax and hemp. E. Fitzherbert, *Bull. Soc. Chim.* [2] xxi. 545 ; *Watts' Dict.*, viii. (1) 792.

Dracæna australis, Carbohydrate from. Ekstrand and Johanson, *Berichte*, xx. 3310; *Journ. Chem. Soc.* liv. 246.

TYPHACEÆ.

Typha augustifolia, Linn. ("Bullrush" or "Cat's Tail.") Ash. *Watts Dict.*, v. 930.

JUNCACEÆ.

Xanthorrhœa hastilis, R. Br. (A "Grass tree.")

1. "On Botany Bay Resin." Prof. Lichtenstein, in *Crell's Journal*, 1799, quoted by Dr. T. Thomson in *Chemistry of Organic Bodies (Vegetables)*, 1838.
2. Amount of picric acid obtained from Botany Bay resin. P. Botley, *Chem. Gaz.*, 1859, 136.
3. Observations on the resin of the *Xanthorrhœa hastilis*, or yellow gum-resin of New Holland. Stenhouse, *Chem. Soc. Mem.* iii. 1845-8, 10-12; *Pharm. Journ.* vi. 88.
4 The Yellow-resin of Botany Bay. *Gmelin*, xvii. 386, where further bibliography is given.

**Xanthorrhœa arborea*,* R. Br. ("Grass-tree.")

1. Volatile oil of Botany Bay resin. Trommsdorff, *Taschenberg*, 1826, 9; *Gmelin*, xiv. 362.

Xanthorrhœa, spp.

1. "On bromine absorptions." Mills and Muter, *Journ. Soc. Chem. Ind.* iv. 96. Resins of various species of Xanthorrhœa are experimented upon amongst others.
2. "Notes on the Xanthorrhœa resins." J. M. Maisch, *Amer. Journ. Pharm.* May 1881; *Journ. Pharm.* [3] xi. 1005.
3. "Acaroid Resin." *Watts' Dict.*, vi. 2.
4. Paraoxybenzoic acid. *Watts' Dict.*, vi. 898.

CYPERACEÆ.

*1 *Cyperus esculentus*, Linn. Analysis of "Earth-chesnuts," the root-nodules, cultivated in Arabia for food. Ramon Torres y Luna, *Ann. Ch. Pharm.* lxxviii. 370.

*2 On the chemical nature of Chufa. By the same, *Ann. Ch. Phys.* [3] xxxv. 194.

*3. See also Semmola, *J. Chim. Méd.* xi. 256; and *Watts' Dict.*, ii. 299.

1. *Scirpus lacustris*, Linn. ("Bull-rush"). Ash. *Watts' Dict.*, v. 206.

FILICES.

1. *Alsophila australis*, R. Br. ("Tree-fern.")
   "On the occurrence of Aluminium in certain vascular cryptogams." A. H. Church, *Proc. R. S.*, 26th April 1888. Abstr. in *Nature*, 7th June, 1888. Besides this species it also includes :—

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*In spite of the specific names given in the memoirs themselves, it is doubtful if they are absolutely correct. There is much difficulty in collecting *Xanthorrhœa* resins true to name.

1. *Cyathea medullaris*, Swartz.
1. *Pteris aquilina*, Linn. ("Brake fern" or "Bracken.")
"Stenhouse's alkaloid" from. *Ann. Pharm.* lxx. 200; *Gmelin*, x. 410.
2. Pteritannic acid and derivatives. Luck, *Jahrb. prackt. Pharm.* xxii. 173; *Gmelin.* xv. 500-4; *Watts' Dict.*, iv., 745.
1. *Asplenium nidus*, Linn. ("Bird-nest fern.")
1. *Platycerium alcicorne*, Desv. ("Elk-horn fern.")
1. *P. grande*, J. Smith. ("Stag-horn fern.")
"On the inorganic constituents of some Epiphytic ferns." W. A. Dixon, *Proc. R. S., N.S.W.*, 1881, 175.

8.—ON THE ACTION OF THE NEPEAN WATER ON TUBES AND BOILER PLATES, WITH SOME REMARKS ON CORROSION GENERALLY.

By William M. Hamlet, F.I.C., F.C.S., Analyst to the New South Wales Government, Sydney.

A water of undoubted purity, so far as regards its use for dietetic purposes, may still be unsuitable for steam boilers, especially those complex tubular boilers of modern construction where dissimilar metals in contact, are frequently exposed to its continuous action. Such a water is that used for the water supply of the city of Sydney. This water may be justly described as a non-polluted upland surface water, derived from non-calcareous strata.

The sanitary-chemical analysis of the water is as follows: the figures being the mean of a series of analyses made at different periods—

	Results expressed in	
	Grains per gallon.	Parts per 100,000.
Appearance in two-foot tube	Slight peaty tint	
Odour on heating to 100° Fah.	none	
Chlorine as chlorides	2.40	3.42
Phosphoric acid in phosphates	none	
Nitrogen in nitrates and nitrites	·010	.015
Do. equivalent in nitric acid	.047	.0675
Do. existing as free ammonia	.000	.000
Organic nitrogen, or 'albuminoid ammonia' ...	.007	.010
Oxygen absorbed in 15 minutes at 80° Fah. ...	.042	.060
Do. 4 hours do	.064	.092
Hardness in degrees, Clark's Scale, before boiling ...	4.5	—
Do, do. do. after do. ..	2.8	—
Poisonous metals	none	
Total solid residue dried at 220° Fah.	7.01	10.01

ANALYSIS OF THE TOTAL SOLIDS.

Sodium chloride	4.100 grains.
Organic matter and carbon di-oxide (loss) ...	1.812 ,,
Silica	.008 ,,
Iron, alumina	.062 to .25
Magnesium chloride	.953
Sodium sulphate	traces
Carbonate of lime	.065
	7.000

Little information can be directly derived from these analyses as to its specific action on steam boilers, and in such cases the analyst has often to gain his information from the incrustation or corrosion produced, as the case may be. Analysis, moreover, does not throw much light in some obscure cases of corrosion, and the action of a water can only be known by actual experiment with the metals themselves.

Having frequently to examine and report upon various samples of water as to their suitability for use in steam boilers, I have hitherto been in the habit of estimating the amount of total solids in a gallon, and then, by calculation, the quantity in a hundred and in a thousand gallons respectively, according to the *amount* of total saline matters present, Then, upon analysis of the solids, a fair idea may be obtained as to the incrusting or scale-producing or corrosive properties of the water. The presence of the sulphates and carbonates of the alkaline earths are set down as incrustants, while alkaline salts and organic matter are likely to produce injurious sludge or corrode the plates by various means.

The relative amounts obtained of each of the above ingredients pretty fairly determine the suitability of water for steam raising.

The Colony of New South Wales, however, spreading, as it does, over a great extent of territory, furnishes various samples of water of almost every possible variety. Some of these give results that perplex the analyst and which sometimes cannot be brought under the rule I previously held to, namely, deductions based on the analysis of the total solids.

In addition, therefore, to the methods of ordinary quantitative analysis, I would point out that I find it necessary in many cases to extend my chemical examination so as to include the following tests, which are, in some obscure cases, the only means, I believe, by which the analyst can judge of the fitness of a given sample of water :—

I. A separate evaporation of the water in vacuo.
II. Estimation of the dissolved gases.
III. The character of the water as an exciting agent when a voltaic couple is placed in the sample for a given time.

IV. Means of ascertaining the amount of dissociation of the solids at temperatures above the boiling point of water.
V. Practical corroding test.
VI. Practical incrusting or scale test.

By the analysis of the water under consideration it will be seen that the latter contains only some seven grains of total solid matter. This consists of organic matter of a peaty nature, and mineral matter consisting of alkaline chlorides and chlorides of the alkaline earths. Nitrates are also present, the amount being somewhat under .05 grain of HNO_3 per gallon.

Concentration by heat, *i.e.*, evaporation at the ordinary atmospheric pressure, decomposes the nitrates to some extent, so that concentration in vacuo is necessary to ensure the correct estimation of the nitrates from a residue, the estimation of the nitrates by Schultz' or Schlœsing's methods invariably yielding higher results.

The reduction of the nitrates in boilers at high pressures brings about the dissociation of the salts and consequent corrosion of the boiler plates, Water heated in sealed tubes with iron show this in a marked degree. The action, moreover, takes place at the ordinary temperature and pressure, time being of course an important factor in the phenomenon.

The water was found to exert a decidedly corrosive action on iron plates at all temperatures between 60° and 212° F. at the common atmospheric pressure. A quantity of iron weighing 106.146 grains was placed into a pint of boiling water and maintained at the same temperature and pressure for one hour. The loss was found to be .0138 grain per hour. One gallon therefore loses .1104 grain of metallic iron, and 1,000 gallons will eat away 110.4 grains, and 63,400 gallons would consume a pound of iron.

SECTION C.—GEOLOGY.

President of the Section, Robert Logan Jack, Esq., F.R.G.S., F.G.S., Government Geologist, Queensland.

WEDNESDAY, AUGUST 29.

The President delivered the following Address:—

ON SOME SALIENT POINTS IN THE GEOLOGY OF QUEENSLAND.

IN bidding you welcome to Section C, I must express my own gratification in being called upon to preside over such a large and representative meeting of Australasian geologists, and in seeing, for the first time, so many whose names and works have long been familiar. It is, I believe, with a due appreciation of the economy of force effected by such gatherings as this that we approach the task of consolidating and recording the results of the work done in the past, and the still graver task of estimating what remains to be done. Following the precedents of the British Association, let me direct your attention to a branch of our science which has come directly under my own observation—the Geology of Queensland, as it appears to the eye of a field geologist.

So much is still unsettled as to the exact age of Queensland formations, that I think it advisable to retain for a little longer the system of using for the latter local terms, such as "Burdekin Formation," although older Geological Surveys, such as that of New Zealand, have happily reached the stage of employing such terms to "series" or "beds"—parts of formations bearing the names of the localities where the most typical of the first observed sections have been found. In comparing these locally named formations with others in European lands, I hope I shall not be understood to imply contemporaneity or anything more than homotaxical relationship.

At the very outset we are struck by the meagreness of the evidence in favour of the existence of the older Palæozoic rocks. There are two, and only two recorded observations in which the question is affected by palæontological evidence. The late Mr.

D'Oyley Aplin, noted in 1867,* the occurrence of branched corals and crinoidal stems at Elbow Creek, Lucky Valley, in blue slates, within a series of slates, sandstones, and calcareous grits, Above the slates Mr. Aplin noted also calcareous grits with shells and casts of various Brachiopoda, Gasteropoda and bivalves. Of these only *Productus* and *Spirifer* were mentioned, even by their generic names. Mr. Aplin regarded the fossiliferous series as Silurian. Of the fossils Mr. Aplin remarks:—"In general aspect they resemble the fossils of the diorite slates at Gympie" (p. 5). To this latter statement of Mr. Aplin, I should attach greater weight than to the determination of two *genera* of brachiopods which range up to a date much later than Silurian. I could even believe, without difficulty, in the absolute identity of the Lucky Valley and Gympie formation. Now the latter has turned out, under the careful study of Mr. R. Etheridge, junr. (to whom I must express my deep obligation for help generously rendered during the last fifteen years), of much completer material than was accessible to Aplin, or Daintree, to be not Upper Silurian as Aplin, and at one time Daintree supposed, nor Devonian as Daintree subsequently believed, but Carbonifero-Permian.

Mr. Daintree observed at Mount Wyatt diggings, certain slates and shales containing *Chonetes sarcinulata*, an *Orthis* allied to *O. rustica*, *Receptaculites* and *Leptœna*, as determined by Professor McCoy. On the strength of these fossils, the formation was assumed to be of Upper Silurian age. The assumption was based on a single distinctly specifically determined brachiopod *Chonetes sarcinulata*, now known to range upward into Devonion times; an *Orthis*, which might be allied to an Upper Silurian species without being itself of that age, the genus ranging all through the Silurian, Devonian, and Carboniferous, a *Receptaculites* and a *Leptœna* (Silurian and Devonian) not specifically determined.

Daintree traced these beds to the Upper Cape and Campaspe, and believed them to extend to the Gilbert Ranges. He moreover laid great stress on the lithological resemblance of the fossiliferous beds of Mount Wyatt, and the probably continuous strata of the Upper Cape, Campaspe aud Gilbert, to the Upper Silurian auriferous strata of Victoria.

Of the auriferous rocks of the Upper Cape, Daintree observes† that they may be divided into lower, middle and upper; the *lower* consisting of laminated granite, mica, and hornblende schists, interstratified; the *middle* consisting of soft thin-bedded mica slates, with occasional bands of silicified mica-and-hornblende-schists; and the *upper* consisting of hard quartzites and silicified mica-slates, He adds—"No fossils have yet been, or are likely to be met with in these beds. The only assertion that can be

*Report on the Auriferous country of the Upper Condamine. &c., fcap., Brisbane, (By Authority) 1867.

†Report on the Cape River Diggings, fcap., Brisbane. (By Authority,) 1868, p. 1.

made in regard to their age is, that rocks of a similar character further north, are uncomformably overlaid by others containing abundance of Upper Silurian fossils." Reference is probably made here to the Broken River, where rocks of a similar character are overlaid uncomformably by a limestone (" Burdekin formation") charged with fossils. The fossils, however, have turned out to be Middle Devonian.

The surmise that the Mount Wyatt beds (which are unconformably overlaid by the Star formation containing *Lepidodendron*, say Carboniferous), and the others which Daintree classes with them (and which are unconformably overlaid by the Burdekin formation—say Middle Devonian) are of Upper Silurian age may prove perfectly correct, but the question is decidedly an open one. Their date may be anything older than Middle Devonian.

As for Aplin's Lucky Valley rocks, they may very well prove to be Carbonifero-Permian, like the Gympie beds.

As, in all probability, the strata on the New South Wales side of the border provisionally mapped as " Upper Silurian or Siluro-Devonian," are continuous with those of Lucky Valley, we look to the work of New South Wales geologists in that region for light on the subject, Mr. T.W. Edgeworth David, in his exhaustive Memoir, " Geology of the Vegetable Creek Tin-Mining Field,"* in referring to some Polyzoa, encrinites, Lamellibranchiata, and univalves found by him in the Parish of Arvid, confesses (p 54) that " these fossils prove the beds to be of marine origin, but do not afford conclusive evidence as to their age."

It seems to me that some vague general term such as Pre-Devonian, would best express the present state of our knowledge of a great part of the region hitherto regarded as Older Palæozoic, while another great portion will have to be handed over to the Carbonifero-Permian. Lithological resemblance is a broken reed, for the same conditions of aqueous arrangement of similar materials, disturbance, pressure, and metamorphism, may and do recur in widely separated times.

The next group of stratified rocks whose horizon can be fixed with some degree of precision, I have named the Burdekin Formation. It represents the Middle Devonian, as is pretty conclusively proved by its fossil contents, It is typically developed in the Burdekin Valley, on the Fanning, and Broken Rivers, and at the Reid River on the Northern Railway. The fossiliferous beds are limestones, occasionally altered to marble. These are not greatly disturbed at the Burdekin, Fanning, and Reid; but on the Broken River they have a dip of about 60°. In the first-named places they rest directly, but uncomformably on quartzites, slates, greywackes and shales, and sometimes on granite. On the Broken River, different conditions

Mem. Geol. Survey, N. S. Wales, Geology No. I. 1887, 4to., Sydney, (Government Printer) prevail. Of this region Daintree observed that—"The entire Devonian system, as developed in Queensland, could be easily and satisfactorily mapped," "On the track from the Broken River to the Gilbert Diggings, Devonian rocks, several thousand feet thick, may be observed, as they are continuous in dip, without being repeated for at least five miles across the strike, with an average dip of 60°," meaning a thickness of at least 23,000 feet. Two years ago, I had for the first time an opportunity of visiting this locality, and found in descending order :—

	Feet.
Grey-white and yellow sandstone, with shales ...	5,280
Shales	1,000
Limestones, alternating with shales, sandstone, and conglomerates, the calcareous beds fossiliferous	10,712
Conglomerates and slates	580
Slates, altered grits, quartzites, siliceous sandstones and conglomerates	3,210
	20,782

The 10,712 feet of calcareous rocks are fossiliferous, and the whole 20,782 feet apparently form an unbroken series. Regarding the 10,712 feet as undoubtedly equivalent to, or homotaxical with the Middle Devonian, the underlying beds may pass downward into Lower Devonian or even Silurian. The only thing that is certain is that they express some portion of the time represented by the unconformability immediately beneath the limestone at Burdekin Downs, the Fanning, and the Reid. How much of that time they account for it is impossible at present to say. They (the beds below the calcareous Devonian rocks) are somewhat altered, and it is noteworthy that the shale beds are highly contorted, while adjacent sandstones and conglomerates are rigidly linear.

Directly, and to all appearance conformably succeeding the Fanning limestone, are what at one time I proposed to call the Dotswood beds. These are grey, greenish, brown and white sandstones, and green and red shales. One of the white sandstones has yielded a plant named *Dicranophyllum australicum*, by Sir J. William Dawson. Interbedded with the stratified rocks are amygdaloidal porphyrites, which are cupriferous. Above the Broken River limestone, it may be remembered, are at least 6,280 feet of shales and grey, white, and yellow sandstones. These probably are the equivalents of the Dotswood beds.

The Star formation consists of grey, green, and blue shales, white sandstones, conglomerates and limestones. In the type district these overlie unconformably the granites, gneisses and

*Quart. Journ. Geol. Soc., 1878, XXVIII., p. 290.

schists which form the country rock of the Star Goldfield and Argentine Silverfield. Twelve hundred feet of these have been mapped, including gaps amounting in all to four hundred feet. These beds have yielded an abundant fauna, including several species of Brachiopioda, Lamellibranchiata, Gasteropoda, and Cephalopoda, two species of trilobites, and some corals, crinoids, and Polyzoa, and a flora of which *Lepidodendron australe* is the most characteristic form.

The Star formation, as above described, resting unconformably on apparently much older strata, and the Dotswood beds, which pass upwards from the Middle Devonian limestone of the Fanning (Burdekin formation) would appear to be distinctly separable. But a recent discovery of fossiliferous beds in the Dotswood Series has proved that the Star and Dotswood beds, although a notable break occurs between them, are part of the same series, the fauna of the two being practically identical. We must seek elsewhere for the leaves inscribed with the history of the period represented by the break, during which in a limited area terrestrial conditions prevailed.

The Hodgkinson Goldfield consists of at least 21,000 feet of shales, slates, sandstones, greywackes and conglomerates, with a few limestones, all highly inclined, and containing *Lepidodendron.* The Hodgkinson beds extend all over the Palmer Goldfield. It is possible that the Hodgkinson and Palmer beds may represent part of the missing strata between the Dotswood and Star beds. If this conjecture (for it is little more) should prove correct, the identification of the little disturbed and not at all metamorphosed Star beds with the Hodgkinson beds, which are highly inclined, a good deal altered, and charged with auriferous reefs, shows how little reliance can be placed on mere lithological resemblance. We may awaken to the fact that in judging of the auriferous or metalliferous possibilities of any tract of country, the conditions of disturbance and metamorphism, are at least as much to be taken into account as the geological age.

Between the Middle Devonian Burdekin formation and the Carboniferous Star formation it is evident that there can be no sequence or passage. The apparent passage at the Broken River and Fanning River must be deceptive.

Mr. C. S. Wilkinson observes* that—"Below the lower marine beds of the Hunter District are beds of shales and sandstones, with several species of *Cyclopteris*, *Knorria*, *Sigillaria*, *Stigmaria*, *Lepidodendron*, &c. . . . . They occur near to, and probably in association with, beds of marine fossils which have been described as lower carboniferous." These beds (which are particularly well developed in the neighbourhood of Stroud) I believe to be on the same horizon as the Star formation; but no passage has ever

* Mines and Mineral Statistics of New South Wales, 1875, p. 132.

been observed in New South Wales, from the *Lepidodendron* beds referred to, upwards into the marine beds of the Hunter district, nor has any been observed in Queensland from the (Carboniferous) Star beds upward into the (Carbonifero-Permian) Bowen River beds, which represent in Queensland the Newcastle Coalfield of New South Wales.

The Bowen River formation lies unconformably on granite porphyry, diallage-rock, actinolite-gneiss, mica and hornblende schists, greywackes and shales, probably on the horizon of the supposed Upper Silurian rocks of Mount Wyatt. The formation begins with a thick bed of volcanic agglomerate, which is succeeded by eight hundred and eighty feet of white and yellow sandstones (called the Lower Series of the coalfield). Above these is a series of bedded porphoritic and basaltic rocks. This is overlaid by the Middle or Marine Series, eighteeen hundred and forty-eight feet in thickness, consisting of grey and yellow sandstones, with bands of reddish-ferruginous, and probably once calcareous sandstones, varying to impure ironstones, with three or four coal seams, The Middle Series is abundantly fossiliferous. Its fauna is almost entirely marine. Such of the forms as are not new are Carboniferous or Permian. The fern *Glossopteris*, whose age was at one time a vexed question, occurs along with the *Protoretepora ampla*, Lonsd., and Brachiopoda of undoubted Carboniferous types. The Upper Series (equivalent to the Newcastle beds of New South Wales) consists of at least nine hundred feet of greyish-green sandstones and red shales, with an abundant flora, of which *Glossopteris Browniana* is the leading feature. As if to show, however, that the fauna of the Middle Series still lived on in adjacent areas, a bed of marine fossils is intercalated among the plant-bearing beds; and in this, every one of the mollusca noted has also been recognised as occurring in the Middle Series, and moreover, fronds of *Glossopteris* have been deposited with them, and must have floated or been blown from an adjacent land surface. There is every indication of a complete sequence from the base of the lower to the top of the upper division of the Bowen River beds.

A period of volcanic activity followed the deposition, and possibly the upheaval and slight disturbance of the Carbonifero-Permian strata, and basaltic masses were intruded along the planes of bedding, locally destroying some of the coal seams, but producing no marked degree of metamorphism among the other strata beyond contact induration.

A little to the south of the Bowen River, the Bowen River formation is traceable into the grey and black shales and sandstones of the Mount Britton Goldfield, where they are not only highly disturbed but somewhat altered, and pierced by impressive dioritic rocks. The metamorphism has not, however, gone far enough to destroy an abundant fauna, sufficient to render easy the identification of the beds with those of the Bowen River, probably mainly of the Middle Marine Series.

A little further south the Upper or Freshwater Series comes in in great force on Walker's Creek and other heads of the Isaacs. These beds are undisturbed and unaltered in this region, and the coal seams are in perfect order. The fossil flora is in good preservation—the silicified trees, which are a notable feature of the Bowen River Upper Series, here bestrew the surface of the ground, having weathered out of the sandstones so plentifully, as to suggest the idea that forests had been felled by human hands and subsequently petrified. An enormous but little known coal-field extends from here southward to the head of the Dawson.

In Cement Hill, Peak Downs, are conglomerates and shales, the conglomerates containing payable waterworn gold and the shales *Glossopteris* fronds. This is the oldest known auriferous drift in Queensland, and it must have derived its gold from the waste of a land existing in Carbonifero-Permian times.

The strata of Gympie Goldfield, consisting of grey shales, black pyritous shales, greywackes, sandstones, grits, and conglomerates, are identifiable by their fossil contents with the Bowen River beds—probably with the Middle or Marine Series. Their relations in the Gympie district to older or newer strata, have not yet, so far as I am aware, been determined. They are only slightly disturbed. Sedimentary rocks which have undergone no alteration alternate with others which have become indurated and semi-crystalline. This local metamorphism is probably due to the intrusion of masses of diorite. The richest deposits of gold occur in the reefs where these intersect the black pyritous shales or "slates," and it is impossible to resist the conclusions that the conditions requisite for the segregation and concentration of the gold in the reefs were furnished by the influence of igneous rocks, or slightly auriferous pyrites in the carbonaceous shales.

By the labours of Mr. James Smith a large area of auriferous rock in the Rockhampton district, including those surrounding Mount Morgan, have been shown to be identical with the Gympie, or Bowen River formation. To this keen observer and indefatigable collector, belongs the credit of having furnished the material for substantiating the claim of the Carbonifero-Permian to much that was regarded as Silurian, chiefly on the ground of "lithological" resemblance.

The Burrum Coalfield is plainly on a higher horizon than the Bowen River field. It contains a fossil flora in which many plants are common to the Mesozoic Ipswich formation and also, it *is said*, *Glossopteris* with a very meagre fauna, most of it peculiar to the coalfield. Had it contained *Glossopteris* alone, or the Ipswich flora alone, it would no doubt have been classed without hesitation as equivalent either to the Bowen River, or Ipswich Series. Probably to call it Triassic would not be far from the mark, in at least a homotaxial sense.

The Burrum field contains good and numerous coal-seams, and in the type district the formation is unaltered and very little disturbed. On the outskirts of the field however the strata, according to Mr. W. H. Rands, who has mapped them in detail, are inclined at high angles, altered into a series of micaceous slates, and finally rests upon granite. These altered rocks are veined with quartz. The fact of the strata of the Burrum field becoming metamorphoised as we recede from the type district, till it ceases to be recognisable, prevents our reading their earlier pages. It is conceivable that they pass downward into the Bowen River beds.

The Stewart's Creek and Rosewood beds (Rockhampton district) are obscure in their relations both to what is above and below: at least their relations have not yet been noted. The Rosewood fossil flora has been studied by the Rev. J. E. Tenison Woods, who however, still regards their position as uncertain. Their flora is, however, closely analogous in its main features to that of the Ipswich formation. It includes *Tæniopteris.* In the Stewart's Creek beds Mr. Smith has recently found a fern which may be *Sagenopteris.* The Stewart's Creek and Rosewood beds are probably newer than the Burrum formation.

The Ipswich Coalfield has at its base a series of ashy sandstones, grits, and conglomerates containing silicified and carbonized wood. These may be seen in Brisbane lying unconformably on the upturned edges of greywackes, slates and quartzose and micaceous schists. To the ashy beds succeed brown, grey and white sandstone, grits and shales, with numerous coal-seams, forming the coalfield proper. These apparently pass upward into the "Rolling Downs" (Cretaceous) formation. But the junction is obscured and disturbed by the basalts of the Toowoomba Range, which intrude into and flow over both formations. The coalfield contains an abundant fossil flora of a strongly Jurassic facies, and is probably the equivalent of the Clarence River beds of New South Wales.

The Rolling Downs formation consists of grey shales, brown and greenish-grey sandstones, often calcareous, with occasional limestones. They are mainly of marine origin, and the appearance of Belemnites and Ammonites along with other marine forms sufficiently marks the change from the plant-bearing Ipswich formation, if it does not enable us to draw a sharp line on the geological map. The Rolling Downs formation has its nearest relation in the Cretaceous of Europe, but a percentage of its fossils are Oolitic. I may repeat what I wrote two years ago, and which is as true now as it was then. "It is remarkable that almost every palæontologist who has worked on Queensland materials has come to the conclusion that fossils from different localities must have been mixed up, and this explanation has appeared to be specially necessary in the case of fossils from the

Rolling Downs. On the other hand my own explorations have satisfied me that Queensland fossils are not more liable to this kind of accident than fossils from other countries, that the mixing-up which has so annoyed palæontologists has been perpetrated by nature herself; that in the Rolling Downs we have a continuous series of beds of enormous thickness, in which, however, from the scarcity of sections, it would be impossible to map out 'horizons'; and that the fossils from the Rolling Downs must be treated as a whole."

Everywhere in the north the Rolling Downs formation lies directly, and of course unconformably, on schists and slates, or granites, the Ipswich formation being absent.

The Desert Sandstone is a monument of the power of denudation. It has covered the whole of the area now occupied by the outcrop of the Rolling Downs formation—in other words, the larger (the western) half of Queensland, though now it only occurs in isolated fragmentary tablelands. It overlies the Rolling Downs formation unconformably, but the junction is not merely an unconformability. It is an overlap. The sandy sediments have filled up the inequalities in the older rocks, the lowest bed occupying the bottom of the hollows, the next joining the older rocks at a higher level, and so on. Consequently the formation, which rests unconformably in the western interior on the Rolling Downs beds, rests unconformably on the Ipswich beds, and comes at higher levels to rest unconformably on the Palæozoic rocks, as the axis of the lofty coast range, which formed the shores of the Desert Sandstone sea, is approached.

The Desert Sandstone varies greatly in composition, texture and appearance from top to bottom, but its individual beds preserve their characters over large areas. The lowest beds are generally of felspathic material, without aqueous arrangement, and are suggestive of wind-sifting only—volcanic dust in fact, altered more or less by subsequent infiltration or segregation of iron oxide or other cementing material. Other beds are of white siliceous sand, and these have often a vitrified appearance, due I believe to partial solution of the silica from the upward passage of hot water. Other beds are of siliceous sand reddened with iron peroxide. Other beds are coarse conglomerates. False bedding is common in nearly all the siliceous strata. A few beds of clay shales occur, and even some seams of coal. Nodules of ironstone and silica occur in places, and these often contain precious opals and other gems.

The Desert Sandstone has till recently afforded very few fossils, except silicified wood, generally structureless and without value for palæontological purposes. Daintree believed it to be Tertiary. Mr. Norman Taylor obtained from it, at Battle Camp, near Cooktown, two fossils, pronounced by Mr. Robt. Etheridge, F.R.S., to be *Ostrea* and *Hinnites*. Nothing of great importance, however, turned up till the opening of the Croydon Goldfield, when the Desert Sandstone resting on auriferous reefs in granite and quartzite country, were found to be charged with marine fossils.

In spite of the undeniable and highly important break represented by the unconformability of the Desert Sandstone on the Rolling Downs beds, Mr. R. Etheridge, jun., informs me that his study of the Croydon fossils leaves him unable to separate the Rolling Downs from the Desert Sandstone in the sense that the one has an older fauna than the other. This is the second time that groups of strata separated by an unconformability have actually been found to contain the same assemblage of fossils. The other instance, it may be remembered, was the case of the Dotswood and Star beds.

The unconformability between the Rolling Downs formation and the Desert Sandstone, both of which are Cretaceous, renders it at least easy to believe that in spite of the similarity of the organic remains the former represents the Lower Cretaceous, during which period, according to Professor Hutton, Eastern and Western Australia formed two islands, while a continental land extended from New Guinea to South America, with a peninsula extending from Fiji to New Zealand. But between the Lower and Upper Cretaceous Periods (if we call the Desert Sandstone Upper Cretaceous—and it *is* older than Tertiary) insular land surfaces existed all over the area lately occupied by the Lower Cretaceous sea. A second depression took place when the Desert Sandstone was deposited, and this depression was even greater than the former. In other words, the Upper Cretaceous sea of Australia was of greater extent than the Lower Cretaceous.

Exceedingly like the Desert Sandstone lithologically, and with an assemblage of fossils which Mr. Etheridge assures me are not generally separable from its fauna, are the Maryborough beds, but their position on the eastern side of the coast range—the island of Lower, and again of Upper Cretaceous times—differs widely from that of the Desert Sandstone. The latter abuts at high levels against the palæozoic range, while the Maryborough beds merely occupy the flat which fringes the coast. No trace of the Rolling Downs (Lower Cretaceous) formation is found underlying the Maryborough beds, which rest on the Burrum Coal-field. I can only suppose that the sea-bottom on the eastern side of the range was much deeper than that on the western, and that the deposition of the Upper Cretaceous (?) sediments did not continue long enough to heap the latter up to the level of the coeval deposits in the shallower mediterranean to the west. I infer, also, from the way in which all the formations from Carbonifero-Permian times onward abut against the range, the great antiquity of the escapement on the eastern side of the Cordillera—and by consequence the great antiquity of the Pacific Ocean.

On the Desert Sandstone are immense areas of basaltic beds, which are largely developed on the Upper Flinders. They are probably Tertiary, and must have been poured out before any extensive denudition of the Desert Sandstone took place. But after the upheaval of the latter and the carving out of the valleys, a second period of volcanic activity supervened, and streams of basaltic lava flowed down the valleys. To this latter period belonged the remarkable thermal spring which gave rise to the auriferous deposit of Mount Morgan.

This will conclude my remarks, as I have never enjoyed the opportunity of studying Tertiary and Post-Tertiary geology in Queensland.

I have tried to place before you an account of the most recent views. I have thought it better in some cases to repeat what has been said before than to omit any portion of the story. If, on the other hand, I say something different from what I may have said last year, or the year before that, I claim to have enlarged my knowledge of the subject in the time. I hope to have made clear to you the nature of the problems we have to face. Above all, I hope to have shown how extremely fragmentary is the story as told in Queensland:—how almost everything that can be called a formation is unconformably related to older rocks: —how formations of widely different dates may, under similar conditions of disturbance, pressure and metamorphism, assume the same lithological characters:—and, again, how the same formation may be locally metamorphosed, so that one portion of it, for instance, may be a coal-field and another a gold-field; and, finally, I hope it has been suggested to you that we look for help in unravelling the structure of Queensland to workers in other lands, and to meetings such as this of those who are—

Not incurious in God's handiwork.

The following papers were read:—

1.—NOTES ON THE METAMORPHIC ROCKS OF THE OMEO DISTRICT, GIPPSLAND.

By A. W. Howitt, F.G.S., of Sale, Victoria.

INTRODUCTION.

The study of those rocks which are now termed Metamorphic commenced when Hutton, at the end of the last century, published his "Theory of the Earth." Since that time the subject has attracted the attention of geologists with an ever increasing interest. Yet it is only now, after the lapse of nearly a century, that the course of early speculative theorizing and of more recent practical research has led to some little understanding of the causes which have produced these effects which one speaks of as metamorphic.

In this paper I propose to record as a small contribution to the study of the Crystaline Schists, the observations which I have made upon the so called Regional Schists of Omeo. Some of the details have been already published, whilst the remainder is now given in anticipation of papers at present in preparation.

It will be well, once for all, and for the sake of clearness, to define the sense in which I use the terms contact-, pressure-, and regional-metamorphism, and I regard dynamo-metamorphism and pressure-metamorphism as synonimous.

By contact-metamorphism I understand these changes produced in rock formations by increased temperature, by mineral solutions, by gaseous emanations, and probably also by increased pressure all due to the proximity of invasive igneous rocks.

By pressure-metamorphism I understand the effects produced upon rock masses, both sedimentary and igneous, by the direct pressure of great earth stresses. These effects will therefore include slaty-cleavage, the crushing of rock masses in situ, and the stretching of rocks laterally and vertically.

Regional-metamorphism as seen in the Omeo district seems to be the resultant of both forms of metamorphism.

GENERAL GEOLOGICAL FEATURES OF THE DISTRICT.

It will be only necessary to say so much of the geological and physical structure of the Omeo district as may suffice to bring before the reader the general features of the localities to which these notes refer.

The Great Dividing Range in Eastern Victoria reaches to almost its greatest altitude near Omeo. It thence rises in a series of plateaux, which during a great part of the Tertiary period, if not even in Mesozoic times, formed part of a great continuous upland, which through subsequent erosion of river valleys, only now shews its traces in isolated tracts of considerable elevation, such as the Snowy Plains and the Dargo High Plains. The Omeo plateau ascends by several steps, if I may so phrase it, rising finally to the great and spreading downs of the Bogong. The elevation of these plateaux lies between 2,500 and 5,500 feet above sea level. Isolated mountains rise above them to the maximum height of 6,500 in Mount Bogong.

The geological structure of this part of the Australian Alps is simple. A mountain mass is composed of sedimentary, plutonic and volcanic rocks, wholly of Palæozoic age, excepting where in limited areas the older formations are here and there capped by flows of basalt, which cannot well be older than the Middle Tertiary.*

* Geological Survey of Victoria ,Progress Report IV. p. 110 ; R. A. F. Murray, Geology and Physical Geography of Victoria, 1887, p. 111.

It is possible to divide the Palæozoic formations into two great groups, which are separated by marked stratigraphical discordance from each other, and which may be shortly described as follows :—

The oldest rocks which have so far been observed in the part of Eastern Victoria, to which I now refer, form a great recurring series of argillaceous and arenaceous beds with quartz veins, in fact the goldfield series of the district. The few organic remains which have been found in these sediments have been Graptolites of Lower Silurian age.* These occur in several localities to the east of the Snowy River. At the Limestone River, one of the sources of the Murray, there are obscure remains of corals in metamorphosed limestones, which are probably Upper Silurian.† The probabilities therefore are that the great series of older Palæozoic sediments in this district represent both the Lower and Upper Silurian Periods, and as such I shall provisionally speak of them. Stratigraphically the next succeeding formations are vast extents of intrusive holocrystalline plutonic rocks, which have invaded the Silurian sediments. I have carefully examined numerous places in North Gippsland where contacts with these rocks have been exposed, and nowhere have I discovered those older formations upon which the Silurian strata must have been laid down. In no case have I found that the Silurian beds have been laid down upon the plutonic rocks, and my present impression is that all the formations older than the former have been absorbed by the invading magmas, which now in their consolidated condition as quartz diorites, granites and granilites, abut in many places against the truncated ends of the sediments. In some places where the natural sections have been favourable, I have clearly seen that the plutonic magmas have eaten their way upwards into the Silurian beds. There is such a section in Tingaringa creek in Eastern Gippsland, and I long ago figured another which I observed at Beechworth.‡

Next in succession to the intrusive plutonic rocks is a great extent, both horizontally and vertically, of acid volcanic ejecta, constituting the formations which I have described elsewhere as the Snowy River Porphyries.§ These occupy an area which may be roughly defined as conforming generally to the space contained between the Snowy and Buchan Rivers. These rocks consist of ancient lavas, tuffs and agglomerates. In places within or near their bounds arise through them mountains of porphyritic rock of a granitic character, which I have seen reason to believe mark the sites of volcanoes of that time.‖

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* M'Coy, Prodromus Palæontology of Victoria, Decade I.

† Murray *op. cit* p. 24.

‡ Geological Survey of Victoria, Progress Report II. p. 77.

§ *Op. cit.*, Report III. p. 181.

‖ *Op. cit.*, Report III. p. 181.

Isolated mountains similar to these and probably of the same great age are to be found to the westward of the area.

The age of the Snowy River porphyries is fixed by the Silurian sediments, which are inferior to them, and the Middle Devonian marine limestones, which, for instance, at Gelantipy rest upon them.

At Bindi, in the Omeo district proper, examples of this series can be studied where the quartz porphyries and fragmental beds pass upwards by gradatures into purely marine limestones, charged with organic remains of the Middle Devonian age.*

These Middle Devonian formations are succeeded at Mount Tambo by a great thickness of coarse conglomerates, shales and grits, which I have provisionally referred to the Upper Devonian, and which close the geological record in the Omeo district, excepting the few Cainozoic basalts before referred to.

In speaking of the Snowy River porphyries I mentioned certain mountain masses of porphyritic rocks which are connected with them, and I also said that similar masses are to be found to the westward of them. At Bairnsdale, where such a mountain (Mount Taylor) occurs, its approximate age is fixed by the capping of Upper Devonian rocks† which rest upon its denuded summit. It seems to me probable that the other isolated mountains of the same character may be referred to this geological age. In the Omeo district such occurrences are to be found at the border of the metamorphic area, and subsequent to the formation of the crystalline schists.

These masses of generally porphyritic rocks may for the purposes of this paper be spoken of as younger plutonic, and they are incidents in the great sequence of plutonic and metamorphic phenomena with which the crystalline schists of Omeo are connected.

It will be perhaps well, before speaking in the following section of a similar occurrence of younger plutonic rocks within the Omeo area, to shortly describe a typical example of the extreme

* I may take this opportunity to refer to a difference of opinion which has arisen between Mr. James Sterling, F.G.S., and myself as to these quartz porphyries, and to their relations to the Bindi beds. In my description of the Tambo beds I described the Bindi limestones as having been laid down upon the red quartz porphyries of the locality which I regarded as belonging to the Snowy River Porphyries. In a paper read before the Geological Society of Australasia (Transactions, Vol. I. Pt. I. p. 18) Mr. Sterling says that the Bindi limestones "together with shales, sandstones and conglomerates inferior to them, have been cut off from the main mass by an eruptive mass of quartz porphyry, which has not only transmuted and absorbed the sandstones and conglomerates along the line of contact, but has indurated and otherwise altered the limestones into subcrystalline white and grey marbles." After this was published Mr. Sterling kindly invited me to visit the locality with him, and we together carefully examined his supposed intrusive contact. I found that the relations of the Bindi beds to the quartz porphyries are precisely analogous to those of the Buchan beds to the quartz porphyries and diabase rocks of that locality. The Bindi beds were deposited upon the quartz porphyries, and are connected with them by a short series of fragmental beds, which become increasingly calcareous in passing upwards. Samples which I collected of the quartz porphyries and of the fragmental beds lying upon them proved, upon microscopical examination of thin slices, to be quite normal in their character.

† Geological Survey of Victoria, Progress Report, III. p .210.

southern edge of the crystalline schists, namely:—Mount Elizabeth at Noyang. I have fully described this area in my paper on the "Rocks of Noyang,"* to which the reader may be referred. Denudation and erosion, which have acted strongly upon the tracts surrounding Mount Elizabeth, have left its refractory quartzose central masses standing some 3000 feet above the valley of the Tambo River. The mountain is composed of several successive invasions of plutonic rocks The earliest is a widely extended mass of quartz-mica-diorite, which has converted the Silurian sediments in contact with it into varieties of hornfels on the southern and western sides. To the north there are no contact schists in that sense, for the altered sedimentary rocks on that side are fine grained mica-schists belonging to the Omeo group.

Younger than the quartz diorites, and intrusive as to them, are great masses of quartz-mica-porphyrites and quartz-granophyrites themselves, traversed by numerous dykes of quartz porphyrites.† Finally the youngest rocks are quartz felsophyrites. These rock masses looked at as a whole, are a great compound intrusive mass, the youngest member of which is a glassy rock which was probably the deeper seated portion of a lava-flow filling the vent of one of those palæozoic volcanoes to which was due the great aggregation of ejected materials found to the eastward of the mountain, and thence extending to beyond the Snowy River.

This intrusive area occurs at the margin of the crystalline schists, and was subsequent to their formation. Other similar areas also are to be seen along their eastern boundary, from the study of which similar conclusions arise. I may now anticipate statements which I shall make further on in the next section, by saying that the crystalline schists of Omeo are not older than the Silurian formations of which some of them are the metamorphised representatives. Some are even somewhat younger, yet certainly older than the Middle Devonian formations of Bindi, which have not been in any way affected by the metamorphic processes, either regional or contact.

A glance at the geological map of Victoria will show the reader that the area coloured metamorphic extends from a little to the southward of Omeo, northwards to near the Murray River being an area approximately ninety miles east and west. These notes, however, refer only to a small southern part of the area in the immediate vicinity of Omeo. Yet I venture to think that if I am able to establish satisfactorily the relations of the metamorphic rocks which are found therein, the deductions to be drawn therefrom will be applicable to the whole remainder of the area.

* The Rocks of Noyang. Trans. R. Soc. Victoria, XX. p. 18.

† According to the system of classification framed by Rosenbusch, which is certainly the best yet devised, these rocks should be termed quartz keratophyrs.

THE CRYSTALLINE SCHISTS OF OMEO.

When I came to examine critically the main tract of crystalline schist by the light of the observations made along its boundaries, I saw that there were also within these large areas of holocrystalline rocks which might prove to be intrusive, and not as had been assumed, the ultimate result of the metamorphism of sediments *in situ*. Thus I came to see further that the schists themselves, which appeared to range from fine-grained nodular mica-schist to coarse granite-gneiss, required to receive a further examination in order to determine whether there were, in fact, at Omeo, as had been supposed, an actual passage from the normal Silurian sediments through mica schist and gneiss to massive rocks, having a granitic character.

Fortunately for such an investigation, a series of violent and unprecedented floods had, some years before the time I speak of, swept out the course of several streams to the bed rock, in positions favourable for examining the supposed sequence. Thus it was that I found myself in a position to take up an enquiry which has led me to the views and conclusions embodied in this paper.

The great series of argillaceous and arenaceous beds which, for reasons which I have already given, I regard as Silurian, is found more or less connectedly to surround the area of the crystalline schists. The strata have been tilted at high angles in a strike usually approaching north-west and south-east. Microscopical examination of a number of thin slices of these rocks leads me to say that their general composition may be described as one in which the original argillaceous paste has been more or less completely converted into minerals of the chlorite group, while in some cases the original elastic grains of quartz have been enlarged by the addition of secondary silica. The condition of these Silurian formations is, therefore, that of one of the earlier stages of metamorphism, impressed upon them during the process of folding together of the strata, the tilling of the beds, and the crushing of their materials. The most appropriate term for such beds as these seems to be argillite, and in places the effects of slaty cleavage are well marked. In certain parts of the Omeo district, and notably where the argillites border the crystalline schists, the former have been subjected to still further changes. The general appearance of the beds remains the same as before, the characteristic alternations of argillaceous and arenaceous beds still continues, but on the cleavage planes there appears a silky sheen, and the planes themselves are frequently minutely corrugated. The internal structure has, however, undergone a complete change. The chlorite minerals have almost or wholly disappeared. The carbonaceous or graphitic admixture is diminished or absent, and the structure of the rock is now that of a mica-schist of microscopical fineness of grain. Such rocks as these approach very closely to the definition of phyllite, and by that designation I shall speak of them. Thus the phyllites illustrate the next stage of structural alterations from the argillites to mica-schist.

Such features as these are well shown in the valley of the Upper Dargo River. In proceeding thence eastward towards Omeo, the first change observable in the Silurian sediments is, that the argillaceous beds become slightly corrugated, or show a wrinkled surface on the glistening cleavage planes. Together with these appearances there are also numerous minute veins of quartz, which either form partings or free fissures crossing the beds. At a still further distance the beds have more or less the structure and appearance of mica-schist; then follows a wide band of gneissose beds, and finally there is reached a tract of holocrystalline massive rocks which are usually of the character of the quartz diorites.

Crossing the area of the crystalline rocks of Omeo still further to the eastward, the Silurian sediments are found much in their normal condition in the valley of the Tambo River, near Tongeo. They form the eastern side of the Bowen Mountains, which are part of the Great Dividing Range between Bindi and Omeo. On the falling ground from the Bowen Mountains towards Livingstone Creek, argillites are increased either by phylites, or directly by mica schist of fine grain. Somewhat further on, as for instance in following the hills from Mount Cooke, towards the Hinnomunjie morass, the beds are well marked varieties of nodular mica-schist, either very micaceous or very quartzose, thus representing in their alternations those of the argillites.

A strong fault runs across this country from near the Tongeo Gap towards the Mitta Mitta River, in a direction approximately N. 30° W. It extends for many miles. On its south-western side there are only intrusive plutonic rocks of the granite and diorite groups. The mica-schists extend to the fault on its north-eastern side, becoming more markedly micaceous when, at the fault itself, they are brought into contact with the igneous rocks. That this contact is not merely proximity, due to faulting becomes very evident when the district is examined. I have elsewhere described this at length, and may refer to that description for fuller particulars.* The line of contact is irregular by reason of promontories of muscovite granite, which extend into the mica-schists. Outlying masses of the same rock are to be found at a distance of more than a mile within the schist area, and dykes and dyke-like masses of igneous rock have penetrated the schists, either passing between the beds, or in some cases across them. The schists, for a considerable distance from the fault are strongly filled with minute pale brown crystals of

*Notes on certain Metamorphic and Plutonic rocks at Omeo. Trans. R. Soc. Victoria, 1887.

tourmaline. These appearances, therefore, prove that the faulting of the strata was accompanied by intrusion of the igneous rocks, and this seems to have taken place not only laterally, but also from below upwards, suggesting that the schists were let down into the granitic magma.

The metamorphism of the sediments was twofold and successive. First, they were converted into argillites, and more rarely into phyllites over a vast extent of country, and as it seems to me through the action of the earth stresses which folded and crushed the strata together. This process was in one sense mechanical, and may be spoken of as Regional-Metamorphism. Second, the altered sediments were subjected to a further metamorphism by being invaded by the granitic magmas. The changes hereby produced were, it would seem, not mechanical, for the strike and dips of the beds appear not to have been altered. The changes produced were in the production of a greater amount of muscovite and biotite, and in the larger size of the individual mica plates, in the increase of quartz in some beds, and finally in the abundance of tourmaline generated throughout the whole of the schists for some distance from the plutonic rocks. These latter changes were, therefore, chemical, and appear to have been not only the molecular rearrangement of the constituents of the sedimentary beds, but also the introduction of silica, boron and probably fluorine.

It will be well now to say, once for all, that in the part of the Omeo district with which I am now concerned, there are not any true contact schists of the hornfels type. These are, however, largely developed round the margins of some of the intrusive areas which border the crystalline schists, for instance at Swift's Creek, and at Noyang.*

In proceeding from the great fault which I have now briefly mentioned, in the direction of Mount Livingstone, that is to say, into the tracts of the more crystalline schists, the rocks which are first crossed are massive porphyritic granites, then schistose rocks of a gneissic character, then near Mount Livingstone a series of bedded gneisses, some of which have that structure designated "augen gneiss." Finally there is reached beyond them a tract of massive holocrystalline rocks which, as far as I have examined them, are varieties of quartz diorites. These extend westward in connected areas, flanked more or less by gneisses to the eastern side of the Dargo Valley, where, as I have already said, there is a further series of schistose rocks which form the western margin in the metamorphic area.

Similar observations may be made in proceeding from Mount Livingstone to the Great Dividing Range, near Mount Birregun, in the south-west, and towards the sources of the Kiewa River, in the north-west.

*The Diorites and Granites of Swift's Creek. Trans. R. Soc. Victoria, xvi. p, 61. The Rocks of Noyang, op. cit. xx. p. 18.

For the purpose of examination of the bedded gneisses, the natural sections which have been laid bare in Greenwattle Creek, near Mount Livingstone, are very favourable. It is thus possible not only to make a minute examination of the individual beds, but also of the relations of the beds to each other, and to the neighbouring massive rocks. The results of the examination which I have made, I am now preparing for publication, but I may anticipate the work by mentioning the principal results arrived at.

The schistose rocks vary a good deal in character. Some can be best described as granite-gneiss, using the term merely in a structural sense. Others have a distinctly bedded appearance, dipping generally south-westward at a high angle. These have a distinctly gneissic structure, being composed of foliations of biotite felspar, and quartz. Other beds are augen gneiss, and finally there are others which can be classed only as mica-schist.

In texture these gneisses vary from crystalline granular compounds of felspar, biotite, and quartz, with only traces of parallelism in the minerals, to completely foliated beds of felspar, biotite, and quartz, or of mica and quartz only, thus forming a mica-schist.

An examination of a number of thin sections of these rocks prepared across the foliation, reveals their character as being entirely different to any of the other metamorphic schists which I have described, either of the phyllites or mica-schists. Of course it is also the case that they have no resemblance to the contact-schists properly so called. The felspathic and quartzose foliations are formed of broken and abraded felspars and quartz grains. Some of the felspars show signs of stretching, and the quartz has a cloudy obscuration indicative of strain.

The filling-in of the foliations is by the detritus from the abraded and broken minerals, together with more or less secondary quartz, which has, together with mica, acted as a cement. The micaceous foliations in these gneisses are of secondary origin, being derived by regeneration from the crushed and abraded portions of the rock. No doubt these are portions of the mica forming the foliations or associated with the felspars and quartz, which, in a fragmentary condition represents the dark coloured biotite of the original constitution of the rock, but the micaceous foliations as a whole are the result of regeneration of the detrital materials.

It may be said, speaking generally, that the more the rock shows evidence of crushing, squeezing and comminution, the smaller are the rounded grains of felspar, and the more numerous are the micaceous bands. Thus, I found that the bands which had most the appearance of mica-schist were rocks of the above-mentioned kind, in which the original structure had been completing obliterated, the result being foliations of biotite separated by undulating foliations of secondary quartz. This character is one which I have nowhere observed in the true mica-schists of Omeo, which have resulted from the metamorphism of sediments. It may be looked upon as one of the indications of the action of pressure metamorphism upon once massive rocks.

It is to be noted that the greater number of "eyes" which I have examined from these gneisses, have proved to be orthoclase, thus perhaps connecting these rocks with the porphyritic granites rather than with the diorites of the neighbourhood. Yet the structure of some of the larger of the "eyes" suggests that they have been partly formed from the remains of originally porphyritic crystals of felspar, and partly by accretions of felspar and quartz, arranged round them somewhat in the "graphic" manner, and being derived from the resolution of the abraded materials. Such solutions as these, represent it would seem, the "secretions" spoken of by Lehmann, in his explanations of pressure metamorphism. The characteristic tails of broken-up materials which are usually attached to the opposite ends of the eyes, show clearly whence the innumerable fragments which form some of the foliations have been derived. The structure of the "graphic" parts, and the presence in them of crystals of biotite, arranged radially to the eye, the layers of biotite which extend from it, and the envelope of biotite which usually encloses it, point clearly and decisively to a compound origin, and to the co-operation of the cause. One of these was mechanical and the other chemical.

These crystalline schists then, resemble in no way those schists which, as I have shown, are the metamorphosed representatives of the Silurian sediments, although they are evidently rock masses which have been subjected to re-arrangement of their parts by pressure metamorphism. The numerous survivals of original mineral constituents in a more or less fragmental condition, point to the former origin of these beds as having been igneous, the kataklastic structure in places of the neighbouring massive plutonic rocks, their occasional tendency to a schistose habit, the completely gneissic structure of some beds, and the completely mica-schist structure of others, as at Mount Livingstone, are stages of the same metamorphic process. It commences with a mere crushing of certain portions of the igneous mass, and ends with a complete re-arrangement of the materials of those rocks which have been crushed and stretched out beyond their point of resistance.

That the condition of these rocks when subject to pressure metamorphism, was not merely one of a partly crystallized magma, is shown by the comminution of their constituent minerals, especially of quartz, which was the last to crystallize. It is also abundantly shown by the manner in which micaceous foliations have been formed from the detrital materials along friction planes.

Results such as these can only be attributed to the gigantic earth movements which accompanied, or perhaps preceeded the invasion of the sedimentary crust by the plutonic magmas.

It will now be evident that there are two well marked groups of crystalline schists in the Omeo district. The phyllites and mica-schists which have resulted from the metamorphism of sediments, and the mica-schists and gneisses which have been produced by the metamorphism of igneous rocks. Both these groups have been metamorphosed by the same general agents, namely, by pressure metamorphism, and in connection with it also chemical action producing molecular re-crystallization. The general result has been that a twofold set of crystalline schists have been produced, to which the general term Regional Metamorphic Schists may still be applied.

In the part of the district which I have taken as the text for this paper, these two groups are found in places apart from each other.

Comparing these two occurrences with the apparent sequence, or passage from the normal argillites of the district through mica-schist and gneiss, to the massive quartz diorites and granites, at the margins of the metamorphic areas, the conclusion seems to be justified that future examination will show that in such places, as for instance at the Upper Dargo, there is a break between the banded gneisses and its mica-schists, or even in the latter, and that the former are not metamorphosed sediments, but the margins of the intrusive plutonic rock-masses altered by pressure metamorphism.

I must, however, point out here, that the gneisses which are to be found in places bordering intrusive masses of diorite, are probably not in all cases due to pressure metamorphism. That is to say, they have not been produced by the re-arrangement through pressure of already solidified and rigid rock masses, such as was the case with the rocks which I have described. For instance, there are in the Swift's Creek area, rocks which are almost fantastically constructed, yet parts of the adjoining rock-masses are crystalline granular. Such gneisses as these differ most materially from the bedded and banded gneisses which I have described. Pressure has probably had to do with their structure, but pressure acting upon a partly crystallized magma, and not upon a rock already crystallized throughout.

In connection with the effects of pressure-metamorphism, which are described by a study of the crystalline schists at Omeo, it becomes important to enquire in how far the smaller and later irruptions of plutonic rocks may have influenced the final results. An example of such a later irruption is given by the Frenchman's Hill, a mount which rises to some height, not far from the great fault, and on its south-west side. The following particulars are the condensed results of an investigation upon which I have spent some time, but the details of which are not yet published.

The Frenchman's Hill is one of those more recent irruptions of which I have said that they now stand out of the areas of intrusive plutonic rocks in various parts of the district. The main rock-masses which surround this hill are granites which terminate on its north-east side at the fault, beyond which are situated the mica-schists and other less altered sediments. The granitic rocks have invaded the schist formations both horizontally from the fault, and from below upwards, appearing as appophyses and isolated patches, as well as in dykes.

To the westward of the Livingstone Creek, which flows at the base of the hill, the granites seem to pass into diorites, by the replacement of orthoclase by plagioclastic felspars.

Younger than the granites and intrusive into them, are masses of holocrystalline rock composed essentially of orthoclase with subordinate triclinic felspars, quartz, and a little muscovite mica. To this class of rock in this district I have applied the term aplite. These rocks not only occur as intrusive masses of some extent, but also are to be found in the mica-schist both as masses and dykes, and even small veins lying between the schist beds or crossing them. In places these aplite veins are so coarse in texture, as through a further accession of muscovite to become muscovite granite or pegmatite.

Younger than the aplites, and again intrusive as regards them and the granites, are masses of rock composed essentially of orthoclase. In one variety the orthoclase is in more or less perfect crystals, and the interspaces between them are filled by a granophyric mixture of felspar and quartz, with the interspaces between them finally filled by limonite, which shows traces that the original mineral was hæmatite.

Another variety of this class of rock consists of orthoclase felspar, with imperfect bounding planes in a ground mass of the same, in much smaller individuals, and a little quartz. A third variety is formed by a network of lath-shaped crystals, with rarely larger porphyritic ones. Finally there is a variety which consists wholly of minute felspars, with little more than a trace of free quartz. This latter form occurs as dykes, sometimes of considerable width and great length, as well in the immediate neighbourhood as at a distance from the mount.

It must be noted that in some samples I have found a small percentage of biotite, which in one variety amounted to an essential part.*

These rocks, which are all younger than the aplites, belong, as a whole, to the group called orthophyr, or orthoclase porphyries.

The samples which contain a considerable percentage of biotite, approach the mica-syenites, but in somewhat aberrant variations.

* In all the analyses which I have made of these rocks I have found a percentage of Na_2O larger than the microscopic examination would have led me to expect.

This group of rocks is poor in quartz, but still later irruptions are very quartzose. These are found only as dykes, or dyke-like masses in the neighbourhood of the hill. They are composed of quartz and felspar, quartz and muscovite, or muscovite and felspar, and some of them contain schorl in considerable amount. These quartzose dykes and veins are evidently connected with this eruptive area, and are the latest eruptions of the sequence that commenced with the granites. The quartz dykes must be distinguished from the ordinary auriferous or metalliferous quartz veins, and they are of that character which I have elsewhere defined as plutonic quartz.*

The manner in which these quartz and quartzose dykes are found to occur near, and at the Frenchman's Hill, is worthy of a short notice. In plutonic rocks, such as the granites of that place, the more basic constituents have first crystallized out of the magma in definite forms as minerals, thus leaving it more siliceous after each successive crystallization. I have observed the same in a marked manner, for instance at Noyang, where the first irruptures were of a quartz-mica-diorite, and the later ones of quartz keratophyr consisting of merely albite and quartz.

In such rocks as the granite and quartz diorites, the last constituent to crystallize has been the silica, and it seems almost certain that it crystallized from the state of a colloid containing a certain but relatively small per centage of water, some of which may be still found in the minute cavities of such quartz.

It seems, therefore, that the quartz dykes of the Frenchman's Hill may reasonably be considered as being the residual silica of the plutonic magma, after its basic constituents had crystallized out, and that the siliceous residum was squeezed out into the fissures during the final consolidation of the rocks. On this view no high temperature would be required, but on the contrary, a decreasing temperature must he implied by the conditions postulated.

The evidence of metamorphism in the rocks of the Frenchman's Hill differs in amount, and even to some extent in kind, from that which I have described already in speaking of the crystalline schists. Thus in the granites, felspars are found to be surrounded by a more or less wide margin of detritus. Other felspars have been broken across, and the spaces between the parts filled in by fragments or new materials. Quartz is crushed into minute fragments, or shows strain phenomena when examined by polarized light The mica is distorted, or with its folea spread open. Such effects as these can be observed, but they are local only. This structure of the rocks is that which Rosenbusch has well denominated kataklastic. Fissures which have been made in the solid rock have been filled up with minute friction breccias, or even

*Notes on the area of Intrusive Rocks at Dargo. Trans. R. Soc. Victoria, xxiii, p. 152.

in places with a regeneration of quartz and felspar in the graphic manner. Moreover there are indications of alterations of temperature in the partial absorption of some of the minerals, as for instance of felspar, and of the production of muscovite from the resulting solutions. Such observations as these may be made as to the aplites in less degree, but not as to the younger rocks of this irruption. The orthophyrs show that they contracted so much in consolidating that the ends of the felspar crystals and the granophyric ground nass left spaces which were filled by hæmatite. The few metamorphic changes were endomorphic, proceeding from the action of the intrusive masses themselves, and not from external causes. This, therefore, leads to the conclusion that the irruption of the Frenchman's Hill area was subsequent to the action of the forces which metamorphised the plutonic rocks at Greenwattle Creek into gneisses by pressure.

CONCLUSION.

In the preceding sections I have dealt with only a part of the metamorphic area which covers so great a length in Eastern Victoria. I have briefly described the principal features of the crystalline schists, and of the plutonic rocks found associated with them, and I have but superficially touched upon the questions raised by the consideration of these rocks. My object has been to record briefly the observations which I have made, and the conclusions to which these observations have led me, leaving more complete details to be given at some future time.

The time requisite for the conversion of the sedimentary and plutonic rocks at Omeo, into crystalline schists, appears to have been one of very extended duration, of which the measure is that of a geological period. The manner in which the great thickness of ancient oceanic rocks has been built up in the district south-east of Omeo, the mode in which the Middle Devonian marine limestones rest comformably upon them, and the total absence in Gippsland of any sedimentary beds which can be referred to the Lower Devonian, long ago suggested to me that the latter period was one of terrestrial condition.*

The great earth movements which produced the alteration of the Silurian sediments into argillites and crystalline schists also, as is shown by the structure of the Omeo district, brought about a great elevation of the earth's crust. It was probably a time of mountain making and of the marking out of the first outline of the Australian Alps.

Along the eastern and western boundaries of the metamorphic area, there is at Omeo evidence of enormous pressure exerted upon the sediments, and upon the plutonic rocks adjoining them.

* Notes on the Physical Geography and Geology of North Gippsland. Quart. Journ. Geol. Soc., xxxv. p. 1.

Within the area there are plutonic rocks and tracts of pressure-schists, but almost all traces of the normal sediments which must have once extended over it are denuded. On the western side, however, these remain in great extent and unknown thickness, and on the eastern side in somewhat less extent. These observations suggest a great anticlinal arch of the crust at this place, even allowing for faulting, which has evidently taken place very strongly.

It seems to me, therefore, that the most reasonable explanation is one which assumes that the earth stresses acted first in folding and compressing the strata, and then in raising up the compressed crust locally into a great north-westerly fold.

The motive power must have been lateral pressure, and this may well have been connected with an adjoining descending area. The conception is then reached of an imprisoned igneous magma, subjected to increased pressure and being thus forced against and following the rising crust.

The relations of the plutonic rocks which occur in extended areas from Omeo to Dargo to adjoining formations, of the diorites at Swift's Creek to the adjoining schists, and of similar intrusive masses elsewhere in the district to the sediments, show that the magmas were forced like wedges between the older fractured rocks, and now fill wide spaces from which the sedimentary beds have been thrust aside, or which in opening, by reason of the upheaving tresses, left vacant spaces to be filled by the invading rocks. At Swift's Creek, and the other places, the strata under such conditions have been deflected from their normal stride some forty-five degrees.

The metamorphic area having been formed, the plutonic rocks again became irruptive, forming areas around the border of the schists, and also in a less degree within them as I have described.

At this stage or possibly later occurred the volcanoes which produced the Snowy River porphyrites and the diabases of Buchan, and these vents to plutonic action apparently died out when in the Middle Devonian period the uppermost of the Buchan tufts and agglomerates and the quartz porphyries of Bindi were submerged and were connected by passage beds with the purely marine limestones of those places.

This then as I see it, is the history of that phase of geological history from the Upper Silurian to the Middle Devonian in which the crystalline schists of Eastern Victoria were formed. It was an age of earth stresses, of putonic action upon the subterranean crust, and of volcanic activity finding a passage to the earth's surface.

The results of this investigation into the structure and origin of the crystalline schists appear to me to arise naturally out of the observed facts, and to accord in a satisfactory manner with the outcome of the extended and exhaustive investigations of some of the present leaders of geological opinion.* In some minor matters, however, I find myself unable to fall in entirely with some explanations of the manner in which the metamorphic changes have been brought about by pressure. The subject is surrounded by enormous difficulties. No direct observation as to the manner in which the schists have been formed are possible, and the sum of experimental knowledge available as a guide to the probable cause and origin of their alteration is but small. The experiments of Daubrée, Fouqué, and Michel-Séir as to the formation of silicates by the action of heat and pressure upon mineral solutions, or by the fusion of suitable mineral mixtures, seem to me to throw no great light upon the chemical or other processes which must have taken place far down within the earth's crust when the crystalline schists assumed the form of mica-schist, or of gneiss. The process which brought about those results must necessarily be obscure to us, and our conclusions are therefore mainly drawn from the results themselves, and from such few experiments as have a direct bearing.

For instance, the behaviour of silica and of the silicates when under such enormous pressure as that of the earth-stresses referred to, and under raised temperature, can merely, as far as I know, be conjectured.

The experimental researches of Professor Spring produced only negative results as regards silica when under pressure not exceeding 10,000 atmospheres.† But the results of his experiments generally are highly suggestive to the geologist. He found that metals, when under great pressure and in a fairly divided state, formed definite compounds with each other, as for instance copper and zinc, and at the highest pressure employed became viscous, or almost fluid. Alumina under a pressure of 5,000 atmospheres formed a mass resembling halloysite, and at that pressure commenced to become fluid.

It thus becomes possible to think of the components of rocks under enormous pressure, and heightened temperature reacting upon each other as quasi-solutions, and thus perhaps forming definite mineral combinations. But this conception of the possible results of pressure alone, even if it is that certain substances become solid or fluid, does not shut out the action of solutions in the ordinary sense of the term.

It has always seemed to me that in considering what explanation

*I desire to take this opportunity of pointing out that my views of the origin of the crystalline schists have undergone considerable change since the time when I first commenced to study them in the field, and when I described them in 1874 (Quart. Journ. Geol. Soc., XXXV., p. 1,) My views were then those of Lyell, and I considered that the Omeo schists afforded strong evidence of their truth. Continued investigation has, however, satisfied me that those views must in a great measure be abandoned, and that the opinions now held as to the origin of the crystalline schists by Lehmann, Geikie, Bonney and others must be adopted, if not in their entirety, yet on the broad lines laid down by them

† Walter Spring, Recherches sur la propriété qui possèdent les corps solides de se souder par l'action de la pression. Bull. Acad. R. Sciences de Belgiqne, 1880, XLIX.. pp. 323-379.

may be given of the processes of metamorphism of the Silurian strata of Omeo, some account must be taken of the amount of water included in them when they were laid down as mud and sand in the Palæozoic oceans. This percentage of water could not wholly or in great measure escape until the strata containing it were raised above the sea level, and became freed from it partly by outflow and partly by admixture with meteoric waters percolating from the surface.

I do not think that they were so elevated before being metamorphosed, and therefore there must have been in them a percentage of mineralized water, which became involved in whatever mechanical and chemical changes affected the strata.

The quartz of the plutonic rocks, and of the plutonic quartz dykes such as occur at Omeo, shows that there was also a certain amount of water in the magmas from which these rocks were derived, although relatively small.

Thus the conclusion is reached that this amount of water in both classes of rocks may have acted as a solvent, and that the solutions which reacted in the schists, which formed the aggregation of quartz and felspar round some of the eyes in the gneisses, which regenerated the detrital material as mica, and which deposited the quartz in foliations and elsewhere, are not solely to be attributed to the action of enormous pressure producing fluidity. But the new views regarding the production of plasticity in rocks may lead to the disregarding of more simple explanations.

The view which has recommended itself to me, is, that the mica-schists and gneisses of Omeo were produced by the co-operation of two causes—first, pressure which caused a schistose structure and an abundance of finely comminuted material,—and second, the chemical action of mineral solutions which were partly contained in the original rocks and partly produced during the long continued course of increasing pressure and rising temperature.

These views, which are suggested by the observations recorded in this paper, are indeed almost those formulated by Lehmann when speaking of the granite magmas in his great work.* That this is so may lead to the reasonable belief that the explanation is at any rate, in its broader features, a sound one.

* Op. cit., p. 54.

I.—Table showing Output and Value of GOLD raised in the different Colonies.

Year	New South Wales oz.	New South Wales Value, £	Victoria oz.	Victoria Value, £	Queensland oz.	Queensland Value, £	South Australia oz.	South Australia Value, £	Tasmania oz.	Tasmania Value, £	New Zealand oz.	New Zealand Value, £	Total oz.	Total Value, £
1851	144,121	468,336	145,137	580,548	...	...	Total yield to end of 1871.	Total Value to end of 1871					[illegible]	1,048,884
1852	818,772	2,660,946	2,738,484	10,953,936	...	...							[illegible]	13,614,882
1853	548,053	1,781,172	3,150,021	12,600,084	...	...							[illegible]	14,381,256
1854	237,911	773,209	2,392,065	9,568,260	...	...							[illegible]	10,341,469
1855	170,146	654,594	2,793,065	11,172,260	...	...							[illegible]	11,826,854
1856	183,946	689,174	2,985,735	11,942,940	...	...							[illegible]	12,632,114
1857	161,043	674,477	2,761,567	11,046,268	...	...					10,437	40,422	[illegible]	11,761,167
1858	286,798	1,104,174	2,528,227	10,112,908	...	...					13,534	42,464	[illegible]	11,260,646
1859	323,084	1,259,127	2,280,717	9,122,868	24	87					7,336	28,427	2,612,061	10,410,509
1860	384,614	1,465,372	2,156,700	8,626,800	4,121	14,676					4,538	17,585	[illegible]	[illegible]
1861	459,879	[illegible]	1,967,453	7,869,812	1,077	3,928					194,031	751,873	[illegible]	[illegible]
1862	616,010	2,467,780	1,658,281	6,633,124	190	675					410,862	1,591,389	2,686,243	[illegible]
1863	467,330	1,796,170	1,627,105	6,508,420	8,000	30,000					628,450	2,431,723	2,730,954	[illegible]
1864	344,054	[illegible]	1,545,437	6,181,748	22,037	81,242					481,171	1,856,837	[illegible]	[illegible]
1865	314,541	1,231,243	1,543,188	6,172,752	25,339	92,938					574,574	2,220,474	2,507,642	9,723,407
1866	287,334	1,116,403	1,478,280	5,913,120	[illegible]	[illegible]			748	[illegible]	735,376	2,844,517	[illegible]	[illegible]
1867	261,407	[illegible]	1,433,246	[illegible]	49,092	170,000			1,364	5,210	686,965	2,698,862	[illegible]	[illegible]
1868	258,774	[illegible]	[illegible]	[illegible]	165,801	[illegible]			632	2,443	637,474	2,504,326	[illegible]	[illegible]
1869	252,130	[illegible]	1,337,290	[illegible]	138,221	[illegible]			177	621	614,281	2,362,995	[illegible]	[illegible]
1870	240,402	931,016	[illegible]	[illegible]	136,773	[illegible]			[illegible]	3,682	544,880	2,157,585	2,145,817	[illegible]
1871	[illegible]	[illegible]	1,355,477	5,421,908	171,938	616,907	28,429	99,364	[illegible]	22,954	730,029	2,787,520	2,613,351	[illegible]
1872	425,130	[illegible]	1,282,521	[illegible]	166,019	660,396	2,404	[illegible]	[illegible]	26,587	445,370	1,731,261	[illegible]	[illegible]
1873	[illegible]	1,395,175	1,241,205	[illegible]	194,806	717,540	98	340	[illegible]	17,865	505,337	1,987,425	[illegible]	[illegible]
1874	[illegible]	[illegible]	1,155,972	[illegible]	[illegible]	1,350,071	8,354	28,844	[illegible]	17,760	376,388	1,505,338	[illegible]	[illegible]
1875	230,883	[illegible]	1,095,787	4,383,148	391,515	[illegible]	13,742	[illegible]	3,010	11,408	355,322	1,407,770	[illegible]	[illegible]
1876	167,412	613,190	963,760	3,855,040	[illegible]	1,284,164	[illegible]	34,015	11,107	[illegible]	322,016	[illegible]	[illegible]	[illegible]
1877	124,111	471,418	809,653	3,238,612	[illegible]	[illegible]	11,811	40,868	5,777	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1878	119,665	[illegible]	775,947	[illegible]	[illegible]	[illegible]	10,746	37,171	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1879	109,650	407,219	758,947	3,035,788	[illegible]	[illegible]	14,230	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1880	118,600	[illegible]	829,121	3,316,484	[illegible]	[illegible]	13,746	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1881	149,627	[illegible]	858,850	3,435,400	270,946	[illegible]	10,076	[illegible]	56,693	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1882	140,469	526,521	898,536	3,594,144	224,893	[illegible]	[illegible]	54,216	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1883	123,806	[illegible]	810,047	3,240,188	212,783	744,740	[illegible]	[illegible]	46,577	170,442	[illegible]	[illegible]	[illegible]	[illegible]
1884	107,199	396,292	778,618	3,114,472	307,804	1,077,314	[illegible]	74,034	42,340	160,404	229,946	921,797	[illegible]	[illegible]
1885	[illegible]	[illegible]	735,218	2,940,872	310,941	1,088,293	18,227	63,065	41,240	[illegible]	237,371	948,615	[illegible]	[illegible]
1886	101,417	[illegible]	665,196	2,660,784	340,998	[illegible]	[illegible]	91,049	31,014	117,250	227,079	[illegible]	[illegible]	5,332,439
Totals	9,784,840	[illegible]	[illegible]	217,671,628	5,176,729	18,484,467	227,065	786,120	450,665	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

II.—Table showing Output and Value of COPPER, COPPER ORE, and REGULUS, in the different Colonies.

Year	New South Wales Tons	New South Wales Value, £	Victoria Tons	Victoria Value, £	Queensland Tons	Queensland Value, £	South Australia Tons	South Australia Value, £	Tasmania Tons	Tasmania Value, £	New Zealand Tons	New Zealand Value, £	Totals Tons	Totals Value, £
							55,190	1,218,781					55,190	1,218,781
1851	...	...	...	...			7,718	209,324					7,718	209,324
1852	...	...	...	...			13,673	374,778					13,673	374,778
1853	...	...	...	...			4,082	176,347					4,082	176,347
1854	...	...	...	...			3,684	94,400					3,684	94,406
1855	...	...	...	...			4,714	151,827					4,714	151,827
1856	...	...	...	...			11,788	407,065					11,788	407,665
1857	...	...	...	...			10,957	[illegible]					10,957	[illegible]
1858	58	1,400					9,240	[illegible]			351	5,000	[illegible]	[illegible]
1859	30	678					10,284	[illegible]			216	2,605	[illegible]	399,823
1860	43	[illegible]			1	60	10,308	[illegible]			137	[illegible]	10,549	[illegible]
1861	144	[illegible]			49	1,450	11,159	447,466			110	1,300	11,462	[illegible]
1862	213	5,742			268	[illegible]	10,917	544,372			51	1,024	11,449	561,470
1863	137	[illegible]			1,100	30,000	10,183	[illegible]					11,420	[illegible]
1864	54	[illegible]			2,000	60,000	11,399	[illegible]					13,353	[illegible]
1865	[illegible]	[illegible]			721	58,440	21,217	618,472					[illegible]	[illegible]
1866	278	[illegible]			3,168	91,872	14,287	810,102					16,713	922,854
1867	393	[illegible]			6,140	[illegible]	19,273	740,703			246	2,700	26,052	[illegible]
1868	816	[illegible]			9,033	73,020	25,046	608,423			84	972	[illegible]	[illegible]
1869	2,084	[illegible]			6,310	76,230	31,474	[illegible]					39,868	774,730
1870	1,000	[illegible]			1,335	[illegible]	26,357	509,780			7	120	[illegible]	[illegible]
1871	1,444	[illegible]			2,400	[illegible]	26,562	637,984					30,450	[illegible]
1872	[illegible]	[illegible]			2,445	196,000	34,416	[illegible]					[illegible]	[illegible]
1873	2,846	239,102			2,441	185,808	34,464	768,502					30,751	1,103,412
1874	4,160	325,140	312	Total value to end of 1884	2,228	164,040	29,003	[illegible]					35,703	1,183,016
1875	[illegible]	[illegible]	37		1,074	[illegible]	33,272	[illegible]					38,660	[illegible]
1876	3,275	249,978	1,037		2,105	147,000	32,145	592,000					38,562	988,978
1877	4,313	[illegible]	1,426		1,039	[illegible]	23,945	563,010					31,843	1,054,373
1878	[illegible]	[illegible]	3,862		574	35,126	20,851	[illegible]			6	115	30,212	[illegible]
1879	4,141	[illegible]	3,031		567	34,791	17,283	[illegible]			55	1,105	23,077	[illegible]
1880	5,394	[illegible]	582		326	20,137	17,877	348,147					24,170	730,343
1881	6,494	[illegible]	693		331	[illegible]	25,462	418,290			5	36	31,985	793,031
1882	[illegible]	[illegible]	381		1,724	14,082	29,544	455,570			9	41	30,616	795,320
1883	[illegible]	577,201			1,800	21,080	22,085	375,325			46	678	32,888	974,284
1884	7,305	[illegible]			1,653	30,872	[illegible]	469,240			20	106	37,520	1,105,387
1885	5,746	[illegible]		189,000	1,340	[illegible]	21,165	[illegible]					29,251	606,823
1886	4,026	[illegible]	3,844	65,348	900	7,000	16,417	230,868					27,187	405,533
Total	78,126	4,964,249	15,205	254,348	54,685	1,925,309	730,431	18,620,603			1,373	17,392	886,620	25,781,991

III.—Table of Outputs of COAL and SHALE raised in different Colonies.

Year	New South Wales Tons	New South Wales Value, £	Victoria Tons	Victoria Value, £	Queensland Tons	Queensland Value, £	South Australia Tons	South Australia Value, £	Tasmania Tons	Tasmania Value, £	New Zealand Tons	New Zealand Value, £	Totals Tons	Totals Value, £
	525,799	[illegible]											525,799	220,524
1851	67,010	[illegible]	No details	Total to 1886									67,010	25,456
1852	67,404	[illegible]											67,404	[illegible]
1853	96,809	[illegible]											96,809	[illegible]
1854	116,642	[illegible]											116,642	[illegible]
1855	137,076	[illegible]											137,076	[illegible]
1856	189,960	117,906											189,960	117,906
1857	210,434	[illegible]											210,434	148,158
1858	216,397	162,162											216,397	162,162
1859	308,213	204,371			5,184	3,460							[illegible]	[illegible]
1860	368,862	[illegible]			12,327	9,244							[illegible]	[illegible]
1861	342,067	[illegible]			14,212	9,922							[illegible]	[illegible]
1862	476,522	[illegible]			24,067	19,263							[illegible]	[illegible]
1863	433,889	[illegible]			24,000	15,000							[illegible]	[illegible]
1864	549,012	[illegible]			25,000	15,500							[illegible]	[illegible]
1865	[illegible]	[illegible]			33,000	19,425							[illegible]	[illegible]
1866	777,008	[illegible]			39,316	21,249							816,324	[illegible]
1867	774,091	357,000			17,988	9,566							792,079	367,406
1868	[illegible]	446,622			19,611	11,519							960,794	458,141
1869	[illegible]	[illegible]			11,129	6,007							938,394	370,503
1870	[illegible]	371,076			22,639	12,311							896,620	384,287
1871	924,524	[illegible]			17,000	9,407							941,524	393,847
1872	1,023,406	[illegible]			27,727	16,120							1,051,193	441,018
1873	1,210,712	710,222			33,613	22,052							1,244,325	738,274
1874	[illegible]	817,524			43,443	19,700							1,360,110	847,224
1875	1,335,926	[illegible]			32,107	14,875			7,719	6,561			1,375,752	856,320
1876	[illegible]	[illegible]			50,627	26,470			6,100	5,185			1,392,043	882,949
1877	1,463,234	[illegible]			60,918	[illegible]			9,470	8,049	*673,972	*535,684	2,607,594	1,474,014
1878	[illegible]	[illegible]			52,580	21,272			12,311	10,464	162,218	89,219	1,826,977	1,090,102
1879	[illegible]	1,017,809			55,012	22,750			9,514	8,080	231,218	127,169	1,911,644	1,175,814
1880	1,465,381	[illegible]			58,052	24,573			12,219	10,386	299,923	164,957	1,835,575	859,978
1881	1,603,118	[illegible]			65,612	29,033			11,163	9,488	337,262	185,004	2,217,155	[illegible]
1882	[illegible]	[illegible]			74,436	33,163			8,803	7,482	378,272	209,049	2,618,858	1,283,213
1883	[illegible]	1,292,803			104,269	44,927			8,872	7,526	421,764	231,970	3,106,612	1,577,226
1884	2,780,727	[illegible]			129,980	54,160			7,194	6,381	480,831	264,457	3,398,732	1,700,251
1885	[illegible]	[illegible]			209,698	87,228			6,654	6,865	511,063	281,084	[illegible]	1,778,449
1886	2,873,738	1,403,140		21,048	228,656	95,243			10,391	6,898	534,353	298,894	3,647,138	1,825,223
Total	[illegible]	[illegible]		21,048	1,492,194	699,398			110,510	93,191	4,330,776	2,388,477	43,353,973	22,559,846

* Previous to 1878.

IV.—Table showing Output and Value of TIN and TIN ORE raised in the different Colonies.

Year	New South Wales Tons	New South Wales Value, £	Victoria Tons	Victoria Value, £	Queensland Tons	Queensland Value, £	South Australia Tons	South Australia Value, £	Tasmania Tons	Tasmania Value, £	New Zealand Tons	New Zealand Value, £	Totals Tons	Totals Value, £
1872	896	47,703			1,383	96,840	...						2,279	144,543
1873	4,571	334,436			3,790	208,997			4	200			8,365	543,629
1874	6,219	484,322			3,193	160,602			143	7,316			9,555	[illegible]
1875	8,080	561,311			4,774	237,879	140	450	366	31,325			13,360	[illegible]
1876	6,958	[illegible]			4,315	187,204	80	140	1,616	99,605			12,969	[illegible]
1877	8,054	[illegible]			3,335	[illegible]			5,746	296,941			17,135	[illegible]
1878	7,210	[illegible]			2,849	[illegible]			5,837	316,311			15,896	[illegible]
1879	5,921	372,340			2,677	120,394			4,391	303,293			13,189	795,943
1880	6,159	[illegible]			2,847	142,977			3,054	341,736			12,060	956,050
1881	8,200	724,603			3,456	103,099			4,124	375,775			15,780	1,203,477
1882	8,670	833,461			4,261	209,904			3,670	361,040			16,601	1,404,411
1883	9,125	[illegible]			3,346	187,292	160	360	4,122	376,446			16,773	1,388,650
1884	6,665	[illegible]			3,383	130,464			1,707	301,423			11,755	953,474
1885	5,193	[illegible]	*11,100	665,200	3,254	[illegible]	40	107	4,242	357,587			23,829	1,590,391
1886	4,967	467,053	1½	90	3,153	162,124			5,728	409,487			13,849½	1,059,854
Total	96,888	7,402,340	11,101½	665,200	50,215	2,472,025	440	1057	47,650	3,578,403	...	...	206,204½	14,119,116

* Total to end of 1885.

V.—Table showing Output and Value of SILVER raised in different Colonies.

Year	New South Wales (Exclusive of silver lead ore, *vide* Table 6) Ozs.	New South Wales Value, £	Victoria Ozs.	Victoria Value, £	Queensland Ozs.	Queensland Value, £	South Australia (Only silver lead ore included in Table 6.) Ozs.	South Australia Value, £	Tasmania Ozs.	Tasmania Value, £	New Zealand Ozs.	New Zealand Value, £	Totals Ozs.	Totals Value, £
1863			1,098	274									1,098	274
1864			4,207	1,051									4,207	1,051
1865			4,054	1,263									4,954	1,263
1866			2,348	587									2,348	587
1867			366	91									366	91
1868			5,761	1,441									5,761	1,441
1869	753	188									11,063	2,903	11,816	3,181
1870	13,868	3,467									37,123	11,380	50,991	14,847
1871	71,311	17,827									80,272	23,145	151,583	40,972
1872	49,645	12,003	8,011	2,002							37,064	9,910	[illegible]	[illegible]
1873	66,998	16,278	14,347	3,087							36,187	[illegible]	[illegible]	[illegible]
1874	78,027	[illegible]	11,906	2,976	1,000	400					40,666	[illegible]	[illegible]	[illegible]
1875	52,553	12,794	21,842	5,461							29,085	[illegible]	[illegible]	[illegible]
1876	69,179	15,450	26,356	6,588							12,683	3,171	[illegible]	[illegible]
1877	31,409	6,073	19,718	4,929							33,603	7,550	[illegible]	18,148
1878	60,563	13,291	22,995	5,748							23,019	5,755	106,577	24,794
1879	83,164	18,071	23,729	5,932	12	285					20,645	4,512	127,550	[illegible]
1880	91,419	21,678	23,248	5,812	697	13,845					20,005	4,500	[illegible]	46,035
1881	57,254	13,026	20,957	5,239	418	19,973					18,885	4,236	97,514	42,474
1882	38,618	9,024	20,343	5,085	1,705	21,235					5,694	1,280	66,360	36,630
1883	77,065	16,489	22,121	5,530	5,234	56,760					10,926	3,785	121,240	82,563
1884	93,667	19,780	27,070	6,767	4,363	36,097					24,914	5,125	[illegible]	67,769
1885	749,174	157,187	28,951	5,307	7,124	61,235					16,624	3,169	[illegible]	229,598
1886	1,015,433	197,544	26,422	5,174	1,631	52,797					12,108	2,946	[illegible]	255,515
Total	2,700,000	570,515	336,750	80,844	22,324	265,027	...	...	...	...	464,548	118,322	3,523,622	1,035,308

VI.—Table showing Output and Value of MINERALS not otherwise Classified, from respective Colonies.

Year	New South Wales (Including iron, antimony, asbestos, bismuth, &c., &c.) Tons	New South Wales Value, £	Victoria (Including lead, antimony, and iron.) Tons	Victoria Value, £	Queensland (Including antimony, mercury, and manganese.) Tons	Queensland Value, £	South Australia (Including lead, spelter, bismuth, iron ore, and maganese.) Tons	South Australia Value, £	Tasmania Tons	Tasmania Value, £	New Zealand (Including antimony, maganese, iron, kauri gum, &c., &c.) Tons	New Zealand Value, £	Totals Tons	Totals Value, £
											*2,846	*49,330	*2,846	*49,330
1856							33	377			1,473	16,591	1,506	18,068
1857							1,422	28,855			2,522	35,215	3,944	64,070
1858							853	14,200			1,814	20,062	2,667	34,262
1859							325	13,778			2,018	20,896	2,343	34,674
1860							169	10,765			1,162	11,291	1,331	22,046
1861							77	4,726			908	10,408	985	15,134
1862							118	3,241			4,946	35,826	5,064	39,067
1863							403	9,082			1,995	31,544	2,498	40,570
1864							569	13,228			2,990	65,500	3,565	78,728
1865							90	1,640			1,867	46,000	1,957	47,700
1866					30	300	715	14,300			2,816	71,897	3,561	86,496
1867		Value to 1874			4½	21	381	8,817			2,685	77,491	3,070½	86,329
1868					75	200	228	6,915			2,690	72,498	2,993	79,609
1869					20	50	170	4,767			2,850	111,307	3,040	116,124
1870					20	60	131	4,110			4,391	175,074	4,542	179,244
1871					3	15	169	5,497			2,850	111,308	3,022	116,820
1872					1,427	109,816	61	2,324			4,391	175,074	5,879	[illegible]
1873					8,946	606,208	14	20			5,054	167,958	14,014	774,186
1874		16,731			5,722	350,010	24	332			4,811	154,167	10,557½	[illegible]
1875	180	5,502			90	710	132	66			2,834	85,816	3,200	92,094
1876	3,018	10,781	2,541	20,964	19	696	17½	229			2,569	70,986	8,164½	118,656
1877	2,900	[illegible]	2,665	21,961	119½	925	84½	1,048			2,231	138,523	8,000½	179,749
1878	1,041	9,612	2,928	21,472	30	1,853	39½	937			6,068	124,058	10,106½	157,912
1879	1,220	12,121	616	4,083	4	40	3,300½	2,303			5,967	143,501	11,205½	162,048
1880	2,455	18,105	475	2,972	6	15	30½	1,091			5,309	156,673	8,340½	179,056
1881	7,127	[illegible]	1,722	3,377	442	3,920	0½	20			10,070	265,187	19,370½	341,469
1882	8,583	[illegible]	1,260	4,680	351	4,797	107	1,500			8,680	261,308	19,050	327,656
1883	3,844	[illegible]	1,835	3,268	547	6,010	303	2,474			10,528	276,830	17,107	322,475
1884	4,207	[illegible]	2,529	5,014	803	6,034	80½	1,303			6,935½	[illegible]	14,584	[illegible]
1885	4,946	[illegible]	60	417	70	300	70½	2,073			6,711	349,960	11,862½	[illegible]
1886	4,049	[illegible]	...	...	5½	400	1,565	11,605			7,308½	307,968	12,947½	[illegible]
Total	43,550	[illegible]	16,640	86,170	18,704½	1,103,100	11,091	173,031	...	...	132,384½	3,862,080	223,276½	5,705,925

* Previous to 1856.

2.—THE DEVELOPMENT OF MINING IN AUSTRALASIA.

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Since the early days, when the Australasian Colonies were first visited by Europeans, mining has made such phenomenal strides that I need offer no apology to the members of the Association for attempting to bring under their notice the development of that art in our adopted country.

Of late years the several Parliaments have voted sums of money for the assistance of prospectors; but it must be borne in mind that although coal was worked by the Government in very early times, convict labour being employed, all the earlier discoveries of gold were hushed up, and the enormous returns which have since been obtained were practically forced upon the people, and were not due, in any way, to the assistance, or even encouragement of the Government. Notwithstanding these discouraging influences, however, mining has by degrees forged ahead, and we now find that the value of minerals raised in all the colonies for the year 1886, reaches a total of £9,147,620, made up as follows:—

Table showing value of Minerals raised from Mines during 1886.

New South Wales.		Victoria.		Queensland.		South Australia.		Tasmania.		New Zealand.	
Coal.	Metal.	Coal.	Metal.	Coal.	Metal.	Coal.	Metal.	Coal.	Metal.	Coal.	Metal
£ 1,403,140	£ 1,230,820	£ ..	£ 2,667,048	£ 95,243	£ 1,415,814	£ ..	£ 333,522	£ 6,898	£ 526,737	£ 298,894	£ 1,169,504

A glance at these figures will show us at once the enormous strides which have been made since 1829, in which year 780 tons of coal were raised in the colony of New South Wales, an output which can now be obtained in one day from several of the going collieries, and since the output of the metals has in many cases increased in like proportion, it is worth tracing the course of this development in order to obtain a true conception of the progress of mining in the colonies.

To avoid prolixity in my paper I propose to submit these data to the Association in a tabular form and to devote only a few lines to the description of the tables.

It will be seen by a perusal of them that the value of the different minerals raised varies greatly, but that Gold is the only one which has been worked in each colony. So uniformly does this metal appear to be distributed that each colony has proved to contain stores of it which are by no means contemptible, while from Victoria the quantity raised reaches an almost fabulous value—Victoria stands first on the list with the enormous output of 54,393,855 ounces, valued at £217,571,528 up to the close of 1886, and New Zealand comes next with 10,997,729 ounces, valued at £43,231,689. The total value of the gold raised in the colonies since 1851 is no less than £318,264,485.

The next mineral in actual money value is Copper, which has reached £25,781,990, of which South Australia contributed £18,620,603, and New South Wales £4,964,269. The next is Coal with a total value of £19,170,764, of which £18,356,732 comes from New South Wales; then Tin, the total value of which is £14,119,115, and New South Wales contributed £7,402,340, Tasmania, £3,578,403, and Queensland, £2,472,025. The Silver raised to the end of 1886 is only £1,035,308. of which the largest quantity is from New South Wales, valued at £570,515, but during subsequent years the returns have been enormously increased by the outputs of Broken Hill and Sunny Corner, as well as other mines.

In minerals not otherwise specified, a total value of £4,840,330 has been raised, New Zealand ranking highest with £3,129,294, this sum being largely made up with Kauri Gum.

It will be apparent that the largest outputs of the different minerals are as follow :—

Gold—Victoria	£217,571,528
Copper—South Australia ...	18,620,603
Coal—New South Wales ..	18,356,732
Tin „ „ „ ...	7,402,340
Silver „ „ „ ...	570,515
Other Minerals—New Zealand	3,129,294

The enormous yield of gold as compared with other minerals should do a great deal to answer the assertions, which are so freely made prejudicial to the gold mining industry, more especially when it is borne in mind that, even in New South Wales the value of gold raised is nearly double that of coal.

It will not, perhaps, be outside the scope of this paper to review briefly the conditions under which these different deposits occur.

As regards the gold by far the greater returns have been obtained from alluvial deposits. In the earlier days this alluvial gold was easily got and in some cases the deposits were of surprising richness. The large returns in Victoria during the years 1852-1862 were almost exclusively from alluvial, and such deposits as the Woolshed Valley, near Beechworth, were by no means uncommon.

Attention was then directed to deep leads, or deposits formed by rivers which had flowed during earlier geological times, and which had since been buried up by flows of basalt that had protected them from the denuding action of the fresh streams, and preserved their wealth intact.

Large sums of money were invested in opening, proving, and working these deep leads, especially in the neighbourhood of Ballaarat, where they have proved exceedingly rich and paid handsome dividends.

Reefs moreover have received much attention, and in many localities, have yielded very large returns of gold.

Perhaps the most valuable mine in the colonies has been the "Caledonian" at the Thames, New Zealand, which paid no less than £552,000 in dividends during one year, but many others have been very rich and have paid very well. Even the reefs however, with few exceptions, have not been worked far below the water level, for when the stone became pyritous and the proportion of free gold decreased, the difficulties and expenses of treatment deterred speculators from undertaking the necessary outlay to carry on the works, and for several years gold mining was by no means so flourishing as heretofore. There were however some mines in which works were carried down to considerable depths, as for instance on the saddle reefs of Sandhurst, and in other localities, and the working was conducted so judiciously that a very small yield was sufficient to pay working expenses, and dividends were declared on stone yielding only a few pennyweights per ton.

The discovery of gold in ironstone at Mount Morgan gave a fresh impetus to this branch of mining and necessitated the adaptation of a process which would deal with such fine gold, a proportion of which was coated with a thin film of oxide of iron. The result was that Messrs. Newbery and Vautin patented a chlorination process, which with certain modifications, has been found to be perfectly satisfactory, and this process has since been adapted to the treatment of pyritous ores.

The reefs which have been worked hitherto are chiefly in Silurian rocks in Victoria, New South Wales, and Queensland, while beds of Devonian age are also traversed by reefs carrying gold. In New Zealand, on the other hand, while reefs have been worked on a small scale in the Silurian rocks of Otago, the most important are those of Reefton, in slates, etc., of Carboniferous age, and tufaceous beds of probably Cretaceous age at the Thames.

The copper ores which have hitherto been worked in Australia, appear to be always associated with rocks of Silurian age, and very frequently with dykes of diorite. The remarkably rich surface deposits of the Burra Burra mine in South Australia seem to have been formed by a secondary action, the soil, and a limestone which rests unconformably upon the Silurian beds containing irregular nests and masses of blue and green carbonates, which lead, however, to lodes in depth. The Cobar and Nymagee copper is associated with Silurian rocks, and in New Zealand some exceedingly irregular deposits occur in serpentine, but have not been successfully worked up to the present time.

The deposits of coal vary quite as much in their geological age as those carrying gold. Those which are worked in New South Wales, the premier colony in this class of mining, are in the Upper Carboniferous and Permian rocks. Three distinct belts of coal-bearing strata occur, separated from one another by some thousands of feet of barren rock. The upper and lower beds contain the best coal, but good workable seams also exist in the middle group. The quality of the coal also differs in different parts of the colony, and whereas the Newcastle coals are of a good, all-round, character, with a comparatively small percentage of ash, and are of a caking nature, those of the Illawarra district are pre-eminently steam coals in which the proportion of ash is their only bad feature, whilst the Mountain coal is of a free burning nature, non-caking, and with a large percentage of ash. Some of the coals of Queensland, *e. g.* that of the Burrum field, belong to the same formation as those of New South Wales, but those of Ipswich appear to be younger. The coals of Victoria are in very small seams so far as proved, and appear to be of Oolitic age, while those of New Zealand, on the west coast, are Cretaceous where the quality is all that could be desired, forming an excellent coke, yielding a large percentage of gas, and, especially those of Westport, being excellent steam coals.

The lignites and brown coals of New Zealand are possibly somewhat younger than the bituminous series, and the coals are of a very inferior quality, but still have a fair local consumption; while the Bay of Islands coal, which is semi-bituminous, forms an excellent steam-coal, and has had a large sale for ocean-going steamers.

The very large annual output in New South Wales has necessitated the opening of the mines on an extensive scale and the employment of winding and hauling machinery on an improved principle. In the Newcastle district there is perhaps little to be desired in this respect in the principal mines, and an output of 500 tons a day is arranged for in several collieries. The underground haulage is chiefly carried on by the tail-rope system; each colliery is connected by rail with the port, and the Government have provided ample wharf accommodation, and hydraulic cranes by which the vessels are loaded with rapidity. In the southern collieries the coals are mostly worked either level free, or by dip drives, and many of the mines own private wharves which are connected with the mines by private railways, or self-acting trams, so that, when not prevented by stress of weather, the loading is also rapid.

In the Queensland collieries there has not been the same pitch of perfection reached as yet, since the coal traffic is somewhat hampered by government railway freight, the principal mines being situated at Ipswich.

In New Zealand the most important mines are those of Greymouth and Westport, and at the first of these a railway has been constructed from the port to the mines, and in one case, right to the outcrop of the coal. The bar-harbour here is the greatest drawback to the success of the district, but even this has been greatly improved by the construction of a breakwater which has served to confine the waters of the Grey River and deepen the channel. At Westport some very heavy expenses have been incurred in the construction of a self-acting tram to a height of about 1,800 feet on which the railway trucks ascend and descend, and a system of endless chain haulage has been introduced throughout the mine. The harbour here has also been a serious difficulty, but has been materially improved lately by harbour works which have been undertaken.

From a productive point of view the collieries are no doubt steadier paying mines than any of the metalliferous ones, but no sensational returns are obtained from them as in the case of many gold, tin, copper, and silver mines; nor is the value of the coal raised so high as would be anticipated from the stress which is frequently laid upon the value of the coal mining industry.

I should not omit to mention, in this connection, the deposits of kerosene shale which are being worked in New South Wales, both in the Blue Mountains, and also at Mittagong. Near the latter place, most extensive works have been erected at Joadja Creek for the manufacture of kerosene, and the various bye-products which are obtained, and these operations are also carried on upon a smaller scale at Hartley Vale. The best shale is always sold for gas making purposes, a large quantity being annually exported, while the second qualities, which have also to be taken out, are treated at the works.

Tin mining deserves our next attention, on account of the value of the mineral raised, and by far the greatest quantity has been obtained from alluvial deposits. Reefs have, however, received some attention, being worked at Mount Bischoff in Tasmania, and in a few places in New South Wales and Queensland. There has not, however, been much enthusiasm in working these deposits hitherto, and there is a great future in store for these more permanent deposits when capital is directed to their working. The conditions under which tin lodes occur in Australia are precisely similar to those which prevail in the older and better known tin-fields of the world, and so do not demand any special description.

Silver mining has attained an importance in the colonies during the past few years, which could hardly have been anticipated from the previous yields. Silver discoveries have been made throughout the length and breadth of the colonies, some of them being of the greatest importance and value. In the majority of cases the silver-bearing lodes are associated with Silurian rocks and granites, but frequently dyke rocks, such as felsites, play an important part in their mode of occurrence. The silver occurs chiefly associated with lead, as galena, or cerussite, but is also found with fahlore, and occasionally with arsenical pyrites. The silver industry may be considered to be yet in its infancy, but in the future will, probably, develop into very large proportions. Regarding those other minerals which have not been otherwise classified, kauri gum has yielded the largest returns. Antimony, manganese, and chromite, have also been raised in some quantities, as well as cobalt and nickel. Iron ores exist, but can hardly be worked for export for many years, and diamonds and other precious stones have been found in large quantities, but mostly of small size hitherto. Lastly, a valuable deposit of alunite has been discovered, the stone occurring in unlimited quantities, and alum is now in the market, which is being manufactured from it, and which is fully equal in quality to the famous Roman alum.

A perusal of these data impresses upon one's mind the fact, that Australasia is an essentially mining country, A place where all classes of ores are found, and one which affords every inducement to further development of its resources. There is no doubt that we have other sources of wealth, but, in my opinion, the future of Australasia will be very largely dependent upon the minerals raised, and the industries dependent upon them. There is perhaps no part of the world where valuable ores are so evenly distributed through the ground, for whether we go north or south, we find mines working, their success depending greatly upon the skill which is brought to bear upon the extraction of the mineral, and the treatment of the ore.

THURSDAY, AUGUST 30.

The following papers were read :—

1.—ON THE AGE OF THE MESOZOIC ROCKS OF THE LAKE EYRE BASIN.

By RALPH TATE, F.G.S., F.L.S., Professor of Natural Science in the University of Adelaide, South Australia.

IN South Australia until the year 1877, the existence of deposits of Secondary age* had not been demonstrated, although Mr. F. G. Waterhouse, in 1862, collected a few fossils at the Gregory, Welcome, and Beresford Springs, which I determined to be identical

* Quart. Journ. Geol. Soc., 1877, xxxiii. p. 258; Trans. Roy. Soc. S. Aust., 1879, iii. pp. 104 and 179.

with species described by Mr. Charles Moore,* from Wollumbilla, Queensland.

Since my first announcement of Secondary fossils in the Lake Eyre basin, several small collections have been received from widely separated localities, and the list of species has now attained to fair dimensions. For the most part, the condition of the fossils does not permit of accurate generic definition, and the same remark applies equally well to those of Wollumbilla, described by Moore, and those of Maryborough described by Etheridge. It is not, therefore, always safe to refer our fossils to described species; and better definitions of the genera and species of the Secondary fossils of Central Australia and Queensland is much to be desired. Nevertheless, where specific identities are possible, the fossils of the Lake Eyre basin are, for the most part, constituents of the Wollumbilla fauna, whilst a few are common to the Maryborough beds.

The occurrence of *Crioceras* and a Ceratite-like Ammonite among the common fossils of the Lake Eyre basin demands their relegation, as also those of Wollumbilla, to the Cretaceous System.

The Wollumbilla collection, offering no restricted Mesozoic types, was regarded by Mr. Moore, on the strength of certain supposed identities with the European Juras as Jurassic, and though admitting the Cretaceous facies of the *Crioceras*, yet he attributed it to beds of very much younger age than those at Wollumbilla. The recent discovery, as already announced, proves Mr. Moore to have been in error. The Jurassic age of the Greenough beds in Western Australia is not likely to be challenged, and between them and the Queensland Cretaceous beds there is no community.

The European identities alleged to occur in the Wollumbilla beds, are *Lingula ovalis Avicula braamburiensis*, *Belemnites paxillosus*, *Serpula intestinalis*, and *Rhynchonella variabilis*. Relying on Mr. Moore's determinations, I have persistently advocated the Jurassic age of the Lake Eyre fossils; but forced to abandon that position by the more decided Cretaceous facies of recently acquired species, it becomes necessary to reinvestigate the claims of the forementioned species to bear the names attached to them.

A well preserved pecimen of *Lingula* from the Lake Eyre Basin, agrees exceedingly well with *L. subovalis*, Davidson; a *Rhynchonella* from the same area is certainly like some varieties of *R. variabilis*, Schlotheim, but it differs by its depressed mesial area, though at the same time I cannot attach it to any described Cretaceous species. Moore's figure of *Avicula braamburiensis* does not represent that shell at all, it may be a *Pecten*, though it is certainly not *Aucella hughendensis*.

Belemnites paxillosus, of Moore, is admitted by Phillips not to be that species, indeed the oblique lateral grooves, and absence of apical furrows places it in juxtaposition with *B. australis*, and removing it far from the Liassic fossil, I name it *B. eremos*.

* Quart. Journ. Geol. Soc. 1870, xxvi. p. 226.

Serpula intestinalis is not figured by Moore, and as I have not seen any related species in the Lake Eyre beds, no opinion can be formed as to the value of the identification.

LIST OF CRETACEOUS FOSSILS OF THE LAKE EYRE BASIN.

Species.	*Other occurrences.*
Crioceras australe, *Moore.*	Upper Maranoa.
Belemnites australis, *Phillips.*	Grey Range; Wollumbilla.
,, Canhami, *Tate.*	
,, Selheimi, *T. Woods.*	Palmer River.
,, eremos, *Tate.*	Wollumbilla.
Cinulia Hochstetteri, *Moore.*	Wollumbilla.
Natica variabilis, *Moore.* (N. lineata, *Etheridge*).	Wollumbilla; Maryborough.
Dentalium arcotinum, *Forbes.* (D. lineatum, *Moore*).	Wollumbilla; India.
Avicula Barklyi, *Moore.* (A. reflecta, Moore; A. orbicularis, *Hudleston.*)	Grey Range; Wollumbilla
,, umbonalis, *Moore.*	Wollumbilla.
,, corbiensis, *Moore.*	Wollumbilla.
Aucella hughendensis, *Etheridge.* (A. Liversidgei, *Eth. jun.*)	Grey Range; Hughenden; Marathon.
Cytherea Clarkei, *Moore.* (Cyprina expansa, *Etheridge*).	Grey Range; Wollumbilla; Maryborough.
Cytherea Woodwardiana, *Hudleston.*	
Gervilleia angusta, *Hudleston.*	
Mytilus inflatus, *Moore.* (M. linguloides, *Hudleston*).	Wollumbilla; Palmer River.
Mytilus rugocostatus, *Moore.* (M. Scoulari, *Tate*).	Wollumbilla.
Myacites M'coyii, *Moore.*	Wollumbilla.
Myacites rugosa, *Moore.* (M. australis, *Hudleston*).	Wollumbilla.
Nucula quadrata, *Etheridge.*	Maryborough.
,, truncata, *Moore.*	Wollumbilla.
Pecten psila, *T. Woods.* (? P. socialis, *Moore*).	Grey Range; Wollumbilla.
Trigonia nasuta, *Etheridge.*	Maryborough.
,, lineata, *Moore.*	Wollumbilla.
Lingula subovalis, *Davidson.*	Wollumbilla; England.

In addition to the above are species of :—*Ammonites* (with the sutures of *Ceratites*); *Alaria*, 2 sp.; *Modiola*, *Narica*, *Leda*, *Pecten*, *Gervilleia*, *Pinna*, *Arcomya*, *Pleuromya*, *Rhynchonella*, and of several uncertain genera of bivalves.

2.—A CENSUS OF THE OLDER TERTIARY FAUNA OF AUSTRALIA.

By Ralph Tate, F.G.S., F.L.S., Professor of Natural Science in the University of Adelaide, South Australia.

3—GLACIAL PHENOMENA IN SOUTH AUSTRALIA.

BY

Ralph Tate, F.G.S., F.L.S. Professor of Natural Science in the University of Adelaide, South Australia.

The subject of glaciation in Australia has been much discussed since I first brought it to scientific notice in the year 1877. The evidences that may be adduced in favour of glaciation are always open to doubt, and their acceptance largely rests on the known ability of the observer to interpret aright the signs of extinct glaciers.

The glaciated surface which I announced in 1877 as well developed on the coast cliffs at Hallett's Cove, south of Holdfast Bay in St. Vincent Gulf, remains as yet unique; but once it is accepted as of glacial origin, many other features obscure in themselves acquire co-ordinate value in relation therewith. It is not my purpose to describe the various signs which now can safely be attributed to glacial action, but simply to bring to your notice such tangible evidences of the glaciated condition of the rock surface at Hallett's Cove, and of its associated moraine debris. Actual inspection would, I am sure, convince you, but under present circumstances, I reverse the usual order, and "bring the mountain to Mahomet," at least so much of the mountain as hand specimens and photographs are capable of conveying of its nature and appearance.

The path of the glacier is traceable for a distance of two miles, along the top of the scarped sea-cliffs at about forty feet above the sea-level; on the north it is cut out from the cliff by encroachment of the sea, from this point the glaciated surface is continuous in a southerly direction for a distance of one mile to Black Point, the north headland of Hallett's Cove. On the line of the glacier, there now intervenes the broad but narrow bay of Hallett's Cove, but on the south headland the track is picked up on about the same trend, though apparently at a little higher level—here again the glacier path is soon cut out by removal of the cliff.

On the north side of the Cove, the glaciated surface is beautifully displayed, the edges of nearly vertical strata are sheared off, and when of quartzite the surface shows a high polish, and when of mudstones conspicuous grooves and striæ. Some moraine *débris* including stones that have been beneath the glacier occur here. On the south side, moraine matter is very abundant and includes many boulders, some occurring as *blocs perches*.

The common rocks of the morainic *débris* are granites, gneiss, hornblende-schists and others, which do not occur *in situ* nearer than the Gorge at Normanville, about forty-six miles to the south. In all seventeen distinct varieties of rock, chiefly metamorphic, and foreign to the immediate neighbourhood, have been collected along the path of the glacier.

The proximity of the Miocene escarpment suggests the possibility of the Pre-Miocene age of the glacier. The Miocene formation, throughout its whole length on this part of the coast, has a conglomerate base consisting of well rounded pebbles of limestone and quartzite, and flat pebbles of slaty rock, but none other than local material has been yet observed, though diligently searched for. It is highly probable that the glacier cut its way through the incoherent Miocene formation, and that some of the Miocene shingle furnished some portion of the moraine *débris*.

Some measure of the antiquity of the glacier is further afforded by the amount of marine erosion that has subsequently taken place. Assuming that the glacier was in an alignment with the two headlands of Hallett's Cove, then a length of three-fourths of a mile by a breadth of one and a-half furlongs, and a thickness of forty feet has been removed since the glacier ceased to exist.

I exhibit the following specimens and photographs illustrating glaciation at this locality :—

1. Slab of quartzite having a highly polished surface and faintly striated.
2. Chip of mudstone, having a smooth surface, strongly striated and grooved, taken from the site represented in the photograph No. 5.
3. Ice-worn pebble, polished and striated on its upper and lower faces, found partly embedded in soil resting on glaciated surface.
4. A small subangular pebble of granite with one smooth face.

In addition to the photographs presenting general views of the locality, I particularly draw attention to :—

5. Showing ice-worn face, whence specimen No. 2 was taken. This is the original discovery; and the area of exposed, smooth, and striated surface is seven yards long and two yards broad.
6. A nearly vertical face of ice-worn surface, indicating a sudden depression in the otherwise plain surface of the glacier path.
7. A large boulder of felsitic-quartzose sandstone.

4.—ORIGIN OF THE LATERITE IN THE NEW ENGLAND DISTRICT OF NEW SOUTH WALES.

By T. W. Edgeworth David, B.A., F.G.S., Geological Survey of New South Wales.

INTRODUCTION.

The term Laterite in the present paper is applied by me to a rock of very variable character associated with basalt. The colour is of a prevailing dull brick red or ochreous hue, and the rock shews every gradation of texture from that of a soft earthy rock, to that of a hard pisolitic ironstone, The characteristics of laterite have been studied by me chiefly at Vegetable Creek, and also to a limited extent in the Tingha District. I have come to the conclusion that the laterites are altered basalt tuffs and scoriæ.

The bulk of the rocks at Vegetable Creek, which are partly sedimentary and partly igneous, are of Palæozoic age. Mesozoic rocks are not represented, unless, perhaps, some of the intrusive dykes belong to that group. A great unconformity consequently exists between the Palæozoic and the Tertiary formations. The latter are represented by sheets of volcanic rocks, chiefly basaltic, from ten to sixteen miles in length, and from half a mile to two miles wide, with small sheets of felsite. Associated with these volcanic rocks are gravel, sand and clay, chiefly of fluviatile origin. These volcanic rocks occupy the sites of old valleys belonging to various epochs of the Tertiary Era. The Tertiary volcanic rocks are characterized by their general horizontality and their association with deposits of stream tin.

A vast period of time must have elapsed between the flow of the earliest and the latest basaltic lavas, as in some cases there is evidence of a lava stream, after it had flooded an old valley and usurped its river channel, having been excavated to a considerable depth by renewed fluviatile forces, and partially covered by sedimentary deposits; and there is evidence then of the newer river gravels being buried under a second massive sheet of lava.

Some idea may be formed of the vastness of the time which has elapsed since the eruption of the first basalts, from the fact that they frequently form the main lines of water-parting at points where they immediately overlie the old river channels, and the gravels in these channels are in some cases over 550 feet above the level of the nearest modern rivers capable of forming such gravels.

The tertiary volcanic rocks at Vegetable Creek may be divided petrologically into:—

1. Felsites.
2. Basalts.
3. Laterite.
4. Tachylite tuffs

At Tingha I have observed representatives of the basalts and laterites only.

MENTION BY PREVIOUS AUTHORS.

Mr. C. S. Wilkinson, F.G.S., etc., describes outliers of red pisolitic iron stone in the Tingha district overlying Tertiary stanniferous gravels, and states that he had not been able to arrive at a definite conclusion as to their origin.*

Amongst the miners at Vegetable Creek and Tingha, the laterite is known as "Ashes," or "Red Clinkers."

STRUCTURE.

Laterite, in all cases observed, occurs in sheets from a few feet to forty feet thick, from half a mile to a mile wide, and is chiefly developed around the points of eruption of the basalt, and consequently for the most part occupies the highest points attained by the volcanic rocks, except in the case of the Wellington Vale Lead. The general shape of these sheets may best be gathered from the geological map accompanying my report on the Vegetable Creek District, shewing their development in the parish of Lorne, County Gough, Vegetable Creek District. The map shews these areas to be of a rudely circular, or elongated-oval shape. Towards the centre of these areas the laterite rises into ridges or sugarloaf hills, the prominence of which is in inverse proportion to the denudation to which they have been subjected.

Such prominences may be devided into two classes :—

1. Hills.—*(a)* Crateriform hills showing more or less distinct crater rings, which are generally breached at one side. These may be described as composite cones of red scoriæ and volcanic dust from fifty to four hundred feet high, the diameter at the summit varying from sixty yards to a quarter of a mile, and the angle of external slope from 20° to 30°.

   Hills of the crater type are best developed, and have suffered least from denudation, in the parish of Lorne, where a tolerably perfect old crater is observable in a hill called "The Gap," of which I have elsewhere given the following description :—†

   "The summit is 400 feet above the general level of the lava sheets which radiate from it, and 200 feet above the general level of the neighbouring Palæozoic rocks. Ascending the "Gap" from the north, the observer passes off the stony lava on to the red dust and scoriæ at a level of about 2,125 feet above the sea. At a level of 2,310 feet a round stopper of stony lava is seen in the midst of the red country, and partly encircled by low walls of

*The Rev. W. B. Clarke gives a similar description of the same formation.

†Geology of the Vegetable Creek Tin-mining Field, p 34.

laterite. From here to the summit the slope steepens to an angle of 20° to 30°, and the rock becomes harder and more slaggy. The top is covered with scrub from six to seven feet high, rendering it difficult for the observer to get a good view of the general shape of the hill. The latter, however, may be gathered from the geological map, which shews the hill to be conical, the edges of the hill top being elevated above its centre, so as to enclose a hollow, the bottom of which is about forty feet below the level of the rim. The basin, or crater, so enclosed is a quarter of a mile in diameter. To the south-east the crater ring has been broken down, probably during a volcanic outburst; and the breach has been further deepened by the Forest Creek, which has its source within the crater. A small natural section is thus afforded of the internal structure of the hill. In the banks of the creek hard masses of spongy laterite, three to four feet in diameter, are seen to overlie a soft purple lava, which here forms a central core in the bottom of the crater. Following the creek down, the observer passes gradually below the level of the soft lava on to a small stream of hard stony basalt, which has evidently welled up from some point beneath the crater. The hill, therefore, possesses all the essential features of a volcanic crater, and may consequently be considered an extinct volcano."

In Portion 724, Parish of Strathbogie North, County Gough, laterite forms the rim and bottom of a semi-circular basin, about six chains in diameter, and evidently an extinct crater, from the centre of which a miniature stream of basalt takes its rise. Hills of this class which have been much denuded pass by insensible gradations into prominences of the next variety:—

(b) Sugarloaf, flat-topped hills, destitute of a central depression at the summit. Crescentic and sugarloaf hills, with summits either flat or shewing very slight depressions occur in the Parish of Astley, County Gough, where they rise only about fifty feet above the general level of the surrounding lava steams; and at Vegetable Creek similar hills occur, but they have suffered more from the effects of denudation.

2. Ridges.—Elongated ridges, having one side more or less steep, and having a slope of from 20° to 30°. The elongated ridges of laterite are more difficult of explanation. A typical example of a ridge of this kind adjoins the "Gap" crater just described. This ridge runs south for half a mile, and then south-east for another half mile. The summit is from one to two chains in width, and formed of laterite. The

western slope is steep and scoriaceous, dipping at from 20° to 30° while the eastern slope is very gradual. Eruptions of lava appear to have occurred at intervals along the ridge. The trend of the ridge may correspond with that of some deep-seated fissure, along the whole length of which the lava has boiled up, so that no craters have been formed, except at points along the line, where the volcanic energy became centralized, as at "The Gap"; or, more probably, the ridge has been formed by the progressive shifting of the volcanic orifice along the line of fissure, in which case each of the small lava sheets, which take their rise from the ridge, may mark the situations which were occupied from time to time by the "Gap" crater, before it came to rest in its present position.

CAVERNS.

A singular structure, locally met with, in the laterite, is that of circular cavernous spaces, shaped like inverted saucers, or comparable to immense bubble hollows.* One of these caverns was met with by Mr. H. Jew in sinking his 220 feet shaft in Reynold's selection in Portion 512, Parish of Scone, near Emmaville.* "When sinking through the hard laterite, Mr. Jew found the ground sound hollow, and as the sinking continued, he broke into a natural cavern at 30 feet from the surface, the base of the laterite being separated from the underlying surface of rotten lava by a space of two and a-half feet. The floor of this hollow was strewn with small round concretions of brown iron ore which had fallen out of the laterite from the roof. The cave extended on all sides as far as Mr. Jew could see, but was not explored for any distance away from the shaft. This hollow is now concealed by wooden slabbing, A similar cavern exists in Portion 1, Parish of Arvid, where the volcanic tuff, five to six feet thick, forms the spring of a low arch from two to three feet high and about fifteen yards wide. The cave has been laid bare through the partial collapse of the roof. These caves have probably been formed by the lava sinking from under the tuff beds, which may have been close to points of eruption, so that the lava would have a tendency to be forced to a higher level here than elsewhere; and so, as the eruption subsided, would, like water, seek to find its own level, and thus leave a hollow between its surface and the harder crust of overlying tuff. Darwin, in his 'Geological Observations,'† describes similar hollows at the bases of small basaltic craters at Chatham Island in the Galapagos Archipelago, where he observed several 'nearly circular pits with perpendicular sides from twenty to forty feet deep,' formed, he thinks, by the falling in of the

*Geology of the Vegetable Creek Tin-mining Field, p. 32.
†2nd Edition, p. 116.

roofs of small caverns, produced by the expansion of gases in the lava which had heaved its surface into huge bubbles or blisters. The caverns in the Emmaville basalts may have had a similar origin and have been due rather to the distension of the surface of the scummy lava, by imprisoned gases, than to the subsidence of the fluid lava from overlying cooled crust or tuff."

Evidence of similar caverns was observed by me about three miles beyond Laurel Hill, on the road from Adelong to Tumberumba, At this point the hard stony basalt rings hollow for a distance of several hundred yards, as the road approaches what seems to be the remains of an old crater which has formed the source of the lava stream. At this point, almost the highest in the range, a semi-circular depression exists, surrounded on three sides by gentle slopes of basalt, and open to the east. In the centre lies a circular pool of water about five chains in diameter. The whole width of the depression is from ten to fifteen chains. On the south side of this old crater the basalt also rings hollow when struck, for a distance of about ten chains down the road. There can be little doubt therefore of the existence here of lava caverns similar to those just described in the laterite of Vegetable Creek.

LIMONITE BEDS.

Lenticular beds of earthy limonite occur locally in small depressions in the laterite, their thickness seldom much exceeding one foot.

ERUPTED BLOCKS.

Angular fragments of quartz-porphyry and granite, about one foot in diameter, occur rather freely, principally near the edges of extinct craters, and rest immediately on the laterite, in which, however, I never found any of them embedded.

MACROSCOPIC AND MICROSCOPIC CHARACTERS.

From hand specimens it will be evident that the rocks, to which I have applied the term laterite, are of very variable character, ranging from undoubted tuffs to decomposed scoriaceous basalt and pisolitic ironstone. One of the most interesting specimens of the tuff is specimen No. 1 (*c*) which has been described by me as follows*:—"In the Wesley ground, in Portion 40, Hamilton, are four low conical hills, each of which is composed of red, or yellowish-red, earthy laterite, the tuffaceous character of the formation being more apparent here than elsewhere. Balls of rotten pink lava, half-inch in diameter, are bedded in an ochreish earth like plums in a pudding. Sharp, doubly-terminated, quartz-crystals with bruised edges, and splinters of quartz as sharp as broken glass, are scattered plentifully through the mass of the

*Geology of the Vegetable Creek Tin-mining Field, p. 31.

tuff, the whole having been derived from the grinding up of the underlying quartz-porphyry during volcanic eruptions." Specimem No. 1 *(a)* is also a tuff formed of a moderately hard base of a dull reddish-brown colour, resembling a half-burnt brick, in which are embedded whitish-grey and brownish-grey fragments, varying in size from that of a pin's head to that of marbles. These shew every gradation of shape from the round to the angular. They consist partly of crystalline rocks such as basalt and felsite, and partly of claystone. The fragments of dark grey basalt shew glistening crystals of limonite pseudomorphous after magnetite, and most of them consist of a thick shell enclosing a small kernel which is readily detachable from the shell. Felted crystals of kaolinized felspar of a pale greenish-grey or rusty-brown colour can be clearly seen under the microscope The spaces between the felspars are partly filled with black crystals of limonite. The hollow in one ôf these basalt lapilli seems of primary origin, so the fragment is probably a hollow bomb. I cracked open the kernel in it and found that it was composed of a reddish-grey amygdule, quite unlike the decomposed basalt forming the shell around it. Most of the large grey fragments, from one-half to one inch in diameter, are also decomposed basalts, and still shew the felted structure of the felspars very distinctly. Some of the whitish-grey fragments are more finely crystalline than the basalt lapilli. They consist of minute grains of greenish-grey kaolin interspersed with dust of limonite. The fragments are probably felsite or altered claystone, as both these rocks are found to underlie the basalts in the neighbourhood of this tuff. Under the microscope the base is seen to consist of semi-transparent microscopic grains of kaolin, most of which show double refraction. Some of them may probably be felspar, but none of them shewed evidence of twinning. The kaolin is just in the condition observable in the partially kaolinized portions of felspar crystals, the crystals breaking up into a mosaic of kaolin. Fragments of limonite are abundant, and dusty grains of the same mineral are tolerably plentiful in the base, though not in such abundance as in the basalt or felsite lapilli. Spherical concretions of limonite occur in the base occasionally.

In specimen No. 1 (*b*) the tuffaceous character of the rock is less apparent owing to its more advanced state of decomposition, the vase and the fragments being blended together. There is a large amount of segregated limonite in this specimen. The limonite occurs in minute spherical concretions, and delicate concentric shells, alternating with ochreous volcanic dust. The limonite also encrusts the fragments of decomposed basalt and forms irregular-shaped shells, one-quarter to half an inch thick, round portions of less decomposed volcanic dust. This iron has evidently been derived from the free magnetite in the basalt, and from the combined iron in their augite and olivine.

These tuffs pass by insensible changes into a hard pisolitic ironstone, like specimens V 7 and V 8 from Portion 530, Scone. These specimens are of a deep brick-red colour consisting of a base of brick-red earth enclosing segregated grains of magnetic iron about the size of peas. Some of the pisolitic concretions are hæmatite and others limonite, but the majority are magnetite. A few minute fragments of fossil plants are observable in specimen V 7, and angular grains of quartz are occasionally noticeable. This rock is more or less cellular, the hollows, which are of irregular shape, being lined or filled with spongy black oxide of manganese.

From the occurrence of fragmental vegetable remains it would appear that water has played some part in the formation of this rock, but there can be little doubt that in its first state it was a volcanic tuff.

A variety deserving special notice is specimen V 22, which contains a great deal of felsite. The possibility suggests itself of this tuff having been formed during the earlier part of the Tertiary volcanic outbursts, when, as pointed out by Mr. Herbert Cox, F.G.S., etc.,* small eruptions of felspar preceded the far more extensive outbursts of basalt. These felsite lavas are confined to an area of about one square mile, as far as is at present known, and have been explored at Bailey's and at the Shallow Lead at Rose Valley, where the thickness of the sheet seldom exceeds three feet. Rich stream tin wash has been worked under this felsite at Bailey's mine.

STRATIGRAPHY.

(*a*) The relation of the laterites to the basalts and their associated fossiliferous beds can be best studied in the immediate vicinity of Emmaville, where good sections are afforded by the shafts sunk to win the stanniferous gravels, which underlie the laterite and basalt. Such sections show that most of the laterite rests immediately on the Tertiary sedimentary beds, but that a small portion of it is separated from them by a sheet of hard basalt. A good section showing the laterite capping the basalt was to be seen in Mr. H. Jew's 220 feet shaft in Reynold's Selection, near Emmaville. As there were no means of my descending this old disused shaft, my section is from information kindly supplied to me by Mr. H. Jew. I was able, however, to examine the rocks in the spoil banks round the shaft, and from the nature of these, as well as from the surface evidence, I was satisfied that the laterite here overlies the soft and hard basalt.

At Foley's 120 feet shaft near Kangaroo Flat, the laterite not only overlies the basalt but is separated from it by a seam of stanniferous sand and gravel. The upper gravel was worked at a

* The Tin Deposits of New South Wales. Journ. R. Soc. N. S. Wales, 1886, xx. p. 105.

depth of eighty feet below the surface on a bottom of basalt, and the shaft was sunk forty feet below that level in hard basalt without reaching the underlying older gravels.

At the lower end of the Vegetable Creek lead between the Wesley Extended deep shaft and Mount Prospect, there is clear evidence of the laterite being partly covered over by the newer basalt, as on both the east and west sides of the gully which runs northerly from the Wesley Extended shaft, the laterite can be traced out-cropping from under the newer basalt for about a mile.

This phenomenon recurs in the Wellington Vale Lead near Deepwater, where laterite is interposed between the older and newer sheets of basalt.

(*b*) As regards the geological age of the laterite, I am inclined to think that part of it is synchronous with the older basalt, and part, possibly of an age intermediate between that of the older and newer basalts.

The age of the older basalts has been decided by Baron von Ettingshausen,* on the evidence of the fossil plants in the underlying sedimentary beds, to be Eocene.

As yet there is not sufficient evidence for assigning any particular geological age to the newer basalt.

PROBABLE ORIGIN.

The above observations may be summarized as follows :—

1. Much of the laterite in New England is clearly a fragmental rock of volcanic origin, being largely composed of lapilli of basalt.
2. Rocks of the preceding class pass insensibly through alteration into pisolitic ironstones and earthy clay ironstones, the former variety being largely composed of secondary magnetic iron, whereas iron is present in the other varieties chiefly in the form of limonite.
3. The laterite occurs in sheets roughly circular or oval, having a maximum thickness of forty feet.
4. The laterite is developed chiefly around points of basaltic eruptions, and constitutes a great part of the material of which some of the old craters are composed.
5. Cavernous spaces occasionally intervene between the bottom of the laterite, and the top of the underlying basalt.
6. Erupted blocks of Palæozoic rocks are occasionally found resting on the laterite.
7. The laterite underlies the newer basalt, and in some cases overlies the older basalt, in one case being separated from it by a thin bed of gravel. Frequently the under surface of the laterite rests immediately on the tertiary sedimentary beds.

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* Contributions to the Tertiary Flora of Australia. Mem. Geol. Survey, N. S. Wales, Palæontology, No. ii, 1888, p. 78. (Sydney, 4to., Government Printer.)

The probable explanation of these facts appears to be that the greater part of the laterite is an altered basalt tuff belonging to the earlier basalt eruptions of the Eocene Period, or possibly to a time intermediate between that of the older and newer basalts. It is highly probable that some of the laterite is an altered scoriaceous basalt. That water has played an important part in altering the tuffs and scoriæ, and possibly in re-distributing them is proved by the occurrence, though exceptional, of small fragments of plants intermixed with the laterite, and by the lenticular beds of limonite occupying local depressions on its surface.

5.—THE MESOZOIC PLAINS OF SOUTH AUSTRALIA, (SOUTH OF LAT. 26°).

By H. Y. LYELL BROWN, F.G.S., Government Geologist, South Australia.

THE area over which the Mesozoic beds form the surface rock, or are only thinly covered by those of Tertiary formation, extends east from the boundaries of New South Wales and Queensland, westward to the boundary of Western Australia, northward it is bounded by the Musgrave Ranges and Latitude 26°, and southward by an irregular line extending from the northern edge of the Nullarbor Plains in Western Australia, round by the Warburton Range, and the northern extremity of the main range to the vicinity of Lake Frome, near which it passes into New South Wales. Here and there along the telegraph line, from Hergott Springs to the Peak and Charlotte Waters, the Dennison, Margaret and other ranges, composed of Primary rocks, protrude through it in the form of islands, rising above the general surface in places to a height of 1,000 feet or more.

Lakes Eyre, Blanche, and Frome, are the principal lakes of this region, although there are numerous others dotted over the area. The largest rivers are the Diamentina and the Cooper, which enter the north-east corner of the colony from Queensland, and spread out into enormous lakes, connected by creeks and watercourses, by which, in times of flood, the lakes are filled. Other rivers are the Treuer or Macumba, and the Neales, with their numerous tributaries, rising in the neighbourhood of the Musgrave Ranges, and flowing eastward into Lake Eyre, with the Warburton, Clayton, Frome, and many other smaller creeks. The general level of this vast territory varies from some two hundred feet above sea level to twenty-five or thirty feet below it, in the case of Lake

Eyre; in consequence of this the fall of the rivers is very gradual, and in many cases their beds are level; this is proved in a curious way in the case of the Warry Warry, a creek in Queensland, which flows into the Cooper, above Innaminka, as rain which falls at its head in the Grey Range flows northwards into Cooper's Creek, while flood water from the Cooper and Wilson flow southward for some distance towards the Grey Range. Again, when the Cooper is in flood, which happens at intervals of two or three years, the water overflows southwards down the Strzelecki Creek into Lake Blanche, northward into Lake Goyder, and south-westward into Lake Hope. The country presents several aspects as regards contour and general appearance according to the nature of the overlying Tertiary and other uppermost beds. These may be summed up under the heads of Tablehills, Tablelands, Stony Downs and Plains, Silt-flats and Sandhills.

The Tableland and Tablehill country occupy a large area in many places, as in the north-east corner of the colony. The general elevation above the plains is about one hundred to two hundred and fifty feet, the upper bed is almost invariably a yellow flinty jasper rock, or porcelainized sandstone and quartzite, varying in thickness up to thirty or forty feet, sometimes it is a conglomerate, and at other times a sandstone; it rests on sandstone, argillaceous sandstone, kaolin, and grit, with thin bands of a loose pebble conglomerate. The pebbles found in the conglomerate consist of agate, jasper, chalcedony, opal, coloured quartz, flint, white and crystallized quartz, and fossil wood, all showing a brilliant polish or glaze.

As these Table-hills generally have sharp well-defined cliffs and escarpments, the stratification can be easily studied. They are either of Upper Cretaceous or Lower Tertiary age, and rest directly on the upper beds of the Cretaceous Formation, in horizontal and sometimes gently inclined layers; their composition and arrangement is the same over wide areas in South Australia, New South Wales, and Queensland, as far east as the Warrego River, where I have had an opportunity of examining them. The topmost bed of jasper rock has generally a conchoidal fracture and amorphous structure, although sometimes containing grains of sand, and pebbles, and becoming a conglomerate; it also occurs as rounded fragments and pebbles of yellow jasper rock cemented together in masses with glazed surfaces.

The Stony Downs are undulating and level plains, flanking the table-lands and extending for miles over the country, and covered with blocks and pebbles of the flinty jasper and other siliceous rock, with sometimes vein quartz, slate and sandstone; these fragments of rock are scattered over the surface of the plains and rest on soft yellow and reddish clay loam, derived from the denudation of the underlying shales. In many places the ground is covered with a smooth pavement-like covering of glazed fragments and pebbles, as in the Stony Desert of the Diamentina, in others the jasper rock lies scattered in slag-like masses and lumps, on the soft loamy surface of the plains, together with gravel shingle, and fragments of agate, chalcedony, quartz, flint, &c. It is difficult to account for the even distribution of these gravel, and rock fragments over such a large extent of plain surfaces, floating ice being the only agent likely to produce such results. Below and surrounding the table-hills and stony downs, are the soft silt plains, which, together with the former, cover the gypseous clays, marls, calcareous shales, limestone, sand, and gravel drifts of Cretaceous age. The greatest thickness of these beds, which has been proved by boring at Tarkininna, is about 1,200 feet. The mound springs, which are the natural indicators of artesian water beneath these plains, are found in many places near the outcrops of bed rock, between the junction of which and the Cretaceous rocks the water has, doubtless, found an easier egress. On the surface, the water often forms accumulations of travertine limestone rising to heights of forty or fifty feet, and showing in the distance across the level plains, where there is a group of springs, like a low range of hills; the deposition of this limestone has in many instances formed raised cups or basins, over the edges of which the water flows. The water of these springs contains soda, and is generally good drinking water; in some cases, however, in the same group of springs, there is a great difference in the quality of the water, which in one spring may be drinkable, and in another, a few feet away, salt. As a rule these spring waters are warm, and must have a considerable temperature beneath the surface. Bores have been sunk by the Government in this formation at Tarkininna, where artesian water was tapped at 1,200 feet, and at Hergott, Coward Springs, Strangway Springs, &c., where a large supply of water was attained at an average depth of some three hundred feet. The supply from some of these bores is over 1,000,000 gallons per day. The supply is doubtless partly derived from a vast wide spread area of underground drifts which are fed from the ranges at the heads of the Cooper, Diamentina, and other rivers, although it appears most likely that there are other sources of supply in the form of deep-seated hot springs beneath the deep Mesozoic basin. The fossils which occur in this formation are found in masses and nodules of limestones, and in the calcareous shales, but generally they are most plentiful in the former, which are often entirely composed of them. A collection lately made by me, in the Lake Eyre district, was sent to Dr. H Woodward, of the British Museum, for examination, including an Ammonite about two inches in diameter, from Primrose Springs. A portion of the same collection has been examined and named by Professor Tate, and is now in the Melbourne Centennial Exhibition. Other fossils I had previously forwarded to Dr. Woodward from the same district, were described and figured* by Mr. Wilfred Hudleston, and included the following :—

Natica, sp. indet.
Myacites australis, *Hudleston.*
Cytherea Woodwardiana, *Hudleston.*
Cyprina, sp. indet.
Modiola linguloides, *Hudleston.*
Gervilleia angusta, *Hudleston.*
Avicula orbicularis, *Hudleston.*

Dr. Woodward has also described and figured† some Mesozoic plant remains, taken from specimens collected by me from the quartzite and sandstone beds apparently of the same age as the porcelanized sandstone and jasper rock of the table-hills, although it lies at a higher elevation, and rests on the primary rock of the main range, which borders the plains southwards of Lake Blanche.

Sand-hills and ridges cover a large portion of the Mesozoic country. They extend in long ridges with accompanying mounds in more or less parallel lines, in patches, isolated hills and ridges, and undulating plains for miles across country, covering up the surface. The sand is usually brick red above, and grey and yellow below, and very fine grained. The fine red sand constituting the upper portions of the ridges is loose and shows no sign of stratification ; but the grey semi-consolidated sand and sandy-clay at the base shows a roughly horizontal stratification.

Along the sand-hill country between Innamincka and Haddon Station, there are isolated red and yellow sandhills and ridges at some distance from the main body. The same can be noticed on the Cooper and Diamentina at intervals along the courses of the river flats. The prevailing strike or bearing of these ridges in the northern portions of the territory, which they cover, is about north-north-west and north-west, while southward and to the east of the Flinders Range it is north-north-east and north east.

In crossing the country from the eastern boundary to the Diamentina, sand hill country is met with at intervals the whole distance, sometimes the ridges are close together, at other times separated by spaces of stony desert, or plain, a mile or more in width, but always keeping a general parallel course. They rest indiscriminately on the clay flats and plains, or the stony downs, their elevation above these varying from ten to seventy or eighty feet, and width from one hundred to two hundred yards at the base. There is no evidence of the sand having been blown along the surface or transported from a distance by water flowing over the surface of the ground, which is as a rule, quite clear of sand between the hills, I am of opinion that in many cases, particularly in those of the isolated ridges and mounds traversing

* Geol. Mag. 1884, I. p. 339, t. 11.
† Geol. Mag. 1885, II. p. 289, t. 7.

the stony desert at long distances apart, the sand has been derived from an undergronnd source through the pressure of subterranean water. There was, in all probability, an outlet at one time connecting the Mesozoic basin which occupies the centre of Australia with the ocean. If we suppose a sudden or gradual closing up of this outlet to have taken place through the subsidence of the land or any other cause, the water not having any vent to escape by, would accumulate in the porous strata until under sufficient pressure to force its way to the surface along cracks or through holes caused by such pressure, and bring with it the sand, in a similar manner to the present mud and sand springs, and thus have caused the depressions now occupied by the great lakes such as Lake Eyre, which is below the level of the sea.

6.—THE DESERT SANDSTONE OF AUSTRALIA.

By the Rev. J. E. Tenison Woods, F.G.S, F.L.S.

Friday, August 31.

The following papers were read :—

1.—ON THE ROCKS OF THE HAURAKI GOLD-FIELDS.

By F. W. Hutton, F.G.S., Professor of Biology, Canterbury College, Christchurch, New Zealand.

The Hauraki Gold-mining District, Auckland, New Zealand extends from Cape Colville on the north to Te Aroha on the south a distance of about one hundred miles, and includes the sub districts of Coromandel, Tapu, Thames, Ohinemuri, and Te Aroha. In geological structure it consists of a sedimentary formation of slates and sandstones, not younger than Triassic, overlain quite uncomformably by a younger formation, chiefly of volcanic origin, which is not older than Cretaceous, and in which all the gold mines are situated. To this statement all geologists are now agreed, but opinions differ as to whether any long interval of time separates the volcanic rocks into two distinct series, the older of which is alone auriferous, or whether all should be considered as parts of one. This point will not be decided until the country in the neighbourhood of Cabbage Bay is satisfactorily made out. In this district the limestones of Oligocene age containing *Hemipatagus tuberculatus*, *Pentacrinus stellatus*, *Ostrea Wullerstorfii* (?), as well as *Fusus*, *Turritella*, *Cucullæa*, and other genera are found in close proximity to the auriferous volcanic series; but the officers of the Geological Survey, who have reported on the district, hold diametrically opposite opinions as to its structure. If Mr. S. H. Cox is right in supposing that these limestones, &c., rest uncomformably on the auriferous series,* then that series will probably be Cretaceous, and the volcanic rocks of Coromandel and Kennedy's Bay, may be much younger. If, however, Mr. A. McKay should be right in saying that the auriferous volcanic series lies uncomformably on the sedimentary series,† then the whole volcanic formation must be considered as not older than Miocene.

PRE-JURASSIC ROCKS.

These consist chiefly of dark coloured sandstones, greywackes, and slates, in which no fossils have as yet been found. The only rock belonging to this formation that I wish to notice is the so-called felsite at Waiohanga Point, north of Graham's Town. This rock was described by me in 1867, as a felsite-tuff. Afterwards I called it a felstone, meaning thereby an altered eruptive rock. By Mr. E. H. Davis it was considered as a clay-stone "cut through by a broad band of pyritous quartz sandstone." Mr. S. H. Cox calls it a felsite, but is uncertain whether it is intrusive in, or interbedded with the slate rocks. When I first visited the locality in 1867–69 the junction between the felsite and the blue slates was hidden by sand; but last year I found the sand washed away and the junction exposed. It could then be seen distinctly that the felsite was interbedded with the slates. Above the slates comes a bed of felsite five feet thick, then four feet of pale slates, and then the main body of the felsite which forms the point. Both the blue slates, and the white felsite, are largely impregnated with pyrites in places, in other places they are free from it.

The felsite is creamy white with an earthy fracture and a hardness of about three. It is irregularly jointed in three directions, and the joints are so numerous that it is difficult to get good specimens shewing a fresh fracture. To the naked eye it is distinctly vesicular, the vesicles being minute and irregularly scattered. It is not laminated, but occasionally there are bands of a coarser material in it. Where it is vesicular there is no pyrites, and the vesicles are probably due to the removal of the latter. Under the microscope, with an inch objective and ordinary light, it is seen to be very finely granular, with minute specks of an opaque white mineral like leucoxene. In places there are rather sharply-defined clouds of lighter and darker, but no distinctly crystalline forms. Occasionally narrow pale bands run through it, in which larger masses of the opaque white mineral are collected. The vesicles are either rounded or angular, and are no doubt due to the decomposition of pyrites. With polarized light and crossed nicols

* Reports, Geological Explorations, 1882, p. 19.

† Reports, Geographical Explorations, 1885, p. 98, &c.

the general tint is dark grey with bright specks ; a few microlites can be seen and more abundant anisotropic angular grains without polarization colours. With an eighth objective it appears as a water-clear glass with minute rods and specks, and occasional layers of larger, irregularly shaped, dark fragments. The quartz-sandstone of Mr. Davis has a microscopic structure similar to that of the felsite, but has in addition quartz grains scattered through it as well as abundant pyrites. The specific gravity of the felsite without pyrites is between 2.494 and 2.505, and Mr. W. Skey has made the following partial analysis of it :—

Silica	73.46
Alumina	22.11
Lime	.77
Magnesia	1.34
Alkalies	1·56
Water	.76
	100.00

Mr. Cox has observed a similar rock interstratified with the slates of Coromandel (*loc. cit.* p. 7), and I am now convinced that this felsite is of clastic origin. It resembles a felstone in appearance, but is much softer and has an earthy fracture, while the small quantity of water contained in it forbids it being considered a slate or clay-stone. Perhaps it will be better to return to the name felsite-tuff, which I originally gave it.

POST-JURASSIC ROCKS.

These cover the greater part of the Peninsula, and are almost entirely volcanic. At Coromandel and at Kennedy's Bay, distinctly stratified scoriaceous agglomerates are found which are the youngest rocks of the formation ; but elsewhere, so far as my observations go, there are no traces of stratification, no vesicular rocks, and different lava streams can rarely be distinguished. Volcanic breccias frequently occur, but they usually pass imperceptibly into unbrecciated rock. Hard dark rocks are comparatively rare, usually they are light-coloured—grey or greenish—and with a trachytic habitus, but soft. At Coromandel they were called trachytes by Dr. v. Hochstetter, and this has apparently been confirmed by Mr. W. Skey, who found the alkali in them to be potash.* However, both at the Thames and at Coromandel, I have always found the felspars to be plagioclase, probably labradorite, or a still more basic variety.

When I first examined the district, twenty years ago, I was much puzzled with these volcanic rocks, for they were unlike anything I had seen before, indeed their equivalents are found

*Report on Geology of Thames Goldfields, 1867, pp. 5-6.

in Hungary, Transylvania and North-west America. Seeing breccias and no vesicular lava streams, I supposed that the whole series was an enormous mass of tuffs dipping slightly to the west or north-west, and traversed by dykes of timazite, melaphyre, and dolerite, which looked very different from the surrounding rocks. As much of this supposed tuff was porphyritic, with glassy felspar crystals, I supposed that these portions had been altered by heat. Five or six years later, having had more experience in acidic volcanic districts, I changed my views and considered these "tuffs" to be submarine lava flows of viscous trachyte.* Professor G. H. F. Ulrich, in a letter, informs me that many years ago he determined the hard black rocks occurring in patches among the light-coloured ones in the goldfields, as well as in the range just beyond its limits, as varieties of augite andesite, the former frequently containing hypersthene.

Last year I made a collection of rocks from this formation, and selected out of it a series of twenty-eight, from which I made sixty-seven thin slices for microscopic examination.

Sedimentary Rocks.—The lowest beds of the auriferous series at the Thames are seen on the south side of Waiohanga Point, between the point and Waiohanga Creek. Here the high bluff of the point is formed by the felsite-tuff already mentioned, and has a steep slope on the southern side. On it rests a white felsitic clastic rock with small round pebbles of the felsite-tuff. Then comes a breccia of fragments of blue sandy-slate in a sandstone matrix, which is composed chiefly of felsite grains, but also contains some quartz and a little chlorite. Upon this is a bed of sandstone, composed of the same materials as the last; and then follows another slate breccia which passes upwards into the andesite and andesitic breccias, which compose the auriferous series. The exposure is not sufficiently clear to measure the thickness of these basement beds. A much better junction of the two formations is seen on the coast a few miles north of Tapu, between the Mata and Waikowhau Rivers,† but I did not visit this again last year.

Volcanic Rocks.—None of these are holocrystalline, but all have a trachytoid texture. They show considerable variety, but nearly all are propylites, that is andesites, in which the bisilicates have been altered into hydrated magnesian unisilicates. Different opinions are held among geologists as to whether the name propylite should be retained. This rock bears the same relation to andesite that diabase does to dolerite, and if one is retained, so also should be the other. I am inclined to think that the change indicated by the terms propylite, diabase, melaphyre, and serpentine is worthy of being recorded in the name of the rock, perhaps by the

*Geology of the Thames Goldfields. Trans. N.Z. Institute, 1878, Vol. vi.

† Second Report on Thames Goldfields, 1868-9, p. 6, and section 3.

adjective chloritic, but as there is no unanimity of opinion, I will use them here. In my collections I find the following rocks :—

RHYOLITE (?). It occurs in numerous narrow branching veins penetrating the andesites on the beach between Tararu and Waiohanga. It is a compact pale-grey rock, with a specific gravity of 2.62, but as no chemical analysis has been made, I do not feel quite sure of its true nature. It is generally much decomposed, but I obtained a specimen fit for partial microscopic examination. With crossed nicols it shows a ground-mass considerably devitrified and mottled with light and dark patches, which retain their relative tints while the stage is revolved. Through this ground-mass small angular grains of quartz and crystals of pyrites were abundantly scattered. The quartz contains, very rarely, small glass inclusions with a fixed bubble, generally it has only clouds or sheets of minute gas-pores, sometimes it is quite clear. There are also patches of a colourless irregularly fibrous mineral, which shows between crossed nicols an aggregate with rather brilliant polarization colours, and with occasional greenish inclusions. This mineral may be talc, secondary after a bisilicate. Calcite occurs in grains in the ground-mass and occasionally in larger patches, which were probably once felspars.

HORNBLENDE DACITE.—This rock occurs in the Waiotahi Creek' and on the shore a little north of Tararu Creek, and is the timarzite of my report of 1868-9. It is a compact greyish-green rock with white felspars and distinct black prisms of hornblende scattered thickly through it. Pyrites may or may not be visible. The specific gravity ranges from 2.62 to 2.76. Two partial analyses of these rocks by Mr. W. Skey in 1869, gave the following results :—

	I.	II.
Silica	54.28	53.66
Alumina	18.58	16.50
Iron oxide—chiefly protoxide...	10.30	11.33
Lime	7.15	8.34
Magnesia	3.49	2.68
Alkalies	5.25	4.66
Water	.95	2.83
	100.00	100.00

I.—From dyke in Heart and Hand Claim, Wiseman's Gully, Thames.
II.—From the dyke in Ballynure Claim, Waiotahi Creek, Thames.

The specimens from the Waiotahi Creek have not undergone much change. The ground-mass is still glassy and of a pale-brown colour.

The felspars are usually clear and slightly zoned with irregular fluid inclusions. Most are well-twinned plagioclase, in one of which, cut at right angles to the brachypinacoid, I found the extinction angles of two adjacent lamellæ to be 20° and 21° on either side of the trace of the twinning plane, thus giving an angle of 41°, which, according to Michel Lévy's method of determining the plagioclase, would indicate labradorite, or a still more basic felspar. Binary twins sometimes occur—in one of them I noticed that one-half was simple, the other polysynthetic. I believe that all are plagioclase. In the Tararu specimen the felspars are entirely decomposed.

The hornblendes are generally well preserved, and shew the characteristic cleavage parallel to 110. They occur in six-sided prisms with the clinopinacoids more or less developed They are occasionally twinned. In ordinary light they are light yellowish brown, but some longitudinal sections are greenish. With polarised light they are strongly pleochroic—and light yellowish brown; β and γ dark yellowish brown. The polarization colours are not brilliant, and the angle $c : \gamma$ goes up to 22°. They contain, as inclusions, rather large crystals of apatite, and occasionally they enclose fragments of plagioclase, giving the rock an ophitic structure.

Pyroxene has been present in small quantity, but it is now altered into chlorite.

Chlorite of two kinds is found. The first is of a bright green colour with confused, often radiating fibres, is slightly pleochroic, and with crossed nicols shews an aggregate with low polarization colours. It is found in both the hornblendes and the pyroxenes, and when in the former, encloses large apatite crystals. The second kind is a pale yellowish-green, fibrous aggregate, with rather bright polarization colours and strongly pleochroic—being bluish-green when the fibres are parallel to the chief section of the polariser, and yellowish-green when they are at right angles to it. This kind is found in small quantity only. The first kind of chlorite, when in the hornblendes, has occasionally been again altered to a colourless aggregate with low polarization colours, and a narrow magnetic border; this change generally begins near the centre of the chlorite. In the specimen from Tararu no fresh hornblende remains, but its place is taken by a colourless aggregate, a part of which is certainly calcite, surrounded by a black border.

A little epidote, I think, occurs in some of the decomposed felspars and in the chlorite; but its presence is doubtful.

Quartz (original) occurs in angular or sub-angular grains up to about 0.005 inch in diameter, but it is by no means common. It contains greenish belonites and six-sided glass inclusions with fixed bubbles. Sometimes it is corroded and penetrated by the ground-mass, which also appears as more or less spherical inclusions of a greenish-yellow colour.

Calcite occurs in the decomposed felspars and hornblendes in the Tararu rock, but I could detect none in those from Waiotahi.

Titaniferous-magnetite, in large grains, occurs sometimes sparingly, sometimes abundantly, but there is very little magnetite dust in the ground-mass. In the Tararu specimen it is changed into leucoxene. Secondary magnetite occurs in connection with the chlorite.

Pyrites is seen occasionally, sometimes associated with the magnetite, but it is in small specks, and in the Tararu specimen is changed into limonite.

Enstatite Dacite.—I have a single specimen of this rock from a boulder in Waiotahi Creek. It is compact, dark greenish-grey in colour, and with greenish-white felspars. The specific gravity is 2.703. Under the microscope the ground-mass is seen to be abundant, composed of a clear glass, with brownish clouds of globulites, and thickly dusted with magnetite.

Felspars are clean, well-twinned plagioclase, strongly zoned with inclusions and negative crystals. They average about 0.025 inch in length. Binary twins also occur.

Quartz (original) is rare, seldom more than one piece in a slide, but when it occurs it is in rather large (0.027 inch) angular fragments, with the same inclusions as the quartz described in the hornblende dacites.

Bastite, in irregular prisms, with a well-marked cleavage. Interference figure sometimes visible, shewing the axial plane to be at right angles to the cleavage. Pleochroism well marked, and pale yellowish ; β and γ bluish-green. It contains inclusions of apatite.

Chlorite, of a blue-green colour, is in some of the pyroxenes. It is isotropic and not pleochroic.

Calcite, as minute grains in the centre of some of the felspars.

Magnetite, in large grains as well as disseminated through the base. Also secondary with chlorite.

There is no pyrites in this specimen,

I am not aware of any enstatite dacite having been previously described.

Hornblende Andesite.—Of these I have five examples. One from the first hard mass of rock, or dyke, up Karaka Creek ; another from a boulder in Waiotahi Creek ; a third from the dyke on the shore a little north of the mouth of Tapu Creek, and two from Coramandel. One of these rocks--from Omaru Island, Coromandel—differs markedly from the others, and I will describe it separately later in the paper. The rest are compact greenish-grey rocks, darker than the hornblende dacites, but lighter than the augite andesites, and porphyritic minerals are not conspicuous in any of them. The specific gravity ranges from 2.665 to 2.728.

The ground-mass is abundant, pale-brown when not devitrified, with rather large grains of magnetite scattered through it, and occasionally felspar microlites which shew no fluxion structure except in the case of a specimen from the north side of Coromandel Harbour.

The felspars are plagioclase, zoned, but not much twinned. In the Tapu Creek rock some are not twinned at all, and others are binary twins which might easily pass for sanadine. But one of these binary twins gave extinction angles of 10° 30′ and 14° 30′ on either side of the composition plane, while none shewed simultaneous extinction; they cannot, therefore, belong to the Monoclinic system, but may perhaps be oligoclase. The felspars are generally clear, but decomposed along cracks in the Tapu rock, and very much decomposed in those from Karaka and Waiotahi Creeks.

Hornblende.—In the Tapu rock the hornblendes are mostly fresh, but with a narrow black border. Prismatic cleavage is not well marked. They are strongly pleochroic, changing from light to dark yellowish brown. The angle $c : \gamma$ up to 19° 30′. In the rocks from the Thames and Coromandel the hornblendes are entirely altered to a colourless aggregate with black borders. but can be recognised as six-sided prisms, shewing the faces 110 and 010.

Augite, unaltered, occurs only in the specimen from the north side of Coromandel Harbour. It is clear, pale greenish-yellow, with brilliant polarization colours, not pleochroic, and often twinned. There are no apatite inclusions.

Chlorite is of two kinds. The first is of a pale blue-green, fibrous in places, feebly pleochroic, and with low polarization colours; it is found in some of the hornblendes more or less filling them. The second kind is bluish-green, not pleochroic and nearly isotropic; it is found in small quantity in square prisms as pseudomorphs after augite.

Bastite occurs in the Karaka Creek rock, but in quantity quite subordinate to the hornblende. It is distinctly cleaved and pleochroic, and pale yellow-brown; β and γ bright blue-green.

Calcite is to be recognised in the decomposed felspars and hornblendes, as well as in the ground-mass of the Thames rocks.

Gypsum (?).—In some of the decomposed hornblendes the colourless aggregate which fills them shews, in places, bright polarization colours. This may be due to talc, or more probably to gypsum, as Mr. Skey has ascertained that this mineral occurs in some of the rocks; but the optical characters are uncertain.

Quartz (secondary) is also present in the ground-mass of those rocks which contain calcite.

Titaniferous Magnetite.—Abundant both as an original constituent and secondary. In the Waiotahi rock some of it is changed into leucoxene, and in the Tapu rock into limonite.

Pyrites is found in small quantity in the Tapu rock, but does not occur in those from the Thames or Coromandel.

Augite Andesite.—These rocks form the bulk of the auriferous series at the Thames, Te Aroha, and at Coromandel. When unaltered they are greyish-black, sometimes with a semi-vitreous lustre, and a specific gravity of about 2.7. As they decompose they pass through dark greenish-grey, light greenish-grey, and pale-grey to white, more or less coloured with limonite. None of them are markedly porphyritic. but as they decompese they get more or less spotted with opaque white leucoxene. The specific gravity varies with the amount of iron present, but it falls as the minerals get hydrated, until in my most decomposed specimen (but one sufficiently hard to grind) it is only 2.153.

Only two of my specimens are sufficiently unaltered to have any augite remaining. Both are from the road up the Waiorongomai Creek, Te Aroha, to the New Era Battery. One of them is from just above the Te Aroha Battery, and is, no doubt, the No. 2 of Mr. Cox's Report (*loc. cit.* p. 16); the other was collected about a quarter of a mile higher up the road, and is probably No. 4 of Mr. Cox's Report. They are much alike, and may be parts of the same rock.

The ground-mass is abundant, of a colourless glass with small specks of magnetite and numerous felspar microlites, which shew no fluxion structure. The one from the lower level has chloritic infiltrations in the ground-mass.

The felspars are plagioclase, generally clear, but some much clouded in the centre. They are zoned with small liquid inclusions and generally contain grains of magnetite. Crystals cut nearly at right angles to the brachypinacoid gave the following extinction angles with reference to the twinning plane :—(a) $7°$ and $8°=15°$; (b) $20°$ and $21°=41°$; (c) $32°$ and $33°=65°$. The last is probably bytownite or anorthite. Binary twins also occur. The microlites in the base give extinction angles between the two lamellæ to $65°$, consequently they are anorthite.

The augite is pale green and pleochroic, often showing polysynthetic twinning. Sometimes it is in square prisms with the prismatic faces badly developed, at others in octagonal prisms with the prismatic faces and pinacoids equally developed. Prismatic cleavage is generally apparent. There are very few inclusions except small needles of apatite.

All my other specimens are more or less decomposed. They come from Te Aroha (No. 5 of Mr. Cox's Report), from the Karaka and Waiotahi Creeks at the Thames, and from Omaru Bay, Coromandel.

Mr. W. Skey has given two partial analyses of the Thames rocks, when decomposed to the pale grey state.

	I.	II.
Silica	50.19	60.78
Alumnia	13.54	15.05
Iron oxide—chiefly protoxide...	12.84	12.18
Lime	9.89	0.60
Magnesia	2.26	0.61
Alkalies	3.30	4.47
Water	7.98*	6.31
	100.00	100.00
Specific gravity	2.510	2.296

I.—From Waiotahi Creek.
II.—Bed rock of principal claims at the Thames.

The greater proportion of silica in II than in I is due to the chlorite and calcite having been leached out, and the secondary quartz left behind, as will be explained presently.

In these rocks the ground-mass is always abundant, and more or less devitrified; and, except in the last stages of decomposition, it always contains chloritic infiltrations. In one of the Te Aroha specimens felspar microlites are abundant, and shew a well-marked fluxion structure.

The felspars, when recognisable, are always plagioclase, zoned with inclusions. In one specimen I noticed twinning on the pericline type, as well as on the usual albite type; the same specimen shewed a crystal which gave extinctions of 30° and 35° on either side of the twinning plane, and is probably, therefore, bytownite or anorthite. Generally the felspars are decomposed to a colourless aggregate which is largely composed of calcite, but may also in part be kaolin, a mineral which is not easy to recognise in minute particles, especially if it be intimately associated with an anistropic mineral like calcite. The abundance of calcite in the decomposed felspars confirms the idea that they were bytownite or anorthite. Binary twins are rare.

Chlorite, as pseudomorphs after augite, and as infiltrations in the ground-mass and occasionally in the felspars. The chlorite in the felspars and ground-mass is pale green and usually isotropic. That in the augites is yellowish, or brownish-green, and is either isotropic, or of a deep and grey colour between crossed nicols. It is often seen to be in prisms either square or octagonal. This chlorite has again been altered, in part or entirely, into a colourless aggregate with brilliant polarization colours, and the cyrstals have then generally narrow black borders. The colourless aggregate may be talc.

* With carbonic acid.

Apatite occurs in small quantity in the chlorite pseudomorphs.

Calcite gets more and more abundant in the felspars as decomposition proceeds, but in the last stages of decomposition it is removed, and the place of the felspars left vacant. The rock then easily falls to pieces. Occasionally calcite can be detected in the chlorites.

Gypsum has been detected by Mr. Skey in some of these rocks, but I have failed to recognise it, unless possibly it may form the colourless aggregate in some of the chlorites.

Quartz (secondary), generally occurs in the ground-mass, and increases *pari passu* with the calcite. In one specimen from Te Aroha a fine granular brownish aggregate, with brilliant polarization colours, is found in the felspars and augites, which is probably chalcedony; it is accompanied by a colourless isotropic mineral, which is no doubt opal.

Titaniferous magnetite is present in the less decomposed rocks, but usually it is more or less altered into leucoxene, and ultimately entirely into that mineral, or occasionally into hæmatite or limonite. In one case however the iron oxides remain unchanged, although the felspars and augites are entirely decomposed and filled with chlorite, chalcedony, and calcite. Secondary magnetite sometimes occurs in connection with chlorite patches in the ground-mass, or as narrow black borders to the decomposed augites.

Pyrites occurs both in grains and in crystals, but varies very much in quantity; being abundant in some rocks, in others quite absent. This is not due to decomposition for often it is abundant in the most decomposed rocks, while in the little decomposed rocks from Waiorongomai it is altogether absent. Neither is it due to locality; for often rocks with plenty of pyrites, and others with none, may be found in close proximity at the Thames, at Te Aroha, and at Coromandel. In one specimen from Waiotahi Creek pyrites occurs only as minute specks in the magnetite. In other cases it is not uncommon to find pyrites closely associated with leucoxene, which is then generally of a yellowish colour. This looks as if the pyrites had been formed from the titaniferous magnetite.

Enstatite Andesites.—These rocks when unaltered are greyish-black in colour, but as alteration progresses they change to a dark greenish-grey. In the former state they are the dolerites and in the latter the melaphyres of my report of 1868-9. On further decomposition they pass into lighter colours, but they cannot then be distinguished from the decomposed augite andesites. The specific gravity of the least altered rock varies from 2.72 to 2.80; in the more altered examples it sinks as low as 2.636. They are found at the Thames in Karaka, Collarbone, Waiotahi, Moanataiari and Tararu Creeks, as well as in deep levels of the Prince Imperial Mine: and they also occur at the Waiorongomai River, Te Aroha.

The following partial analyses, made by Mr. W. Skey in 1869, have been published.

	I.	II.	III.
Silica	51.63	56.16	30.33
Alumina	14.69	16·92	16.67
From oxide—chiefly protoxide ...	13.06	9.55	10.35
Lime	5.95	6.15	7.01
Magnesia	4.51	3.38	3.66
Alkalies	8.39	5.23	2.48
Water	1.77	2·61	9.50
	100.00	100.00	100.00
Specific gravity	2.797	2.797	2.686

I.—A little altered rock in Freeman's Bay Claim, Warotahi Creek.
II.—A more altered rock from the first dyke-like mass up Tararu Creek.
III.—A still more altered rock from the dyke-like mass below the old Point, Russell claim, Moanataiari Creek.

The ground-mass is generally small in quantity, colourless, and more or less devitrified, but in the specimen from the deep levels of the Imperial Crown Mine it is fairly abundant, and composed of a pale brown glass. In another specimen from the Waiotahi it is also an abundant brown glass crowded with felspar microlites which show no signs of fluxion structure. Many of them have chloritic infiltrations.

The felspars in the less altered rocks are clear and zoned with inclusions. They generally shew twinning on the albite type, but in the Tararu rock twinning on the pericline type occurs also.

Binary twins are not infrequent, but all are I believe plagioclase. Two different individuals gave extinction angles on either side of the composition face of 20° and 18° = 38°, and of 15° and 13° = 28°. Neither of these binary twins could therefore be monoclinic, but they may be oligoclase. In the more altered rocks the felspars get cloudy, generally in the centre, but sometimes along cracks and round the margin, until they are entirely decomposed; and this lends support to the idea that these are two different kinds of plagioclase in the rock. In two specimens they are infiltrated with chlorite; in one of these the infiltrated felspars are clear, in the other they are decomposed.

Augite.—Pale green or yellowish-brown, not pleochroic, in square or rectangular prisms, the prismatic faces scarcely developed, and the orthopinacoids sometimes rather longer than the clinopinacoids. They often shew polysynthetic twinning along a central band. Prismatic cleavage is not always well developed; in one case a clinopinacoidal cleavage is more apparent, crossing the twinning plate at right angles. Polarization colours brilliant. Angle c : $\gamma = 39°$. Inclusions minute or none.

Hypersthene.—In one specimen only, from Karaka Creek, does unaltered rhombic pyroxene occur, where it forms intergrowths with augite. In ordinary light it is pale yellowish-brown, but is strongly pleochroic: α pale yellow-brown, β darker reddish-brown, γ bluish-green. Absorption $\gamma > \beta > \alpha$. Cleavage well marked, parallel to 010. Polarization colours rather brilliant.

Protobastite.—In another specimen, from Waiotahi Creek, protobastite occurs instead of hypersthene. It is in rectangular prisms with the prismatic faces but slightly developed. The cleavage is well marked, parallel to 010, and the axial plane is at right angles to it. One transverse section shewed a bisectrix with the axial plane parallel to 100. In ordinary light it is pale yellowish-brown, but is slightly pleochroic; α pale reddish-brown, β yellowish-brown, γ bluish-green. Absorption $\gamma > \alpha > \beta$. The polarization colours are very brilliant. Remarkably free from inclusions except a little magnetite and apatite, and a few fragments of glass. It is not fibrous and the crystals are sometimes arranged in groups.

Bastite occurs in all the specimens, except that with protobastite. It is in long rectangular prisms formed almost entirely by the pinacoidal faces. Cleavage, parallel to 010, is in general well marked. In the specimens from Collarbone Creek it occurs in more or less stellate groups. The axial plane is at right angles to the cleavage. In ordinary light it is pale yellow-brown, but is feebly or rather strongly pleochroic; α pale yellow-brown, β and γ bluish-green. The polarization colours are not brilliant. It is an aggregate, but with a distinct maximum extinction parallel to the cleavage.

Chlorite is found either as a pseudomorph after augite, or else as an infiltration in the ground-mass, or the felspars. It is bluish-green, not at all or faintly pleochroic changing from darker to lighter; partly isotropic and partly with gray polarization colours. It usually contains minute apatites. In a purple coloured rock from the Karaka, it is bordered with secondary ilmenite, which is often converted into leucoxene on the outer side, while the inner side is not altered.

Epidote (?)—A little is sometimes seen in the ground-mass or in the felspars, but it is rare, and doubtfully identified.

Calcite is only abundant in those rocks in which the felspars are decomposed, but it also occurs occasionally in the chlorites.

Siderite (?)—A brownish, translucent aggregate with the absorption of calcite occurs in some of the bastites in the rock from Collarbone Creek, which may be siderite.

Quartz (Secondary.)—I have found this in a rock from Karaka Creek.

Titaniferous Magnetite—Generally abundant in large grains not only in the ground-mass but also in the felspars and pyroxenes. Intergrowths of ilmenite and magnetite in parallel bands are very conspicuous in several specimens.

Mr. W. H. Hobbes has suggested that the bands of leucoxene may have been formed by decomposition along the solution planes in ilmenite crystals,* and as the whole crystal appears sometimes to change into leucoxene, and as Mr. Skey's analyses shew a large quantity of iron protoxide, this may perhaps be the case. But on the other hand, these iron oxides are decidedly magnetic, so much so that the whole rock is sometimes magnetic, and the analyses of Mr. Teale and others have proved that in some European and West African rocks intergrowths of the two minerals certainly occur.†

Pyrites is usually in small quantity or absent, but occasionally it is abundant. In two cases I found it associated with magnetite, often surrounding it; while other magnetite grains have minute particles of pyrites scattered through them. It seems evident that some of the pyrites has been derived from the magnetite.

GENERAL ACCOUNT OF THE CHANGES THAT HAVE TAKEN PLACE IN THE ROCKS.

From the foregoing descriptions it may be gathered that there are three distinct stages in the alteration of these rocks, due to changed conditions. In a few specimens the alteration has stopped before the first process was complete; in others the first, or the first and second stages have been passed through; while some have passed through all three.

1st Stage.—The first alteration is the conversion of the anhydrous bisilicates into the hydrous magnesian unisilicates, chlorite, and bastite (part of the silica and iron and all the lime having been eliminated), with the occasional formation of secondary magnetite This change has been almost universal over the whole area, only two of my specimens having escaped altogether, both of which are, I think, from dykes. The hypersthene appears to have yielded first, then the augite, and last the hornblende, but this may not always have been the case; indeed in the specimen from the north side of Coromandel Harbour the augite has resisted longer than the hornblende. The chlorite was in part dissolved simultaneously with its production and was d posited as infiltrations in the ground-mass and occasionally in the felspars. Epidote was formed but rarely, if at all. The apatite which was in the bisilicates remained unchanged in the process. During this

* Bull. Museum Comp. Zool. Harvard Coll. Geol. Series, ii, p. 8.

† Quart. Journ. Geol. Soc. xi. p. 650.

alteration the felspars were not decomposed, the magnetite and ilmenite were not oxidised and the ground-mass was little if at all devitrified.

The formation of pyrites was quite independent of this change in the bisilicates, for many rocks with a chlorite contain no pyrites, while in the older slates and felsite tuff, pyrites is abundant without any chlorite. Part of the pyrites appeared to have been derived from magnetite or titaniferous magnetite, but this may not have been the origin of it all. The formation of pyrites was not so universal as the chloritization, it being absent, or in small quantity, in many localities.

Whether this impregnation of the rocks with sulphides took place before or after the chloritization, or whether the two were simultaneous, there is no evidence to shew.

2nd Stage.—The second series of changes was the destruction of the felspars and the formation of carbonates, kaolin, and a little secondary quartz, most of the silica being eliminated. The chlorite was bleached and gradually removed, together with the apatite. The ilmenite was changed into leucoxene and the ground-mass was devitrified.

3rd Stage.—In this the iron oxides were hydrated and gradually removed, and the carbonates also were dissolved out; leaving nothing but quartz, kaolin, leucoxene, and pyrites.

The first series of changes took place at depths beyond the direct action of surface agents, probably by means of warm acidulated water and hydrogen sulphide. The second set of changes were no doubt due to the direct action of cold carbonated surface-water in limited quantity; and the third set of changes to the same agent, but in much larger quantity. The second and third set of changes would be gradually brought about by the removal of the overlying rock by denudation. The first series of changes is probably connected with the volcanic action which caused the eruption of the lava streams.

The changes seem to be much the same as those that have taken place in the Washoe District, Nevada, as described by Mr. G. F. Becker, in the Reports of the U. S. Geological Survey for 1880-81. But in the New Zealand rocks epidote, if it occurs at all, is rare, the chlorite is not strongly pleochroic, and the pyrites does not appear to have been derived from the direct decomposition of the bisilicates, although some of it may have originated from secondary magnetite. Also the Washoe rocks appear to have no rhombic pyroxene, but I have not seen Mr. Becker's full Monograph on the district.

STRUCTURE OF THE DISTRICT.

If we omit the tuffs of Coromandel, Kennedy's Bay, &c., then so far as my observations go, the only clastic rocks belonging to the auriferous formation are those at Mata and Waiohanga, already described as forming the basement of the series; but Mr. Davis states that fragments of slate occur in some of the breccias in Karaka Creek.* These breccias are composed of angular fragments of andesite in an andersite matrix, which is in general so much decomposed that I was unable, except in one case, to obtain a specimen fit for microscopic examination. The single exception was the breccia exposed on the beach north of Tararu Creek, just below the cemetery. Here, it is a pale greyish-white rock with an earthy fracture, and largely impregnated with pyrites. The microscope shews an abundant divitrified ground-mass with secondary quartz and leucoxene, in which lie crystals of felspar decomposed into calcite, and isotropic chlorites, probably pseudomorphs after augite, but much decomposed. I have no hesitation in calling the rock a decomposed lava stream. In other places the matrix of the breccia passes insensibly into evidently eruptive rocks. Probably all are brecciated lavas, or perhaps some of them may be the friction-breccias of dykes. Mr. Davis mentions a block in a breccia in Tinker's Gully as being itself part of an older breccia,† and this may perhaps be due to a dyke breaking through an older breccia.

These breccias are by no means limited to the base of the series, but occur at many horizons and in many different places beside the Hape, Karaka, and Tararu Creeks. They are all, I think, local and of small superficial extent. Mr. S. H. Cox identifies the breccias of Hape Creek with that found at the bottom of the shaft of the Queen of Beauty Mine.‡ This may be correct, but similar breccias are also found in the upper part of the shaft of the same mine, and others in the Waiotahi and Moanataiari Creeks. Another was passed through in an early drive in the Moanataiari Mine,§ and another occurs at the point north of the mouth of the Kuranui Creek. I see no reason for identifying the breccia at the bottom of the Queen of Beauty shaft with any one of these more than another; but if Mr. Cox's view of the structure of the district should turn out to be correct, four or five additional bands of breccia, at least, will have to be introduced into his section.

A microscopic study of the other rocks of the series shews that they are mostly lava streams in which fluxion-structure is rare, so that they must generally have consolidated after movement had ceased. Only two among my specimens shew fluxion-structure. One is a hornblende andesite, probably a dyke, from the north side of Coromandel Harbour, and the other is an augite andesite, certainly a lava, from rather high up Mount Te Aroha. The total absence of vesicular texture in all the lavas over so wide an area,

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* Reports Geological Explorations, 1870-1, p. 65.
† loc. cit. p. 56.
‡ Reports Geological Explorations, 1882, p. 10.
§ Reports Geological Explorations, 18(8-9, p. 31, fig. 1.

is difficult to explain, but it is no doubt connected with the absence of fragmental volcanic rocks, and both point to a viscid anhydrous condition of the lavas on first extrusion.

Surface decomposition has penetrated downwards in a very irregular manner and has left, in places, isolated masses of dark undecomposed rock surrounded on all sides by the paler products of decomposed. A very good example was seen in a shaft in the Caledonian Mine which was sunk vertically for forty feet alongside a hard mass of decomposed rock.* Also at the three hundred and fifty feet level of the same mine a hard patch was met with which was supposed to be isolated. Mr. Cox gives another explanation of the position of this last mass,† but he seems to have overlooked Mr. Davis' section. One of the early drives in the Moanataiari Mine passed under a large isolated block of hard rock,‡ and in the Puriri District many large spherical masses of undecomposed andesites occur in the decomposed portions.§

This irregular decomposition may account for some of the hard masses which still appear at the surface, but nevertheless I think that many of them are dykes. This was my opinion in 1868, but, with the exception of Mr. Davis, the Government Geologists who have reported on the Thames since 1870, have treated the whole series as a volcanic formation of great thickness without any contemporaneous dykes, but possibly with some belonging to a later and quite different period. Indeed Mr. Cox seems to think that the hard portions are regularly bedded with the softer portions and dip to the W.N.W. at an angle of about 26° with all the regularity of a sedimentary formation, and as quite unbroken by dykes. The microscopic examination of these rocks has, however, tended to confirm the idea that some of the hard masses are true dykes. I base this opinion on the absence of magnetite dust in the base and its collection into large grains; on the grouping of the pyroxene crystals; and on ophictic structure; for all these things prove that the cooling process was slow and that during the whole time the mass of rock was at rest. I will briefly describe a few of these dyke-like masses.

1.—On the shore a little north of Tapu Creek a dyke, ten feet thick and running north-west, is plainly to be seen. This dyke is a hornblende andesite with an abundant pale brown ground-mass containing rather large grains of titaniferous magnetite. The hornblendes are partly fresh and partly changed to chlorite. S.G. = 2.680.

2.—A little way up the Moanataiari Creek, on the south side, and below the old Point Russell Claim, there is a mass of hard dark

* Davis, Reports Geological Explorations, 1870-1871, p. 63, and section 6.
† Reports Geological Explorations, 1882, p. 30, and fig.
‡ Reports Geological Explorations, 1868-9, p. 31, fig. 1.
§ Reports Geological Explorations, 1868-9, p. 35.

greenish-grey rock, fifteen feet thick at the base, sharply defined on the western side—the line of division dipping 55° West,—but on the eastern side passing insensibly into the soft decomposed rock. It is an enstatite andesite with a small amount of devitrified ground-mass. The crystals are plagioclase (much decomposed), bastite, chlorite pseudomorphous after augite, and titaniferous magnetite in large grains, changing into leucoxene. It has been supposed that this mass cannot be part of a dyke because it passes insensibly into soft rock ; but there is no reason why a dyke should not decompose, and its almost holocrystalline texture as well as the large grains of magnetite in the ground-mass seem to me to be decisive against its being a lava stream. S.G. = 2.716.

3.—In Collarbone Creek a hard dyke-like mass occurs a little above its juncture with the Karaka. The rock is an enstatite andesite of a greenish-black colour and highly charged with pyrites. The ground-mass is fairly abundant, colourless, with large magnetic grains and felspar microlites. The crystals are plagioclase, averaging 0.024 in length, sometimes infiltrated with chlorite, and pyroxene in stellate groups often 0.05 inch in diameter, some of which are altered to chlorite or bastite. S.G. = 2.767.

4.—When walking up the bed of the Karaka Creek the first hard rock observed is a dyke-like mass crossing the creek and forming a small waterfall. It is a hornblende andesite very compact and of a dark grey colour. The ground-mass is abundant, pale in colour and contains rather large grains of magnetite. The felspars and hornblends are all decomposed, the latter into a colourless black-bordered aggregate, with occasionally a little chlorite ; there is also some bastite. The minute texture of this rock is not so chracteristically dyke-like as any of the foregoing, but, as it differs mineralogically from the surrounding rocks, it will probably prove to be a dyke. S.G. = 2.665.

5.—The hornblende dacites from the Waiotahi were originally described by me as dykes. The place where I observed them is now covered up, but a microscopic examination of specimens confirms my opinion that they come from dykes, because they have a distinctly ophitic structure, and large grains of magnetite in the base.

6.—I have also enstatite andesites from boulders in the Waiotahi and Karaka both of which, I have no doubt, came from dykes. Both have large magnetite grains in the ground-mass and both shew intergrowths of rhombic and monoclinic pyroxene.

Looking over the whole of my specimens I should judge that of the three hornblende dacites, two are from dykes, the third from a lava stream. The enstatite dacite is a lava. All the five hornblende andesites appear to be from dykes. Of the fourteen augite andesites a large majority are lava streams ; and of the ten enstatite andesites the majority are dykes. So that, in a broad way, it may be said that the auriferous series consist of lava streams, chiefly augite andesites, pierced by dykes of hornblende and enstatite andesite.

Three other rocks which I obtained deserve a slight separate notice.

7.—Enstatite andesite from the three hundred and thirty feet level of the Prince Imperial Mine. This is the rock through which No. 2 reef runs. This reef averages from six inches to two feet in thickness, and has yielded large quantites of gold. For about fifty feet on each side of the reef the rock is decomposed, and there is no distinct boundary between the hard and the soft. At this level the hard rock above the reef is fifty feet thick, and that below the reef sixty feet. The whole thickness, including the reef and decomposed portions, being two hundred and ten feet. At the five hundred and sixty feet level the lower portion of the hard rock disappears, whether the upper one does so also is not yet known. These hard belts (called diorite by Mr. Cox) are formed by a greenish-black rock with abundant small felspars visible to the eye. The ground-mass is fairly abundant, pale brown with chloritic infiltrations. The plagioclases are clear or slightly decomposed. Of the augites some are fresh but others are altered into a bluish-green chlorite, partly isotropic and partly with low polarization colours. Bastite is in long rectangular prisms, strongly pleochroic, and with fairly brilliant polarization colours. Magnetite is abundant in grains. Pyrites is rare. I take this rock to be a lava stream. S.G. = 2.729.

8.—Chloritic augite andesite from the three hundred feet level of the Waiotahi Mine. It is a greenish-grey rock with opaque white spots of leucoxene and with a rather earthy fracture. The ground-mass is abundant, devitrified, and infiltrated with chlorite. The felspars are decomposed into a colourless aggregate of calcite and perhaps kaolin. A brownish-green chlorite forms pseudomorphs after augite; it is partly isotropic and partly shews grey polarization colours. Secondary quartz is scattered sparingly through the ground-mass. Leucoxene is abundant in small specks through the ground-mass and in large white spots. Pyrites is in small quantity but there is no magnetite. This is the typical 'tufanite' of Sir James Hector.* It is also the rock mentioned by Mr. Cox in his report of 1882 (p. 9, No. 54) as having "a dioritic appearance but seems to be mechanically formed." This deceptive appearance is due to the leucozene spots which often look like rolled fragments of a white felspar. Undoubtedly the rock is a decomposed lava stream. S.G. = 2.590.

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* Reports Geological Explorations, 1870-71, p. 147.

9.—Hornblende andesite from Omaru Island, Coromandel. This rock differs in appearance from all other hornblende andesites that I have seen, in that it is black, and has a semi-vitreous lustre. It looks like an augite andesite, but the hornblende is distinct, though small in quantity. The ground-mass is not abundant and is made up of small felspar laths with a dirty brown substance (opacite) between them. The felspars are pliagioclase shewing twinning on both albite and pericline types, and are strongly zoned with negative cystals. Brown hornblende occurs sparingly and is sometimes changed into a pleochroic chlorite which is bordered with brown opacite. Magnetite is in rather large grains and most of it is decomposing into limonite. The rock is, I think, a dyke. S.G. = 2.646.

Although I collected every variety of rock that I could find at the Thames, including specimens of the Miocene dolerites of the Geological Survey, I have failed to find any sharp line of division. If two, widely separated, volcanic formations are present at the Thames they cannot be recognized by mineralogical characters. The absence or presence of pyrites would quite fail as a test and no one has supposed this to constitute a difference. Chlorite offers a better chance, because if this mineral was only formed at depths, it would not occur in a newer and superficial formation but, under these conditions, neither would it occur in the upper parts of the auriferous series, so that although its presence might indicate the older series, its absence from a rock would be no proof that the rock belonged to a newer series unless it could be shewn that the whole of the upper beds of the older series had been removed by denudation. Of this I have seen no stratigraphical evidence and can find nothing under this head in the published reports that appears to me to have any importance. If there were two widely separated series, as supposed, we should expect to find that all or nearly all the bisilicates of the older series had been altered into chlorite, &c.; while in the newer series only the ordinary series of charges would have taken place and there would be no chlorite. But if there was only one series, we should then expect to trace a gradual change in the rocks from those most altered to those in which the alteration of bisilicates into chlorite had only just commenced: and this is precisely what we do find.

Mr. Cox says that the younger volcanic series is undoubtedly distinct from the auriferous series because it is found at very different levels; sometimes at 1500 feet or more, at other times on spurs which are comparatively low lying, not more than three hundred feet above the level of the sea (*loc. cit.*, p. 20), and from this he infers "that the auriferous rocks had been deposited, upheaved, fractured, and partially denuded—indeed so much so that the conformation of the country corresponded more or less with that which at present exists—before the younger rocks were deposited upon them." I am sorry that I cannot agree with Mr. Cox here.

Granting, for the sake of argument, that he has been able to distinguish two series and to identify them accurately; still it seems to me that the older series, being composed of viscous lava flows, would have consolidated at steep angles and that the later products of eruption would have flowed down these steep slopes and would now be found at all elevations. Viscous lava is known to have consolidated at angles up to 80°, while as the places indicated by Mr. Cox in his map are a mile and a half apart, a slope of 10° would be sufficient to account for the difference in level. Some also of the supposed newer dolerites are certainly nearly vertical dykes. Also Mr. Cox allows that this younger series at the Thames occupies the spurs and higher ground only, so that the valleys of the present creeks and rivers must have been entirely cut since these later lava flows took place.

SOURCE OF THE GOLD.

To discuss with anything like completeness the question of the sources of the gold requires a knowledge of chemistry far beyond what I possess, but I think that a geologist may be of assistance to the chemist by pointing out to him the lines on which chemical investigation might probably lead to successful results; and this is all I hope to do here.

Origin of the Gold-veins.—There can, I think, be no reasonable doubt that the gold came out of the volcanic rocks and was not brought into them from below. Five different lines of reasoning tend equally to this result.

The first is that, after thirty-six years of prospecting, we find the gold-veins to be confined to the volcanic series, or to the slates in immediate contact with the volcanic series and not found in the older formation. At Tapu Creek the auriferous veins penetrated a short distance down into the slates, but the lodes in the slates always consisted of soft, stiff, blue clay (mullock), charged with small nodules of quartz,* and were evidently infiltration lodes, from above. Mr. Cox informs us that they soon pinched out in the slates and that the mines were abandoned† There is, I believe, no mine at present working in the slates although some were tried at Tiki near Coromandel. This is a district that I have not examined personally. As the volcanic series is a superficial one, overlying the slates, it follows that the gold must have originated in that superficial series; for if not, the lodes would have penetrated the older as well as the newer rocks and would have been found equally in both.

The second argument is founded on the nature of the gold-veins. These are often small, irregular, branching veins, sometimes only a quarter of an inch in thickness, traversing the rock

* Reports Geological Explorations, 1868-9, p. 24.
† Reports Geological Explorations, 1882, p. 40.

in all directions and rapidly dying out. The idea that these small branching viens were leaders from large and well-defined lodes has been disproved in many cases, but there is evidence to shew that occasionally they lead into large veins of nearly barren quartz called "buck-reefs."* Of this I shall speak again, at present I merely wish to point out that in a large majority of cases these so-called leaders have led to nothing. In the Thames district, gold is very widely distributed. On the first opening of the fields the ground was taken up *en masse*, as in an alluvial field, and not upon supposed lines of reef only. This is apparent in the map which accompanies my Report of 1868-9, in which I say that of 1200 claims thus taken up at hazard, about one-half had found gold. Most of these claims have turned out too poor to pay for working, but the fact remains that gold was found in them. Some of the larger lodes are merely country rock infiltrated with silica, and have no defined walls. Such were the Golden Crown, the Shotover (Hunt's), and the Middle Star.† In 1871 the country rock on the south side of the Shotover was crushed for a distance of sixty feet from the lode, and yielded from 5 dwt. to 8 dwt. of gold to the ton. The Golden Crown Co. has also crushed part of the spur belonging to them with fair results. These cases might be explained by supposing an outward infiltration from the lode, but it is very doubtfnl if these lodes are of such a character as to allow us to suppose that they were part of extensive fissures filled from below.

The third argument in favour of the origin of the gold-veins by lateral segregation is that, speaking roughly, the amount of gold in the veins varies with the state of decomposition of the country rock, the veins in decomposed rock being richer than those in undecomposed rock, as I shall presently bring evidence to prove. At Puriri the gold was in small irregular veins in decomposed rock and they stopped altogether when they approached the boulder-like undecomposed cores.‡ If the gold had come up from below, we can see no reason why it should specially affect the decomposed rocks.

The fourth argument is taken from the very recent origin of some of the gold viens. This might be inferred from those cases, like Puriri just mentioned, where the decomposition is evidently due to surface weathering, and the gold-veins appear to have been formed *pari passu* with the decomposition. But stronger evidence was found in the old Star of the South No. 2 Claim, which was situated on the spur facing Shortland, between the Karaka and Hope Creeks. Here irregular veins of quartz occurred at the junction of the face of the rock with slipped ground, due evidently

* Cox, Reports Geological Explorations, 1882, p. 25.

† Reports Geological Explorations, 1868-9, p. 24.

‡ Reports Geological Explorations, 1868-9, p. 35.

dently to a land-slip, and these veins contained gold.* We can hardly suppose that the thermal springs have brought up gold so near to the surface and at so recent a period, and yet have left no other evidence of their existence.

The fifth argument is founded on the quality of the gold itself, which is an electrum similar to that found in similar volcanic rocks in Hungary and Nevada, but different from that usually found in older formations.

I think therefore that we must look to the volcanic rocks themselves for the source of the gold, and with the gold the quartz also; and that we may dismiss all idea of either of them having been brought up by thermal springs. If the quartz of the buck-reefs, which are either barren or do not contain more than 10 dwt. of gold per ton, is also due to lateral segregation, as appears probable, then we may suppose that, in these cases, the greater part of the gold was deposited from solution in the feeders before reaching the main fissure. It is more probable that the bulk of the gold should have been deposited in the fissures which were feeding the buck-reef, than that the whole of the gold should have come from the buck-reef and the bulk of it should have passed out into the small fissures. The process I have suggested seems to have taken place at Coromandel, and at Te Aroha, but Mr. Cox has pointed out that in the Moanataiari Mine an auriferous vein, with clearly defined walls, crosses a buck-reef obliquely.† In this case undoubtedly the buck-reef is the older of the two, but this single fact is not sufficient to form the basis of an induction that all buck-reefs are older than the auriferous viens.

Sir James Hector is of opinion that "the quartz which forms the veins and infiltrates the auriferous gangue must have been introduced into these rocks subsequent to their original formation, but not derived from their partial decomposition, as the rocks themselves are deficient in silica, considering the felspathic nature."‡ But my microscopic examination of the rocks has shewn that large quantities of silica have been removed from the bisilicates and from the felspars, only small portions having remained as secondary quartz, and this silica must have gone somewhere. That the rocks are *now* deficient in silica, goes far to disprove the opinion which Sir James Hector would found upon it.

Indications of favourable Country-rock.—Mr. Cox says that "the white fairly hard stone is the best country," that "reefs in good ground are remunerative but in hard ground do not pay," that "hard green dioritic belts and jointy or shingly ground are not good for gold," that "moderately hard country traversed by small veins and of a pyritous nature near the reefs is the best,"

* Reports Geological Explorations, 1868-9, p. 26, fig. 2.
† Reports Geological Explorations, 1882, p. 25
‡ Reports Geological Explorations, 1868-9, p. 27.

and that "it is universally admitted throughout the field that a moderately hard tufaceous sandstone country is the class of rock most favourable for gold, and that where this is pyritous and carries small black veins—(of protosulphide of iron (?))—which run into the reefs, rich deposits almost always occur."* Sir James Hector also says "all varieties of these rocks are auriferous only in proportion to the amount of sulphides they contain."†

From this we may infer that the most favourable country is where the rocks have gone through the first and second stages of decomposition already described, having been changed into what the miners call "kindly sandstone," and especially where these rocks are abundantly charged with pyrites. However we must remember that numerous auriferous veins occur in the hard rocks also, and that the greater expense of working them here may account for some of them having been failures. Also, I much doubt if Sir James Hector's induction is founded on a sufficiently wide basis of fact; but I shall have to return to this subject again.

Facts connected with the lodes.—Gold occurs in the veins in four ways—(a) in auriferous pyrites, (b) scattered in small grains through massive quartz, (c) in threads or scales, some of which are pseudomorphs after botryogen or copiapite, ‡ between the points or quartz crystals in comby veins, the quartz at the base of the crystals being often stained red, and (d) in calcite at the Success Mine, Coromandel. It is never found enclosed in a quartz crystal. Mr. W. Skey§ says that he "was not able to observe any other matrix than quartz, or highly quartzose rock, where the gold at least was in paying quantity."

In some of the claims in the upper and middle portions of Taruru Creek manganese oxides occur along with the gold to the almost entire exclusion of iron compounds.‖ The auriferous veins usually contain abundance of pyrites, but other sulphides—stibnite, blende, arsenical-pyrites, copper-pyrites—are in small quantity only, and these have been introduced subsequently to the gold.¶ Carbonates of lime and of iron have been introduced into the veins after the quartz.**

According to Mr. Davis, the occurrence of "pyrites in the matrix of the lodes is a *sine qua non*," that "the hanging wall of roof need not of necessity carry pyrites, but rather the richness of the reef is increased by the diminution of pyrites in the roof, provided that the foot wall is rich in them," and that "leaders

* Reports Geological Explorations, 1882, pp. 23 to 44.
† Reports Geological Explorations, 1868-9, p. 27.
‡ Campbell, Trans. N.Z. Inst. XIV. p. 457.
§ Reports Geological Explorations, 1870-1, p. 84.
‖ Reports Geological Explorations, 1870-1, p. 85.
¶ Reports Geological Explorations, 1868-9, p. 24, and *ibid* 1882, p. 44.
** Reports Geological Explorations. 1867, p. 8, and *ibid* 1868-9, p. 2[illegible].

joining the reef on the hanging wall probably increase the yield of gold for a time, but leaders from the foot-wall seldom."* On this I must remark that I have often seen small veins carrying rich gold without any pyrites at all, but in the larger reefs pyrites generally occurs.

Theories.—Sir James Hector, who has had excellent opportunities for studying the subject, finds the source of the gold in the pyrites of the country-rock In his printed instructions to me in 1867 he says, "The composition of the several rocks in the vicinity of the lodes at Coromandel shews their singular character, arising, as I suspect, from all the soluble matters of what was once a basic rock having been removed and replaced by silica and partly by iron pyrites containing gold. That this mineral is the main source of the gold is shewn by a section of the lode ground I made 1864, when I found that the so-called quartz reefs were contained between two varieties of pyritous rocks, the sulphurets having been removed from the overlying rock, but still remaining in the lower, the reef itself being a band of mullock containing kernels and geodes of quartz and carbonate of lime, and evidently formed by infiltration." The attached analyses shew that the hanging wall contained neither gold nor pyrites, while the foot-wall contained about 11.68 per cent. of pyrites: but it is not stated that this pyrites contained gold. In 1869 Dr. Hector says "whatever may be the age of the impregnation of these rocks with sulphidrs, the gold they contain seems first to have appeared in them at the same time.† He then says that the quartz was brought up from below, as I have already mentioned, and he adopts the generally accepted opinion that thermal waters and acid vapours were the agents that produced the changes.

Mr. Davis, I suppose, agreed with Sir James Hector as their conclusions are identical. I also held the same opinion in 1869. In 1882 Mr. Cox pointed out that the pyrites in the decomposed rocks is not itself decomposed, and could not therefore be the source of the gold. The pyrites, he thought, was formed contemporaneously with the gold in the veins, the mineral waters which deposited the gold and the quartz in the reefs having found their way through numerous small joints in the rocks, decomposed their felspathic constituents and deposited from solution the crystals of crystalline grains of pyrites.‡ Mr. Cox thus accounts for the presence of pyrites in the surrounding rock being a favourable indication of gold, although it is not decomposed; he looks upon these pyrites as the overspill from the reef of materials brought up in fissures.

Undoubtedly, under ordinary circumstances, much of the pyrites remains in the rock unaltered, and can be washed out of it,

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* Reports Geological Explorations, 1870-1, p 68.
† Reports Geological Explorations, 1868-9, p. 39.
‡ Reports Geological Explorations, 1882, p. 44.

even when the rock has decomposed to clay. It is one of the last minerals to decompose, but that it does dissolve slowly is proved by the presence of iron sulphate in all the old drives. Mr. Cox's theory, however, implies that all the gold and most of the gangue came up from below, and I cannot accept it for the reasons already given.

Sir James Hector's theory seems to me to be more probable, provided that the quartz be supposed to come from the bed-rock equally with the gold; but it does not satisfy me altogether because—(1) I cannot see how, during any stage of alteration of the rocks, auriferous pyrites could be removed from the rock, and, in the absence of organic matter, be redeposited as auriferous pyrites in a fissure in the neighbourhood; (2) pyrites is not confined to the volcanic series, but occurs also in the slate formation, but gold does not accompany it there; and (3) I rather doubt the statement of the intimate relation between pyrites and gold.

It is certainly by no means the case that gold occurs wherever pyrites is abundant, or where it has once been abundant. The rocks contain quite as much pyrites in the Karaka and Tararu Creeks as they do in the Moanataiari and Waiotahi Creeks, but the gold is much less in quantity in the former localities than in the latter; indeed the two rocks described in this paper from the Prince Imperial and Waiotahi Mines contain very little pyrites, although one of them encloses a very rich vein, and there is no evidence to shew that they even contained more than they do now. The rocks of Te Aroha and of Heevin's Point at Coromandel also have much pyrites, but not much gold; while the slates and felsite tuff at Waiohanga Point are largely impregnated with pyrites, and yet there is no gold, although in places the pyrites has been completely decomposed. On the other hand, the rocks of the lower part of the Shellback Creek contain little or no pyrites, and little or no gold.

Again, I am not convinced that the pyrites of the country rock is so uniformly auriferous as is generally supposed. That the pyrites from the lodes is auriferous I allow, but the evidence that the pyrites of the country rock is also auriferous is but slight. In 1868 Dr. Hector exhibited, at a meeting of the Auckland Institute, pyritous vein rock from the Golden Crown, which was highly auriferous, and a portion of the bed-rock which also contained gold, but it is not stated that in the latter case the gold was in pyrites. In 1869 Dr. Hector, speaking of pyritiferous rock from the Kapanga Mine, Coromandel, says, "It was from this rock that the iron pyrites formerly examined for gold was obtained, which yielded at the rate of 4 oz. to the ton." But on turning to these analyses I find that the pyrites is said to have been brought from an auriferous leader, and from the Kapanga Mine; it is not said to have come from the country rock. Mr. W. Skey says that in two cases at the Thames, pyrites was roughly separated from a quantity of rock free from all appearance of quartz veins, and these, when separately assayed, gave no positive indication of gold; but some pyrites from the Long-drive Claim, selected with the greatest care, so as to avoid anything like a quartz vein, gave distinct traces of gold.* This is the only analysis that I can find which gave positive results, and it is of great importance; but numerous assays of pyrites taken at different distances from reefs are required before this point can be considered as settled.

A piece of carbonised wood, about an inch in diameter, highly charged with pyrites, was found in the Maid of England Claim, Waiotahi Creek; the pyrites here being probably due to the organic matter having reduced the iron sulphate which circulates through the rock. This pyrites was examined by Mr. W. Skey, who reported that it contained no gold.† Sir James Hector, however, says that "the specimen was not sufficiently large to give a reliable indication of the presence or absence of gold,"‡ so that the evidence is not conclusive; but as far as it goes, it is against the idea of iron sulphate containing gold in solution. I am not aware of the iron sulphate, found in the old drives, having been tested for gold.

If it should turn out that pyrites in the country rock is an indication of gold in the neighbouring veins, but that the pyrites is not decomposed and is non-auriferous, then I would suggest that, as part at least of the pyrites has been formed from magnetite, the gold may have been originally in the magnetite and have been released during the formation of the pyrites. I do not think that this has been the case, but it is a point worthy of investigation by the chemist. The pyrites is no doubt a secondary mineral formed in the rock after consolidation, and if it should turn out to be generally auriferous, we must suppose either that the gold came from below with the sulphur, or that its source is the titaniferous magnetite, which is one of the original constituents of the rocks.

But there are other secondary minerals constantly associated with the gold veins, which must not be overlooked. They are chlorite and bastite. As chloritic-andesites, or propylites, are also found in Nevada and in Hungary as well as at the Thames, and as in all three places they contain gold and silver in remarkably similar proportions, it would seem *a priori* that the chlorite might be connected with the occurrence of the precious metals in veins. Now Prof. F. Sandberger has proved that the mica of the gneiss of the Black Forest contains small quantities of several metals including silver, and other observers "have shown that a large

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* Reports Geological Explorations, 1870-1 pp. 84-5.

† Laboratory Reports No. 4, 1869, p. 17, No. 465.

‡ Reports Geological Explorations, 1868-69, p. 32.

number of metals are present in the micas, the augite, the hornblende, and the olivine of the crystalline rocks."* Mr. Becker has also found gold and silver in the diabases that bound the Comstock lode, most of it in the augites. This gold and silver is in much the same relative proportions as the Comstock bullion; and he further found that the decomposed diabases contained only about half as much of the precious metals as the fresh rocks.† That is to say, one-half of the gold and silver has passed out of the decomposed rocks, and has, no doubt, been deposited elsewhere. If therefore we assume that the pyroxenes of our volcanic rocks contain gold and silver, that the conditions necessary for dissolving them rarely obtain, but that one of the exceptions has been in the Hauraki gold-fields, we have a hypothesis which will, I think, explain most of the facts.

The first change that took place in these rocks was, as I have shewn, the conversion of the pyroxenes into chlorite and bastite with the liberation of silica, lime, and some iron. If gold and silver were partly removed with these substances we can conceive that while the lime was altogether removed the silica and iron might have been deposited with the precious metals in fissures and the iron converted into pyrites by hydrogen sulphide. During the second series of changes the whole of the chlorite with the remaining gold would be removed and auriferous quartz would be deposited in the veins. If the decomposition of the felspars took longer than that of the clorites, which is very probable, pure crystallised quartz might be deposited on the auriferous quartz. In the third series of changes the carbonates, which had been formed during the second series of changes, were dissolved and part may have been deposited occasionally on the quartz.

This, it will be seen, gives a fair explanation of the principal facts connected with the reefs, and also explains why the white rock, from which the chlorite has been removed, is more favourable for gold than the harder dark-green rocks in which the chlorite still remains. But no reason is apparent why the sulphides of antimony, zinc, arsenic, and copper, should have been formed subsequently to the iron sulphide. Absence of gold in the well crystallised quartz shews that silica continued to be removed after all the gold had gone; and we might account for the fine threads and scales of gold between the points of quartz crystals by supposing that during the second or third series of changes the auriferous pyrites in the veins was in some places dissolved and that the gold was redeposited, while the sulphur and most of the iron were removed in solution, nothing but red stains being left behind. If this hypothesis is the true one I should expect that, as the whole of the gold in the veins in the hard dark rocks is due

* Green's Physical Geology, Ed. 1882, p. 560.

† U. S. Geol. Survey, 1880-81, p. 309.

to the first set of changes, it would exist chiefly as auriferous pyrites; while in the softer "kindly sandstone" more gold would be added in auriferous quartz without pyrites.

These are however surmises, which I am not in a position to test, and are intended merely to direct the steps of other investigators. I must however add that if my views are correct, it will be useless to follow the reefs far down into the slates. This conclusion is, I am aware, opposed to the opinions of Sir James Hector and Mr. Cox,* and I can only say that I hope time may prove me to be wrong.

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* The Section here given as of Te Aroha is Mr. Cox's Section of the Thames through Tararu Creek.

2.—CUPRIFEROUS TUFFS OF THE PASSAGE BEDS BETWEEN THE TRIASSIC HAWKESBURY SERIES, AND THE PERMO-CARBONIFEROUS COAL-MEASURES OF NEW SOUTH WALES.

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INTRODUCTORY.

The late Reverend W. B. Clarke divided the workable Coal-measures of New South Wales and their associated formations, including the overlying Hawkesbury and Wianamatta Series, in the following manner* :—

Mesozoic.	Wianamatta Shales.
	Hawkesbury Sandstone.
Palæozoic.	1. Upper Coal-measures.
	2. Upper Marine Beds.
	3. Lower Coal-measures.
	4. Lower Marine Beds.

Mr. C. S. Wilkinson, F.G.S., etc., in the latest edition of his "Notes on the Geology of New South Wales," adopts the following classification for these rocks, separating the Narrabeen beds from the Hawkesbury :—

Mesozoic.	Triassic.	Wianamatta Shales.
		Hawkesbury Series.
Palæozoic.	Permian.	Upper Coal-measures, Newcastle Series.
		Middle Coal-measures, East Maitland Series.
	Upper Carboniferous.	1. Upper Marine Series.
		2. Lower Coal-measures.
		3. Greta & Stony Ck. Ser.
		3. Lower Marine Series.

He also describes the chocolate shales which underlie the Hawkesbury Sandstone. [See pp. 74-75], but regards them as an integral part of the Hawkesbury Series.

* Remarks on the Sedimentary Formations of New South Wales, by the Rev. W. B. Clarke, M.A., F.R.S., 4th Edit., p. 66.

Between the Narrabeen Shales and the topmost beds of the productive Coal-measures there intervenes a considerable thickness of strata, at present unnamed, which, for convenience in this paper, will be termed the *Estheria Shales*. The cupriferous tuffs about to be described form an intercalated stratum in the latter.

Prospecting operations by means of the diamond drill, have lately proved that these tuffs are somewhat extensively developed, and they are now known to extend from Bulli on the south to at least as far as Holt-Sutherland on the north, a distance of seventeen miles.

The study of the occurrence of this shale, as will be shewn in the sequel, is not only of great scientific interest, but may prove of considerable economic importance, as affecting conclusions as to the probable depth of the Coal-measures in the improved area between Parramatta and Sydney.

Mention by Previous Authors.

As far as the author is aware the only description of these shales published hitherto, is the one given by himself in a paper read before the "Geological Society of Australasia," on May 13, 1887.* The only possible previous allusion to these shales was made by Mr. Bensusan in 1878.† In the reference given below it is recorded that Mr. Bensusan laid on the table at a meeting of the Royal Society "a specimen of indurated clay from the boring at Newington from a depth of 1150 feet, showing a nodule of quartz containing metallic copper, which had been cut through by the diamond drill borer. The clay is similar to that found at Bulli 700 feet above the coal seam." The expression "nodule of quartz" here seems to infer that the stone in which the copper occurred was a derived fragment, and does not imply that the native copper was "in situ" in the shale.

The first person, as far as the author is aware, who unquestionably observed native copper "in situ" in these shales, was Mr. John Waterhouse, M.A., Head Master of the High School, West Maitland, who assures the author that he noticed scales of metallic copper "in situ" in the shale core from the Newington bore, in the year 1878. No description of this however was given by him at the time.

Mr. W. A. Dixon, F.I.C., F.C.S., informs me that some years ago a sample of copper-bearing shale was sent to him for assay from near Bulli, but he did not publish any description of it.

My colleague, Mr. William Anderson, was the first to discover the tuffaceous origin of the cupriferous shale, its resemblance to

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*Trans. Geol. Soc. Australasia, I., Part III., pp. 82-89.

† Journ. Roy. Soc. N.S. Wales, 1878, XII., p. 254.

the tuffs associated with the Lower Carboniferous strata at Abden, near Kinghorn, Fife, having suggested the idea, which was found to be correct upon a microscopic examination.

LOCALITIES.

Cupriferous shales have been discovered at the following places:—

1. At the 1,312 feet (completed in 1878) diamond drill bore at Newington, on the Parramatta River, near Parramatta, where it was observed by Mr. Waterhouse.
2. At Bulli, the shale is said to outcrop in the hills at a level of about 700 feet above the Bulli coal seam.
3. At the 2,307 feet diamond drill bore completed in 1887, at Dent's Creek, on the Holt-Sutherland Estate, between Port Hacking and Botany Bay.
4. At the 1,586 feet diamond drill bore, completed in 1886, at Heathcote, on the Illawarra line, twenty-seven miles southerly from Sydney.

STRATIGRAPHY.

The stratigraphical relation of the cupriferous shales to the formations above and below them is best illustrated by the complete sections afforded by the Holt-Sutherland and Heathcote Bores. Both these bores commenced in the sandstone of the Hawkesbury Series, and were continued through the underlying Passage Beds into the coal seams of the Upper Coal-measures.

The following is an abridged descending section of the Dent's Creek Bore:—

TRIASSIC.

Hawkesbury Series.

Thickness 771 feet, chiefly greyish-white and yellowish-white sandstones, gritty in places with occasional beds of fine greyish-white quartz conglomerate from $2\frac{1}{2}$ feet to 24 feet thick, and beds of dark grey shale from half a foot to 22 feet thick, with leaves of *Thinnfeldia.** The horizon of the Labyrinthodont remains, lately discovered at Biloela, probably occurs at about 200 feet below the commencement of this series.

PASSAGE BEDS.	*Narrabeen Shales.* Thickness 591 feet, popularly called the "chocolate shales"; chiefly purplish-red or chocolate ferruginous clay shales, fine dark grey mudstones, and whitish-grey sandstone, with occasional bands of dark clay shale with fragments of carbonised plants. At Narrabeen, nine miles (?) N.E. from Sydney, these beds contain *Thinnfeldia* (?), and *Glossopteris tæniopteroides* (?).

* See Stephens, Proc. Linn. Soc. N. S. Wales, I. pt. 3, p. 931; and II. pt. 1, p. 156.

PASSAGE BEDS.

Estheria Shales. Thickness 638 feet, including the cupriferous shales and tuffs. Three hundred and sixty-seven feet chiefly fine-grained greenish-grey sandstone with pebbly-bands and a little fine conglomerate, greenish-grey indurated clay shale and dark grey mudstone.

Seventy-one feet clay shale and mudstone, dark reddish-purple slightly mottled with green, passing towards the base of the beds into dark greenish-purple and bluish-black tuffaceous shale and seven inches of tuff.

Two hundred feet greenish-grey carbonaceous sandstone with beds of fine conglomerate 10 feet to 28 feet thick, containing pebbles of grey felsite, and black, red and green jasper, and indurated greenish-grey clay shale.

Valves of a species of *Estheria* were found by me at depths of 1,362 feet, 1,627 feet, and 1,651 feet, and subsequently by Mr. W. Anderson, at depths of 1,963 feet and 2,000 feet.

PERMO-CARBONIFEROUS.

Upper Coal Measures.

Thickness proved 307 feet at least. Chiefly sandy-clay shales, dark grey, carbonaceous, with frequent bands of fine grained clayey-sandstone. A bed of fire-clay two feet thick, with fragments of plants converted into coal, occurs at sixty feet below the commencement of these beds; and thin ferruginous bands at twenty-eight-feet above the first coal seam, hard quartzose-sandstone and clayey-carbonaceous sandstone, and five feet eight inches of fine conglomerate.

4′ 2″ (about) Upper coal seam.

64′ 7″, Chiefly dark grey carbonaceous sandstone with small flakes of coal, with a few thin beds of dark shale, a few thin beds of fine conglomerate near underlying coal seam, and a five inch layer of clay ironstone at eight feet above the lower coal seam.

5′ 3″ (about) Coal-seam (lower).

6′ 0″ Black sandy shale, clayey sandstone and shale with films of coal.

The following is an abridged section of the core from the diamond drill bore at Heathcote, eight miles and fifty chains distant from the Dent's Creek Bore, bearing S. 29° W.

TRIASSIC.

Hawkesbury Series.

Thickness 340 feet coarse greyish-white and yellowish-grey sandstone, passing towards base of series into fine sandstone, alternating with fine dark sandy-shale and clay shale, the last containing well preserved leaflets of *Thinnfeldia.*

Narrabeen Shales.

Thickness 650 feet (about), 86½ feet chocolate ferruginous clay shale breaking with semi-conchoidal fracture, getting darker and more sandy towards the base. 573½ feet (about) chiefly fine grained greyish-white and yellowish-grey sandstone with coaly grains in places, with bands of dark and light grey shales becoming more carbonaceous downwards, with six inches of quartz-pebble conglomerate at base of beds.

Estheria Shales.

Thickness 310 feet (about).

57′ 0″ Greenish-grey gritty sandstone, and fine grained grey sandstone, and grey clay shale.

45 Feet tuffs and tuffaceous clay shale, dark greenish- and reddish-purple, interbedded with greenish-grey sandstone and coarse grit, *cupriferous* at depths of 1065½ feet and 1072 feet from the surface.

178 Feet (about) carbonaceous gritty sandstone, dark grey mudstone, grey clay shale, black clay shale with fossil leaves, and at base of beds 75 feet of conglomerate and fine sandstone with bands of chert.

PERMO-CARBONIFEROUS.

Upper Coal Measures.

Thickness 213 feet (about) grey and greenish-grey clay shales, dark carbonaceous sandy-shales, and dark carbonaceous sandstone with gritty bands, with small concretionary nodules of clay iron-stone, and four feet of gritty compact sandstone immediately over-laying coal seam.

4′ 8″½ Coal seam, splint coal with thin layers of bituminous coal.

60′ 0″ Dark grey carbonaceous shale and clayey sandstone passing downwards into forty-eight feet of dark grey sandstone.

6′ 1″ Coal seam.

1′ 9″ Dark shale.

LITHOLOGY.

Some idea of the lithological character of the Cupriferous Shales and Tuffs may be gathered from the following detailed sections of them :—

I. *Holt-Sutherland.*

Commencing at a depth of 1728′ 11″ from the surface.

Feet.	Inches.	
3	0	Clay shale, dark grey with purple bands.
28	2	Mudstone and sandy clay shale, the former greenish-grey, the latter dark reddish-purple, about a quarter shales and the rest mudstone.
1	10	Mudstone, pale inky-grey.
1	6	Sandy shales, grey.
0	6	Clay shale, dark reddish-purple.
0	8	Reddish-purple shale.
0	1	*Cupriferous* reddish-purple shale.
1	4	Reddish purple clay shale, etc.
0	$2\frac{1}{2}$	*Cupriferous reddish-purple clay shale.* [Assay, No. 85.]
1	6	Greenish-black and purplish-black clay shale.
0	$4\frac{1}{2}$	Core missing.
0	$11\frac{1}{2}$	Purplish-black clay shale.
1	11	(about) Dark greenish-black clay shale.
0	6	,, Reddish-purple clay shale.
3	$1\frac{3}{4}$	Dark greenish-black siliceous clay shale.
0	4	(about) Purplish-black clay shale.
1	2	Dark greenish-grey sandy shale.
1	0	Sandy clay shales with flakes of *native copper.* [Assay, No. 82.]
1	$8\frac{1}{2}$	Dark greenish-grey sandy clay shales.
1	$6\frac{1}{2}$	Dark greenish-grey or greenish-black siliceous clay shale with semi-conchoidal fracture.
0	$7\frac{1}{2}$	Dark greenish-grey to black siliceous shales.
3	6	Greenish-black clay shale.
0	5	*Cupriferous* greenish and purple black clay shale. [Assay, No. 84.)
0	$5\frac{1}{2}$	Sandy greenish-black tuffaceous shale. [Microscpic section made from this.]
0	$8\frac{1}{2}$	Hard greenish-black siliceous clay shale.
0	$2\frac{3}{4}$	*Cupriferous shale,* dark greenish-grey. [Assays, Nos. 94 & 95.]
2	7	Dark greenish and purplish-black siliceous clay shale.
0	6	*Cupriferous shale,* dark greenish-grey to greenish-black. [Assay, No. 81.]
10	$2\frac{3}{4}$	Clay shale, crumbling, passing into greenish-black and purplish-black mudstone.
Total 71	0	

II. *Heathcote.*

Commencing at about 1047′ 2″ from the surface.

Feet.	Inches.	
2	9	Clay shale crumbling, with pale purple bands, wafers and films of lime.
0	6	Greenish-brown hard clay shales.
0	4	Greenish-brown clayey sandstone
0	9	Dark greenish-grey hard clay shales.
1	9	Greenish-grey clayey sandstone.
4	10	Greenish-grey and purplish-grey hard clay shale.
0	9	Clay shale.
1	8	Hard greenish-grey clay shale with wafers and films of lime
2	2	Dark grey, dark purple, and greenish-grey crumbling clay shales.
2	1	Dark greenish-black and purplish-black sandy clay shales and mudstones.
0	6	Purple clay shale with small conchoidal fracture, with flakes of *native copper*.
18	10	(about) Purplish-black, dark grey and dark greenish-grey clay shales sandy in places with small conchoidal fracture and crumbling in places, with one inch of *cupriferous* shale at a depth of 1072 feet.
2	6	Greenish-grey clayey sandstone, fine and compact.
1	4	Laminated dark-grey shales and mudstones.
4	5	Gritty greenish-grey sandstone.
2	0	Coarse grit fragments of lydian stone, and quartz up to half an inch in diameter.
0	3	Dark greenish-grey sandy shale.
2	9	Dark greenish-grey and dark purplish-grey shales.
8	0	Grit and fine compact sandstone.
3	8	Greenish-grey clay shale.
5	5	Dark purplish-grey, and greenish-grey slightly mottled clay shale, with films of brown calcite (?).
0	3	(about) Reddish-purple shale.
2	0	Dark greenish-grey clay shale chiefly crumbling.
3	0	Compact dark greenish-grey sandy shale and mudstone.
3	0	Crumbling dark purplish-grey and greenish-grey shales.
Total 75	6	

Several of the beds described above in these two sections as sandy shales and mudstones when further examined may prove to be tuffs chiefly of volcanic origin.

No microscopic sections have as yet been prepared of the Heathcote cupriferous purple shales, but their external resemblance to the Holt-Sutherland shales is so close as to make their tuffaceous origin all but certain.

At Holt-Sutherland out of a total thickness of seventy-one feet at least three feet showed native copper more or less freely. Seven and a-half inches of the core shewed native copper in addition to those portions mentioned.

At Heathcote about seven inches of core altogether were cupriferous.

MACROSCOPIC CHARACTER.

Small hand specimens of the core from Holt-Sutherland shew the rock to be of a dark purplish-black or greenish-purple colour.

The texture varies from that of a grit containing particles one-sixteenth to one-eighth of an inch in diameter to a very fine grained compact shaley rock. The latter has a small conchoidal fracture, while the former breaks with uneven wedge-shaped chips with flatter surfaces.

The fine grained rock, even when examined with a pocket lens, shews no structure with the exception that here and there it is seen to contain scales of native copper from one-twentieth to one fourth inch in longest diameter, averaging one-tenth inch, and about one-fortieth inch thick.

Their prevailing shape is circular, more or less.

The gritty tuff is seen without the help of the pocket lens to be a fragmental rock composed of black, green, brown, red, and grey particles. The average size is about one-twentieth of an inch, though many of the fragments are from one-eighth to one-sixth of an inch in diameter. On freshly broken surfaces of the tuff some of these particles shew bright cleavage planes. Minute irregular grains and scales of metallic copper can easily be detected in places, and rarely a thin plate of bright native copper is seen filling the interspace of a minute vertical joint.

When soaked in water the fine and gritty tuffs gradually break up into fragments of one-quarter to half an inch in diameter. The fine tuff, however, even when soaked for several days, does not become disintegrated or softened so as to form any fine sediment. The gritty tuff, however, when similarly treated, yields a fair amount of muddy material.

The specific gravity of the gritty tuff is 2.62. The hardness of the fine compact tuff is from $2\frac{1}{2}$ to 3.

CHEMICAL COMPOSITION.

The followng analysis of the tuff has been made by Mr. J. C. H. Mingaye, F.C.S., Analyst and Assayer to the Department of Mines :—

Analysis.

Combined moisture	5.32
Moisture at 100°	3.38
Silica	56.28
Alumina	24.21
Oxide of iron	7.34
Metallic copper	.08
Lime	1.10
Magnesia	2.36
	100.00

"This mineral was dotted over in places with minute specks of metallic copper. Two large assays were made for gold and silver, and neither of these metals found present."

Assays of these cupriferous shales were made for the Department of Mines by Mr. W. A. Dixon, F.C.S., seven were made for gold and silver from the Holt-Sutherland shale, and one for gold and silver from the Heathcote shale, and one from the Holt-Sutherland shale was made for copper, gold and silver. The samples of shale for assay from the Holt-Sutherland bore were selected by Mr. C. S. Wilkinson, F.G.S., &c., and myself. The following is the result :—

No. 77. Purple and grey shale containing metallic copper.

Copper......0.21.
Gold (?)......9 dwts. 19 grs. per ton (?).
Silver......11 dwts. 2 grs.

It will be observed that the percentage of copper in this sample was considerably higher than in that assayed by Mr. Mingaye. As there was some doubt as to the correctness of the quantity of gold contained in this assay, eight more assays were made for gold and silver, with the following results :—

No. 81 (A). Dark grey shale shewing plates of native copper, and representing a length of six inches of core.

Silver......8 dwts. 11 grs.
Gold......a trace.

No. 82 (B). Representing a length of twelve inches of dark-reddish grey shale showing flakes of metallic copper.

Silver......none.
Gold......none.

No. 83 (C). Representing seven and a-quarter inches of dark grey shales.

Gold......a trace.
Silver......3 dwts. 22 grs.

No. 84 (D). Representing five inches of shale,

Gold......a trace.
Silver......5 dwts. 21 grs.

No. 85 (E). Showing flakes of native copper and representing three inches of clay shale.

Gold......a trace.
Silver......4 dwts. 13 grs. per ton.

With regard to these samples Mr. Dixon states—"The first of these only gave the exact button of silver due to that present in the litharge used. On parting the other buttons a minute speck of gold was left in each case, but quite unweighable, therefore less than thirteen grains per ton in each."

No. 93. Representing four inches of cupriferous shale core from Heathcote Bore, from a depth of 1,065 feet below the surface.

Silver......13 dwts. 1 gr.

No. 94. Cupriferous reddish-grey shale from Holt-Sutherland, from 1,787 feet, representing two and three-qnarter inches of core.

Silver......7 dwts. 20 grs. per ton.
Gold......a trace.

No. 95. Representing one and three-quarter inches of cupriferous shale core from Holt-Sutherland.

Silver......11 dwts. per ton.
Gold......a trace.

"No. 95 contained more gold than the others, but still unweighable."

A considerable amount of the iron present is in the form of magnetite as proved by powdering the rock and extracting the the magnetic iron with a magnet. I was unable to determine whether metallic iron was present, but this may be decided subsequently when a larger body of the rock is obtainable for treatment. A great deal of the silica is undoubtedly free, as grains of quartz can easily be detected by the naked eye, and this probably accounts for the silica being in excess of the proportion required by the alumina to form kaolin.

The combined water is probably chiefly present in the clayey material of the rock, and kaolinised felspars in the basalt lapilli.

The magnesia and lime present are in much smaller proportion than I expected, judging from the amount of epidote and secondary hornblende visible under the microscope.

MICROSCOPICAL CHARACTER.

If macroscopic character and chemical composition alone were taken as guides the true nature of the rock might remain hidden in obscurity, but a whole flood of light is thrown upon its origin by the microscope when applied to the examination of carefully prepared thin slices of the tuff. After several unsuccessful attempts to make thin sections of this rock by grinding down with water and emery after previously boiling the specimens for days in Canada balsam, Mr. C. Murton succeeded in preparing some good sections of this rock by filing it down dry after the rock had been hardened as before by boiling in balsam.

The microscopic sections at once reveal its volcanic origin.

The bulk of the rock is built up of rounded or subangular particles of crystalline rocks chiefly if not wholly of volcanic origin. Some are black and opaque but for minute lath-shaped felspars, many of which are still so far free from decomposition as to allow light to pass. Others shew various shades of green and are more or less translucent, and others are of a brown pink colour and some pale greenish-grey. The whole are cemented by a grey, or more or less transparent base. Opaque intensely black grains and crystals are sprinkled through the slide and are observable in the volcanic particles as well as in the base.

Slide No. 1a is seen to belong to a fragmental rock, the fragments varying from the size of a small pin's head to that of dust shot. The prevailing colour of the fragments is greenish-grey and purplish-black. A fine crystalline pseudomorph of copper is visible near the centre of the slide as shewn in the drawing. The clear grain just above the copper pseudomorph is quartz. The large fragment of lava below the copper crystal showing the lath-shaped felspar is of a reddish-black or reddish-purple colour. The felspar is opaque from kaolinization. The large fragment of lava to the right of the centre is a fragment of purplish-grey and reddish-purple trachyte (?). The felspars are more minutely crystalline than in the previous species, and have four-sided, or nearly circular shapes, enclosing dark spots, but there is no tendency whatever even at the edges to decompose into greenish mineral. The elongated oval fragment of lava consists of micro-crystalline lath-shaped felspar, with a great deal of pale greenish-grey, and viridite-like decomposition material. Magnetic iron is frequent in some quantity. To the left of the centre and a little below it is a pale yellowish-grey fragment which to judge from the cleavage may be a decomposed augite. There are besides in this slide occasional fragments of a pale greenish-grey colour, of a somewhat serpentinous appearance. This is made up of a great number of little crystals of tabular shape, yellowish-grey colour, and semi-translucent in a pale greenish-grey base shewing vanishing outlines of lath-shaped felspar with occasional dark green patches. These are probably tabular felspars. Here and there are brick red fragments inclining to vermilion in places. They are evidently fragments of lava which owe their red colour to some secondary chemical action. The large black grains are titaniferous iron. The smaller dark grains are magnetite, nearly colourless grains of various shades of grey also occur: all the fragments are more or less rounded, and many of them as round as shot.

In Slide No. 2a there are deep grass-green translucent grains, and one of a bright bluish-green tint, which may be carbonate of copper. There is a great deal of epidote and chlorite. Several large greenish-grey grains are very rich in magnetic iron.

Two species of felspar are observable in one of the greyish-purple trachyte lavas. One shows in stout stunted tabular forms, and is much kaolinised, the other occurs in slender lath-shaped prisms and is semi-translucent.

In Slide No. 3b is a microscopic vein of metallic copper traversing a pale greenish-grey mineral. A micro-porphyritic crystal of felspar occurs in one of the fragments of decomposed basalt. A bright bluish-green mineral in the same slide is perhaps copper carbonate.

In Slide No. 2c from Holt-Sutherland, is one undoubted fragment of deep bottle-green hornblende, showing characteristic cleavage and strong dichroism.

One class of fragments is a lava of a transparent pale greenish-grey, with patches of yellowish-green, and dotted all over with opaque ragged crystals of ilmenite. Slender prisms of turbid felspar are just recognisable in the ground-mass, and acicular radiating crystals of actinolite or epidote strongly pleochroic, occur as secondary inclusions in the greenish patches. The fragments of this lava appear to be enormously rich in ilmenite.

Another specimen similar to the above consists of a holocrystalline base of felted felspar, with pale greenish-grey interstitial material and abundant ilmenite in small aggregates with ragged edges. A micro-porphyritic multiple-twinned felspar is enclosed in this ground-mass. Hornblende is present in green transparent grains, shewing the characteristic prismatic cleavage. The original outlines of the crystal have been completely obliterated by friction. One of these yellowish-green grains shows faint traces of an original augite cleavage, but the hornblende cleavage predominates, so that it is probably uralite. Some of the lapilli of lava are very sharp and angular, composed of an intensely black ground-mass, in which are enclosed lath-shaped felspars and small yellowish-green patches, one of the larger ones looking like a pseudomorph after olivine. Black opaque patches are very frequent. The majority of them are lapilli of basaltic lava, but those surrounded with the opaque whitish zone and showing a rough hexagonal shape, are probably ilmenite fringed with leucoxene. Black magnetic iron and ilmenite are plentifully sprinkled through the rock, as fine dust, as well as in crystals and crystalline aggregates. A purple amethystine colour prevails in the ground-mass surrounding some of the ilmenite, the colour being probably due to a small quantity of manganese, or possibly to the titaniferous iron.

ECONOMIC VALUE.

These shales, apart from their great scientific interest, may at some future period be of value for two reasons :—

1. For the metals contained in them.
2. For the indication which they afford as to the depth of the underlying Bulli coal-seams.

1. At Holt-Sutherland the total thickness of the copper-bearing portions of the shales is at least three feet. This thickness, however, is made up of a number of different layers, several of which are separated from one another by bands of shale which do not show native copper freely, though they probably contain a small proportion of the same metals which occur in the more productive bands. The thickness of the metalliferous bands is respectively one inch, two and a half inches, one foot, seven and a half inches, five inches, two and three quarter inches, and six inches. The highest ore band is about twenty-four feet above the lowest, and the beds are separated from one another by from one foot to nine feet of comparatively barren shale.

At Heathcote there are two thin beds shewing native copper, the upper six inches thick, and seven feet above the lower, which is only one inch thick.

Assuming, therefore, that a continuous bed of cupriferous shale extends from Heathcote to Holt-Sutherland, a distance of eight and a half miles, having an average thickness of one foot, there would evidently be a large body of metalliferous strata.

The average specific gravity being taken as 2.6, every acre of shale would contain 3,160 tons of copper-bearing rock which would yield on the average (the average yield of copper being assumed to be 0.15%) 3 lbs. $5\frac{3}{4}$ ozs. of metallic copper and 7 dwts. 7 grs. of silver per ton. If, therefore, the value of the gold be left out of consideration, and, as already stated, gold was only found in appreciable quantity in one doubtful assay, the value of copper and silver in the aggregate would be only 3s. 9d. (?) per ton, so that the shale is far too poor to work at present for these metals.

2. As regards the question whether the copper shales form a reliable horizon from which to calculate the probable depth of the underlying Bulli seams, a very interesting question suggests itself.

At Holt-Sutherland and Heathcote the thickness of strata between the cupriferous shale and the coal seams is almost identical, being 440 feet. At Newington, however, on the Parramatta River, the cupriferous shale is either on a different geological horizon to that of the Narrabeen Shales, or if it be on the same geological horizon, there must be a complete change of dip accompanied by a thinning out of the Narrabeen Shales, for the following reasons:—The dip from Coal Cliff to Holt-Sutherland is northerly, and between Heathcote and Holt-Sutherland, the amount of dip is about 1 in 38 = 139 feet per mile. Newington is about twelve miles northerly from Holt-Sutherland, therefore, supposing the surface levels to be the same, and that the northerly dip continued at the same rate, the cupriferous shales at Newington should be 1,668 feet deeper than at Holt-Sutherland, but the surface at Newington being about one hnndred feet lower than at Holt-Sutherland, the increase in depth would be 1,568 feet. At Holt-Sutherland the copper shales were first struck at 1,764 feet from the surface, therefore at Newington they should theoretically lie at a depth of about 3,330 feet instead of 1,150 feet as is actually the case. There must, therefore, either be an upper cupriferous shale horizon belonging to the Narrabeen Shales, or if these cupriferous shales at Newington are on the same geological horizon as those at Holt-Sutherland and Heathcote there must be a reversal of dip from north to south between Holt-Sutherland and Newington. If the latter is the case, it may be due to a gradual rising up in this direction of the old floor on which the rocks of the Coal-measures and the succeeding formations were deposited. Strong evidence of this is afforded by the existence of the old inlier known as Waimalee Hill at Prospect, near Parramatta. The Rev. W. B. Clarke considered the Waimalee Hill of earlier origin than the Wianamatta Shales, as he says that the latter have been formed * partly from the waste material derived from the former, and if this old diorite (?) hill be earlier than the Wianamatta it may also be earlier than the Bulli Coal-measures which may consequently mantle round its base, and some of the formations intermediate between the Wianamatta Shales, and the Coal-measures may almost entirely thin out as they approach the old inlier. The solution of this question will obviously have a very important bearing on the future of coal mining in the neighbourhood of Prospect near Parramatta. Against this evidence of the possibility of the Newington cupriferous shale being synchronous with that of Holt-Sutherland, must be adduced the fact that layers of tuffaceous shale, certainly in part of volcanic origin, have lately been observed by me in the core from the diamond drill bore at Moorbank, near Liverpool. These layers were intercalated with the lower beds of the Hawkesbury Sandstone just above the chocolate shales of the Narrabeen beds.

* Remarks on the Sedimentary Formations of N.S. Wales, 4th Edit., p. 73.

Some green fragments, much like malachite, may be seen in the microscopic section of the tuffaceous grit, in Slide No. 4a. This evidence is confirmatory of the existence of two horizons of volcanic tuffs, and suggests that the iron oxides which impart the reddish colours to the chocolate shales and the purple shales, may have been derived from the magnetic iron in the volcanic tuffs.

PROBABLE ORIGIN.

The cupriferous tuffs and tuffaceous shales are evidently partly of volcanic and partly of sedimentary origin, as proved by the presence in them of both basalt lapilli and rounded quartz grains. Two facts indicate Kiama, or the line of volcanic country between Kiama and Mittagong, as the probable source of the volcanic particles; first, the presence of minute segregated veins of metallic copper in the basalt at Kiama; second, the resemblance of the Kiama and Mittagong lavas to those of which the fragments in the tuff at Holt-Sutherland are composed. About four years ago a Mr. — Cameron brought from Kiama, a sample of basalt which contained native copper. Under the microscope the Kiama basalt is seen to consist of a holocrystalline base in which are micro-porphyritic foreign crystals of triclinic felspar and straw-coloured augite. The base is composed of the lath-shaped, felted, triclinic felspars, with a large proportion of bottle-green chlorite, and a considerable quantity of magnetic iron and ilmenite. Minute segregated veins of metallic copper are visible in three slides exhibited. These veins are about one-fortieth inch thick, and their surfaces shew well formed crystals of copper. Their secondary origin is evident from the fact that they intersect all the minerals composing the base of the lava. The genesis of these veins of copper in the basalt is difficult of explanation. Metallic copper may have been present in a finely divided state in the basaltic magma, and have segregated along the shrinkage cracks formed in the lava on cooling; or it may have been precipitated in such cracks from some solution of copper salts. Its occurrence in veins proves that it was not precipitated by metallic iron in the basalt from a solution of sulphate of copper. In the tuffs, however, at Holt-Sutherland, there can be little doubt that the copper was chemically precipitated.

The above facts point to the following conclusions:—

1. That at some period, intermediate between the close of the Permo-Carboniferous and the commencement of the Triassic (if, indeed, the Hawkesbury Series be Triassic), volcanic explosions, accompanied by showers of volcanic dust, occurred probably in the neighbourhood of Kiama and Mittagong.
2. That this dust fell into the waters of the lagoons or estuaries in which the lower part of the Estheria Shales had already been deposited.

3. That then no more dust fell during the accumulation of the upper part of the Estheria Shales, and the bulk of the succeeding Narrabeen beds.
4. That then fresh showers of volcanic dust fell and became interbedded with the basement beds of the Hawkesbury Sandstone, as proved by the thin layers of tuffaceous grit in the core from the Moorbank bore.
5. That these tuffaceous grits belong to a geological horizon different from that of the Holt-Sutherland, Heathcote, and Bulli tuffs, and therefore should probably be correlated with the Newington cupriferous shales.

ACKNOWLEDGMENT.

My thanks are due to Mr. J. Waterhouse for kindly allowing me to examine the specimens of the Newington bore: to Messrs. Jones, Black and Tidswell for doing me a similar favour with regard to the Liverpool core; and to Mr. W. J. Slee, Superintendent of Diamond Drills, for the facilities he afforded me for examining the Heathcote core at the drill stores belonging to the Department of Mines.

3.—MICROPETROGRAPHICAL NOTES ON SOME OF THE HYDROTHERMAL ROCKS OF N. S. WALES.

By T. W. Edgeworth David, B.A., F.G.S., Geological Survey of New South Wales.

[*Abstract.*]

These rocks are divided according to ultimate chemical composition into ultra-basic, basic, intermediate, and acid igneous.

Of the ultra-basic group there are two extra-terrestrial representatiyes in the Bingera, and Barratta Meteorites, described by Professor Liversidge. Of terrestrial ultra-basic rocks the chief representatives in New South Wales are serpentines, which rocks, near Gundagai, are considered to be formed from the extreme metamorphism of talc schists.

Of the basic group there are numerous representative varieties, ranging from glassy tachylites to coarse dolerites. A remarkable intrusive Cherzolite basalt occurs near Bulli. This is composed of fragments of granular crystalline olivine one to four inches in diameter, and black crystals of augite, half to two inches in diameter, interlaced with anamesite basalt. Leucite basalt has been discovered lately at Byerock and at El Capitan, near Cobar. True gabbros, composed of diallage and a felspathic mineral resembling saussurite have lately been found at the Canoblas near Orange.

Intermediate group.—Glassy lavas, hornblende andesites, probably belonging to this group have recently been observed by the author at Nelson's Bay, Port Stephens. Diorites are of much less frequent occurrence than is popularly supposed.

Acid igneous.—Volcanic glasses belonging to this group have been met with at Port Stephens, Bulladelah, and near Grafton. Felsite lavas of Eocene age occur at Bailey's Mine and Rose Valley near Emmaville, where they overlie rich stanniferous gravel. The spherulitic felsites of Emmaville were also described, and Professor Liversidge's account was quoted of the Hartley granite, which was found by him to contain galena, and small crystals of staurolite.

Pumice occurs at several sheltered spots along the coast line near Sydney, and similar pumice has been observed by Mr. R. Etheridge at Lord Howe Island. Professor Liversidge who has analysed some of this pumice from Bondi, comments on its resemblance to that ejected from Krakatoa in 1883. These fragments of pumice have probably been drifted from some of the volcanic islands of the Pacific, possibly Krakatoa.

MONDAY, SEPTEMBER 1.

The following papers were read :—

1.—THE GEOLOGICAL SEQUENCE OF THE BOWNING BEDS.

By JOHN MITCHELL, of the Public School, Narellan.

[*Abridged.*]

In the present paper I propose to give briefly my conclusions on the Geological Sequence, or Stratigraphy of the Bowning Beds, with some remarks on the Cave Flat or Goodradigbee River Beds.

As regards the former these conclusions are the result of careful and frequent investigations made during a five years residence in the district. My remarks on the Goodradigbee Beds, are on the other hand, simply based on observations made while on a few short visits to the localities where the outcrops form conspicuous features of the country. For the Bowning Beds I shall retain the same boundaries east and west, as those given in my paper, "Notes on the Geology of Bowning,"* namely, the porphyry near the junction of Limestone and Barber's Creeks on the east, and Flinter's Gap (Conroy's Gap) on the west.

* Proc. Linn. Soc. N.S. Wales, I., 1886.

The principal portion of the Bowning Beds is that lying between the eastern boundary and the porphyry ridge about a mile west of the town, and forming a synclinal basin. Here the sedimentary rocks have escaped in a remarkable manner the work of metamorphism. In the eastern half of the basin this escape is particularly remarkable, while in the western half the exceptions consist in the silicification of some of the original strata over certain areas. The general strike is nearly north and south, and the dip east and west in the syncline, and the dip for the whole area north of west; and in the syncline ranges from 0° to 90°.

The basin is traversed by numerous small creeks, many of which cut the beds at nearly right angles to the strike, and all more or less expose the strata. The Great Southern Line crosses them in a similar direction and exposes good sections in many places.

Sequence of the Beds.—That ternary arrangement of deposition, which has been shown by the late Professor Phillips, Dr. Geikie, and other eminent geologists, to have taken place in the formation of the sedimentary rocks of Palæozoic times in Britain and elsewhere is also a marked feature of the Bowning Beds, though it does not repeat itself here with such marked and regular persistency, as it is shown to do in some of the localities cited by the authorities mentioned above.

In the lower beds the succession of the ternary order is clearly defined. For on the east at Silverdale, where they are well exposed, grit, shale, and limestone may be seen repeating themselves rather frequently. The bed that I shall refer to in the course of this paper as the Lower Limestone bed, is, in reality, composed of a number of thin strata of grit, shale, and coralline limestone, succeeding each other with tolerable regularity. In each case at this stage the strata are thin, ranging from an inch or two, to as many feet, the shale and grit usually being thinnest. These succeeding changes of sedimentary deposits indicate that our Silurian sea floor, like those of the same age in other quarters of the globe, was subject to frequent change of level.

Above this cycle of beds a considerable bed of grit occurs, followed by the principal bed of limestone, which in turn is covered by the Lower Trilobite Shale bed, affording the last and most striking example of this particular order of sedimentation to be found in the series.

Among the upper beds the limestone is absent; but still a ternary order is maintained by shales, grits or sandstones, and conglomerates.

On the eastern side of the syncline the order of the beds is as follows:—Grit and shale followed by the Coralline Limestone which, as above pointed out, is interbedded with grits and shales, then succeeds the grit separating the two limestones, and next the thick bed of limestone, in the structure of which Favosite corals have played an important part. Above the limestone is the Lower Trilobite bed of shale, sandstone in part, probably seventy feet thick. A very impure limestone, about twenty feet thick, is the next in ascending order, and from the prevalence of trilobites, I have designated it the Middle Trilobite bed. From the great preponderance of the genus *Phacops*, Mr. C. Jenkins, L.S., in his paper on the Geology of Yass Plains, denominated it the "Phacops Bed."

Above it lies the great shale bed, which I estimate to have a thickness of 1,300 feet to 1,500 feet. In the lower portion thin bands of flaggy sandstones are found, and the same feature is present towards its close. In the eastern half of the syncline I have not found any fossils in this bed, though throughout markings that resemble seaweed prints are observable. On the western side, however, I have obtained small Brachiopods and Gasteropods, from the upper strata. It would appear from the absence of organic remains that it must have been formed under a deep sea. After the completion of this bed, conglomerates, sandstones (some flagstones), and shales, repeat themselves not less than three times, producing a total thickness that cannot be less than seven hundred feet. Some of these later shales are very soft and laminated, and the shales throughout would largely come under the designation of mudstones. Crowning the series is a thick bed of a remarkable conglomerate, compact, hard, and in part metamorphic. The whole thickness of the eastern section I estimate at 2,000 feet to 2,500 feet.

The western section of the syncline at the base, includes some grits, friable sandstones and shales, which are not found in the eastern half. These appear to have a thickness exceeding seven hundred feet. Therefore, the sedimentary rocks in this section must nearly, if not, be quite 3,000 feet in vertical measurement.

In this portion also, some of the beds have undergone a greater degree of metamorphism. The limestone which has diminished in thickness, has become silicified, and were it not for the fossils could not be recognised.

From the porphyry ridge on the west side of syncline to Flinter's or Conroy's Gap, the beds enumerated as occurring in the syncline, appear to be repeated, but as extensive metamorphism has taken place in them they are not distinguishable.

Besides that agreement of the Bowning Beds with Palæozoic rocks of other parts of the world., in the ternary charater of arrangement, the shales possess some features common to the Silurian rocks of Britain. One of these is the tendency to form into concretionary masses of concentric rings. Another is the distribution of nodular masses of lime through certain of them. In some cases these nodules are in general of a spherical form, and enclose fossils. Occasionally they occur in layers covering considerable areas. The upper layer of these nodular masses is found in the Upper Trilobite bed.

The capping conglomerate bed which is now only found fringing, or adjacent to the Bowning Hill, possess some features of special interest. In some parts it has a very homogeneous aspect, and can with difficulty be separated from the metamorphic and porphyritic rocks of the locality. The cause that produced this partial metamorphism has not become evident to me.

Even where it is highly altered the shale on which it rests does not appear to have suffered any physical change. On first acquaintance with this conglomerate, I was of the opinion that Bowning Hill at the period of its formation, had been an isolated island in the then existing sea. With further examination I doubt the correctness of that view, though there can be little doubt that it marks the neighbourhood of a sea shore.

Life.—Beneath the limestone on the east of the syncline the grits contain prints of Brachiopods, but it is not till the limestone bed is reached that fossils become conspicuous. The lower of the two beds mark a sudden invasion of many organisms, the corals being foremost.

The commonest genera are :—Corals, *Favosites*, *Cyathophyllum*, and *Heliolites*; Brachiopoda, *Pentamerus oblongus*, and *P. galeatus*, *Atrypa reticularis* and *A. marginalis*, *Leptæna*, *Strophomena*, and *Rhynchonella*. Lamellibranchiata are very few. Gasteropoda, *Murchisonia*, *Loxonema*, *Pleurotomaria*, *Euomphalus*, *Bellerophon convolutus*. Cephalopods, *Orthoceras*, one species being like *O. annulatum*. The small Mollusca and Molluscoida occur in the thin shale beds intercalating the limestone, while the large ones are chiefly associated with the corals.

In the upper limestone bed the general facies of the fauna remains about the same, but some large Gasteropods in addition make their appearance. Of these *Euomphalus Clarkei*, is the most plentiful, and is also typical of this zone.

Near the close of this bed I have obtained the lowest trilobite remains, represented by portions of a *Cheirurus* and *Cromus*, found in the shales that towards the end, as they had done in the earlier part, began to interrupt the growth of the limestone for short intervals, before they finally superseded it.

In the Lower Tribolite bed the corals rapidly wane, and by the time the tribolites have reached their maximum, only a few *Cyathophyllum* remain. Crinoids are represented by numerous stems and cups of small size, Cystideans by plates, Cirripedes by *Turrilepas* of a large size. Brachiopods by *Othis biloba*, *Atrypa marginalis*, *Rhynchonella*, *Spirifera crispa*, *Discina*, *Leptæna*, *Lingula*, and *Pentamerus*. Gasteropoda are represented by *Pleurotomaria*, and *Euomphalus*, but both rare. Cephalopods by *Orthoceras*. Trilobites by *Encrinurus*, *Cromus*, *Calymene*, *Proetus*, *Bronteus Partschi*, and *B. longispinifex*, *Acidaspis Verneuili*, *Staurocephalus* near *S. Murchisoni*, *Sphærexochus mirus*, *Cyphaspis* and others, the number of species so far obtained being perhaps twenty-five. Ostracods by several species of *Entomis*, and Polyzoa by *Fenestella*, *Glauconome*, &c. It is worthy of note that in this bed also occurs *Phillipsastrea Verneuili*, which in Britain is a Devonian fossil. Sponges are represented by six-rayed spicules.

In the Middle Trilobite or Phacops bed, corals have dwindled down to a few genera of which the most prominent is probably a *Zaphrentis.* Crinoids are represented by stems, Brachiopoda chiefly by *Orthis* and *Leptæna.* One of the former is probably *O. testudinaria.* Gasteropoda by *Euomphalus*, and *Pleurotomaria.* Pteropoda by *Conularia.* Cephalopods by *Orthoceras.* The individuals belonging to any of these genera except *Orthis* and *Leptæna*, are poorly represented. Here, as in the previous bed, trilobites are the most characteristic feature. They are represented by five or six genera as follows :—*Phacops*, including probably *P. caudatus*, *P. longicaudatus* and *P. fecundus*, *Acidaspis* three or four species, *A. longispinns* and *A. Leonhardi* being among them. *Proetus bowningensis*, and *Cyphaspis.* The individuals belonging to the species of most of these genera were numerous ; but those of *P. caudatus* and *P. longicaudatus* were particularly so, and their remains form a large proportion of the rock constituting the bed.

Of the life in the Great Shale bed there is little to record. During the period taken for its formation many of the forms of life found in the preceding beds apparently became extinct and some new forms made their appearance. In the Upper Trilobite bed, the Brachiopods are represented by *Leptæna* ; Gasteropoda by *Murchisonia*, *Loxonema*, *Euomphalus*, *Bellerophon* and others. Lamellibranchs by several genera, making an approach to the Devonian. Pteropods by *Conularia.* Cephalopods by *Orthoceras.* Trilobites are represented by *Acidaspis longispinus* and *A. Leonhardi*, *Phacops caudatus* and *P. fecundus ?*, *Proetus*, *Cyphaspis Bowningensis*, and *Calymene Blumenbachii.*

The corals number two or three genera only, the most important being *Pleurodictyum.*

The general facies of this bed shows a rapid approach to the Devonian Group. The Brachiopods exhibit a great diminution both in genera and species, and on the other hand the Lamellibranchs have increased, a further evidence of the transition above referred to.

In the Upper Conglomerate bed, I have found corals representing a good many genera belonging to the limestone beds below, and some *Orthis*, *Rhynchonella*, and *Megalodon.*

In addition to the fossil above enumerated, I have obtained several graptolites from micaceous sandstones in the Lower Trilobite bed, on the eastern side of the syncline ; and in shaly sandstones on the western side, in the Great Shale bed.

From this brief outline it will be seen that there were four or five stages in which life flourished more vigorously in the Bowning series than in any others, and that the prevalence of life over the area was intermittent. This intermittency was much greater than would appear, simply from a perusal of this paper, for even in the beds I have represented as yielding fossils in greatest abundance, strata may be found in which none can be detected. The apparent total absence of life from the area while the formation of the Great Shale bed was in process, represents a long period even geologically; and on its re-appearance, a greater change than really seems to have occurred might reasonably have been expected.

Another noticeable feature in the fauna is the small number of *Spirifera*, and they, like the *Pentameri* are confined to the lower beds, chiefly the limestone and Lower Trilobite beds.

The representative fossils of the Bowning beds show a very suggestive parallelism in what may be termed typical forms, with the European Upper Silurian. This parallelism is the more remarkable, inasmuch as it occurs in beds situated in northern and southern hemispheres, and in latitudes nearly the same. These latitudes too, must then, as now, have been separated by a different climatic zone.

CAVE FLAT OR GOODRADIGBEE BEDS.*

Immediately westward of the Bowning beds, the Cave Flat or Goodradigbee beds are met with. As far as I have been able to ascertain, they are not separated from the Bowning beds by any intrusion of eruptive rocks. Their united thickness seems to be much greater than that of the Bowning beds. They consist of slates, shales, sandstones, and conglomerates, with a very large bed of limestone, which is separable into two parts. The character of the shales and conglomerates differ widely from those in the Bowning series. In colour the former are violet, reddish, and greenish-brown, and mottled. The conglomerates are composed of finer particles, and therefore present a less shore structure.

The strike and dip agree with that in the Bowning Beds. The latter, in some parts is almost perpendicular, and at Cave Flat ranges from 40° to 63° in the Limestone bed.

Life.—The great mass of these beds below the limestone has yielded no fossils. From a sandstone or hardened shale immediately below the limestone at Cave Flat I have obtained a *Lingula* and some Gasteropods.

The limetone is rich in corals, some at least resembling the form in the Bowning limestone. The Brachiopods are specifically very different. Most of the Bowning forms, and this is especially

*To these beds the term "Murrumbidgee Beds" has been applied, but this appellation seems to me inapplicable, as the Murrumbidgee flows over so many beds, and therefore renders the term too indefinite.

the case with the Spirifers, which in these beds are represented by many species, while in the Bowning Beds there are few. *Rhynchonellæ* are plentiful, and *Atrypa* is well represented by numerous individuals of at least one species; but the familiar *A. reticularis* and *A. marginalis* have not been unearthed. Gasteropods are represented by large and small *Murchisonia.*

From a collection of fossils from the Cave Flat Limestone, in the Australian Museum, and collected by Mr. C. Jenkins, L.S. of Yass, Mr. Felix Ratte has identified the jaw of a fish, and some forms collected by myself resemble fragments of a *Coccosteus.*

The general facies of the life has led to the conclusion that they are of Devonian age; but it remains yet to be proven whether they follow or are contemporaneous with the Bowning beds. From a thin band of shale at the base of the greater limestone bed I obtained a trilobite, belonging to the genus *Cromus*, and apparently identical with one in the Bowning beds and which I have never found above the Lower Trilobite bed of that formation. This of itself is not of much consequence, but nevertheless suggests the possibility of contemporaneity of the two series.

One of the most interesting features of the Cave Flat beds, is the numerous and large caves in the limestones. Some of them contain bone beds of considerable extent. In the case of two at least, this was clearly proved in June last by Mr. R. Etheridge and myself, during a few days exploration.

2.—NOTES ON CERTAIN BOULDERS MET WITH IN THE BEDS AND REEFS OF THE GYMPIE GOLD-FIELD, QUEENSLAND.

By William H. Rands, F.G.S., of the Geological Survey of Queensland.

In the course of a Geological Survey of the Gympie Goldfield, I have several times noticed the occurrence, in a fine shale, of isolated boulders of considerable size, which will form the subject of these notes.

Short descriptions of the Geology of this field have been written by the late Mr. C. D'O. H. Aplin, Hon. A. C. Gregory, and more lately by my colleague Mr. R. L. Jack;* it will be sufficient, therefore, if I here state that the auriferous strata consist chiefly

* Report of the the Government Geologist for Southern Queensland (C. D'Oyly H. Aplin), Brisbane. By authority, 1868. Report on the Geology of the Wide Bay and Burnett Districts by A. C. Gregory, Brisbane. By authority, 1875. Progress Report for 1885, by R. L. Jack, Government Geologist, Brisbane. By authority, 1886.

of limestones, black and grey pyritous shales, sandstones, greywackes, grits, and conglomerates, interbedded with these are rocks of volcanic origin, some of the above having undergone considerable alteration. In all, there are about 2,020 feet in thickness of the auriferous strata, which lie with great regularity dipping to the east.

A large number of fossils have been collected from these beds by Mr. Jack and myself, which were sent to Mr. Robert Etheridge, Junr,, for examination, who pronounced them to be homotoxia with the Carbonifero-Permian.

There are four distinct zones of black shale, or "slate" as it is locally termed, and the reefs, as a rule, are payable only when in contact with these shales. It is in the upper of these beds, which is about 200 feet thick, that the boulders referred to occur. The bed consists of a fine black pyritous aluminous shale.

The boulders are not very numerous, nor do they appear to have been distributed generally over the field, as it is only in a few mines that I have noticed them.

I will describe two of these boulders, as instances :—One from the No. 1 North Phœnix Mine, at a depth of three hundred and seventy feet, consisted of a fine-grained siliceous rock—a siliceous greywacke. It was found about the middle of the bed, at a point where the shales had, for a foot or two in thickness, passed into what might be more properly called a fine aluminous sandstone. The boulder was flat and smooth, its dimensions being 13 inches × $10\frac{3}{4}$ inches × 5 inches.

In the Phœnix Golden Pile Mine at the 700 feet level, several boulders were met with in driving a cross-cut in the shale; they consisted of a coarse altered greywacke, containing ill-defined crystals of felspar, and cubical and pyramidal crystals of iron pyrites. The largest of these was broken in two; the dimensions of the part preserved were $3\frac{1}{4}$ inches × $5\frac{1}{2}$ inches × $4\frac{1}{4}$ inches, the length of boulder must originally have been at least double that, making it $3\frac{1}{4}$ inches × $5\frac{1}{2}$ inches × $8\frac{1}{2}$ inches. These were in fine laminated pyritous shales.

It is difficult to say where these boulders have come from, or how far they may have travelled, for although greywackes similar to those of which they are composed are found among the rocks on the field itself, they are also common throughout the whole of the Devonian and Lower Carboniferous rocks which occupy a large area in this district

The presence of boulders of such size, in a rock which was originally a fine mud or silt, would seem to indicate that glacial conditions existed at the time the Gympic rocks were being deposited, they having been dropped from floating ground-ice; I should, however, state that I have not found a single instance of the boulders being grooved or striated, they are usually rounded and smooth.

The only other explanation, I can see, that would account for their occurrence, is that they may have fallen from the roots of floating trees.

A granite boulder was found on the foot-wall of the O'Connell Reef in the O'Connell Prospecting Claim at a depth of two hundred and forty feet. A portion of the boulder was given to me, and its position described by the manager, who was present when it was taken out.

The stone consists of a coarse-grained pink granite, composed of pink orthoclase, large clear blocks of quartz, and a little decomposed mica. Judging from the curve of the fragment in my possession, the boulder must have been at least seven and a-half inches in diameter; it was smooth and rounded. This is the only instance of a granite rock being found anywhere in the neighbourhood of the field. The nearest granite, *in situ*, to my knowledge, is that of the Black Snake Range, situated about twenty miles west of Gympie; the boulder, however, has probably travelled a greater distance than that, as the granite of the range is different in character to that of which the boulder is composed.

The question arises, how did it come into that position? In the first place, the fissure of the reef must have remained open, for some time, sufficiently to allow of the introduction of a stone of that size down to the depth at which it was found (240 feet). It would appear, too, that the land at the time must have been submerged, for had it been conveyed there by a land stream, the open fissure in the reef would have been entirely filled with boulders and silt carried along by it. I therefore have come to the conclusion that it was conveyed, and dropped, probably, from floating-ice, into its position, and while perhaps other blocks of similar rock were dropped on to the floor of the sea, and have since been removed by denudation (which the presence of large faults on the field shews it must have been very great), this one which happened to enter the fissure has been preserved.

Mr. Jack in his Report on the Bowen River Coalfield speaks of the occurrence of large isolated boulders of granite, &c., in the midst of strata composed of fine sandy or muddy material, for which he can see no other explanation than floating-ice; and it is possible that this boulder may have been deposited at the time the coast country was submerged, and that the Bowen River, Burrum, and the other Palæozoic Coal Measures were being formed.

3.—ON METAMORPHISM AND THE ROCKS OF THE BATHURST DISTRICT.

By W. J. Clunies Ross, B.Sc., F.G.S.

[*Abstract*].

The paper was in two parts. The first dealt with some of the problems of Modern Geology, and pointed out the uncertainty as to the origin of many Metamorphic rocks and the vagueness with which terms are used in reference to rocks. Suggestions were made as to the direction in which investigations might be made. The second part contained a brief description of some of the rocks found in the Bathurst District. The rock on which Bathurst itself stands was described, and also the drifts of the neighbourhood. The Metamorphic rocks of the district were alluded to, and the alterations which some of the fossiliferous rocks have undergone described. The rocks in the neighbourhood of the Sunny Corner Mine were also dealt with.

4.—ON THE ADVISABILITY OF ESTABLISHING AN ASSOCIATION OF MINING ENGINEERS IN NEW SOUTH WALES.

By Felix Ratte, Ing., Arts et Manuf., Paris, of the Australian Museum, Sydney.

5.—ON THE DISCOVERY OF FOSSILS AT ROCKHAMPTON.

By James Smith, of Rockhampton.

[*Abstract.*]

In a lengthy communication the author described various localities in the neighbourhood of Rockhampton, where fossil organic remains had been found by him. These are of three ages—Permo-Carboniferous, Mesozoic, and Post-Tertiary, and extend over an area of three hundred miles by forty. " from the sea to the Drummond Range."

Permo-Carboniferous.—The oldest formation is a succession of thin variegated shales, much tilted and metamorphosed, forming the Athelstane Range, a long ridge running diagonally through the municipality of Rockhampton. The fossils are much broken up, but casts of crinoid stems are recognisable, with Zaphrentoid

corals, *Orthis resupinata*, Martin, Fucoid remains, and fragments of *Spirifera*, *Loxonema*, *Platyschisma*, &c. In the Lake's Creek beds, four miles down the north bank of the Fitzroy River, the author refers to an indurated pyritous shale containing large *Producti*, *Aviculopecten multiradiatus*, *Protoretepora ampla*, Lonsd., *Fenestella fossula*, Lonsd., with numerous Brachiopods and other shells. This is the great fossil producing series of the district.

At Neerkol, in the Stanwell district, similar beds occur teeming with an extraordinery abundance of Polyzoa, chiefly *Protoretepora* and *Fenestella*.

The Lower Training Wall quarries, about ten miles from Rockhampton, on the Fitzroy River have yielded *Euomphalus*, *Goniatites striatus*, Sby., and traces of corals. The shales here are much hardened and indurated. At Gracemere Ridges, six miles west of Rockhampton, *Orthis resupinata*, Martin, *Strophomena depressa*, &c., have been met with. Blaenavon, near Lilymere, yields fine crinoidal marble, which is distinguished by *Myriolithes queenslandensis*, *Retzia lilymerensis*, *Pleurotomaria Strzeleckiana*, and *Polyzoa*.

One of the most important localities, from the number of recognisable species found there is Encrinite Creek, and contiguous localities, thirteen miles west of Rockhampton. Here have been obtained *Poteriocrinus Smithii*, *Poteriocrinus crassus?* *Protoretepora ampla*, *Rhombopora laxa*, *Fenestella internata*, *Polypora? Smithii*, *Productus brachythærus*, *Chonetes*, and others. The polyzoa are very marked and exemplify the abundance with which this class occur in the Queensland series. The Building Stone Quarry, at Stanwell, may be noted as yielding some peculiar vertical pipings resembling the genus *Arenicolites*.

Other localities yielding fossils of Permo-Carboniferous age are Stanwell Creek, from Fairy Bower to Mount Gordon the fossils being contained in boulders; Kooingal; and lastly the Mount Morgan district. The fossils from the latter, although not fully determined, evidently show that at least some of the surrounding rocks are of Permo-Carboniferous age. Fossil wood is found in the Stanwell building stone, and at Mount Sanderson, Stanwell.

Mesozoic—Mr. Smith records two localities in the Rockhampton district yielding Mesozoic plants. Wycarbah, twenty-four miles west of Rockhampton, and Stewart's Creek, Stanwell. In the much altered rock at the former the leaves of a Cycad, *Ptilophyllum obligoneurum* are plentifully met with. At the latter locality, an earthy ironstone contains plentiful remains of *Tæniopteris* and other ferns.

Post-Tertiary—The paper concluded by a brief description of Olsen's Caves, and a long list of fossils from the stalagmite is given, including the shells of *Helix*, *Pupa*, *Bulimus*, and the bones of Marsupials.

6.—HOW FAR CAN AUSTRALIAN GEOLOGISTS SAFELY RELY UPON THE ORDER OF SUCCESSION OF THE CHARACTERISTIC GENERA OF FOSSIL PLANTS OF A FAR DISTANT REGION, IN THE DETERMINATION OF THE ORDER AND RELATIONSHIP OF AUSTRALIAN TERRESTRIAL FORMATIONS?

By R. M. Johnston, F.L.S., Government Statician, Tasmania.

To Australian geologists, the question proposed at the head of this paper is of the very deepest importance. Hitherto, questions relating to the order and relationship of Australian rocks have been, in a very large measure, influenced by the opinions of eminent Palæontologists, formed mainly upon deductions made with respect to the order of the appearance of certain genera in Europe, or in far distant regions.

I wish it to be taken for granted in criticising some of their conclusions, that I yield to no one in esteem for their valuable labours. Happily for me, the question upon which I may have to express any widely different opinion is not one affecting the exact determination or classification of the organisms themselves. The question which I propose to confine attention to does not raise doubt as regards the determination, or affinities of the plants characteristic of particular rocks, Although, even in such matters, there are many obscure points from which difficulties may arise.

The question here discussed is of quite a different nature, and may be expressed as follows:—How far does the assemblage of the characteristic genera of a particular formation in a distant region (say Europe) afford a clue to the proper determination of the stratigraphical position and relationship of Australian rocks? The belief that the community or resemblance of organic remains in rocks of different regions indicates strict contemporaneity—once so prevalent amongst Palæontologists—is not yet dead, although the recent utterances of a few leading authorities show that such a belief is no longer tenable.

Geikie for example, states in his last work* that "similarity or identity of fossils among formations geographically far apart, instead of proving contemporaneity may be compatible with great discrepancies in the relative epochs of deposition."

* Text Book of Geology, p. 619.

So far there is complete accord, but when the same author goes on to describe the difference between *homotaxial* and *contemporaneous* relationship of rocks of different countries he makes use of an ambiguous phrase, which cannot be accepted without much qualification. He states, "In fine, in every country where the fossiliferous geological formations are well displayed, and have been properly examined, the *same general order of organic succession can be made out among them.* Their relative age within a limited geographical area can be demonstrated by the law of superposition. When, however, the formations of distant countries are compared, all that we can safely affirm regarding them is that those *containing the same, or a representative assemblage of organic remains belong to the same epoch in the history of biological progress* in each area. They are *homotaxial;* but we cannot assert that they are contemporaneous, unless we are prepared to include within that term a vague period of many thousand years." The value of this statement entirely depends upon what may be deemed to be the true meaning of the phrase "*containing the same, or a representative assemblage of organic remains.*" Does it mean such close relationship embracing not merely a characteristic assemblage of genera, but also complete identity as regards the principal characteristic species of each genus of the assemblage?; or, does it mean a similar assemblage of organisms identical so far as the genera are concerned, but differing with respect to the number and identity of their respective species? Upon the answer to these two queries depends the possibility of accepting Dr. Geikie's statement.

Where in the rocks of two regions far apart, both genera and their species are absolutely identical within a very large and characteristic assemblage, there would *prima facie* be good grounds for classing *homotaxial* relationship; and consequently it might be allowed that the formations in which this identical assemblage of organisms occurred, belonged to the same great epoch; but if the characteristic assemblage, however great, only involved identity so far as genera are concerned, it would not of itself form sufficient evidence to prove either homotaxis or contemporaneity; for such an assemblage of particular genera might possibly occur in inverted order in rocks of widely separated regions belonging to different great epochs or systems.

It is but right to state that this is partly admitted by Dr. Geikie, for, in the same work, (p. 619) he observes:—"A species may have disappeared from its primeval birthplace, while it continued to flourish in one or more directions in its outward circle of advance. The date of the first appearance and final extinction of that species would thus differ widely according to the locality at which we might examine its remains." And again he clearly announces this view by observation.

"At the present day for example, the higher fauna of Australia is more nearly akin to that which flourished in Europe far back in Mesozoic time, than to the living fauna of any other region of the globe. There seems also to be now sufficient evidence to warrant the assertion that the progress of terrestrial vegetation has at some geological periods, and in some regions been in advance of that of the marine fauna. And among such examples we mention that the "Cretaceous flora of Aix la Chapelle with its numerous dicolytedons has a much more modern aspect than the contemporaneous fauna." But while such clear thinking writers as Dr. Geikie allow all that is necessary in the restrictions to be placed upon the phrase "community," or "general facies of organic remains in common," there is good reason to fear that many Geologists and Palæontologists, in dealing with fragmentary collections of plants from widely separate regions, still perpetuate in their mode of reasoning ancient fallacies, some of which have been referred to by Prof. Huxley in "Lay Sermons."*

Examples of two of these fallacies are as follows :—

(1) "Animals and plants began their existence together not long after the commencement of the deposition of the sedimentary rocks; and then succeeded one another in such a manner that totally distinct faunas and floras occupied the whole surface of the earth, one after the other, and during distinct epochs of time."

(2) "The population of the earth's surface was at first very similar in all parts, and only from the middle of the Tertiary epoch onwards, began to show a distinct distribution in zones."

(3) In the latest edition of Prestwich's "Geology," Prof. Prestwich, in discussing geological equivalence has made a great advance in his treatment of the great problem of stratigraphical geology. But while he insists that in distant areas, strata cannot be correlated by identical *species*, and although acknowledging to some extent the effects of migration of forms of life from one region to another, he still clings to the idea that rocks of distant regions may be properly correlated by the aid of "the presence of *the same characteristic genera*." But it must be borne in mind that English geologists have not had this aspect of the question pressed home so closely to them in a practical way; for unlike Australian workers, they have not been hampered in their schemes of local classification by references or dependence upon the widely differing association with respect to the stratigraphy and palæontology of a far distant region.

If English geologists had now to form afresh their Systems and subdivisions of Systems upon the lines laid down by Professor Prestwich, with strict dependence upon the evidence of the association of Australasian stratigraphy and palæontology, the

* Geological Contemporaneity, p. 228.

difficulties of the matter would have at once become apparent to them, as it now appears to Australian geologists, in attempting to correlate their rocks with European equivalents.

In further opposition to some of the statements objected to, we have to look at the following facts :—

(1) Among the prevailing genera of plants in the Carboniferous beds of Europe, are *Alethopteris*, *Neuropteris*, *Odontopteris*, *Pecopteris*, *Sphenopteris*, *Tæniopteris*, *Danæa*, *Ulodendron*, *Poacordaites.* Eight out of the nine genera also prevail in the Mesozoic rocks of Tasmania, while not one of them is present among the coal plants of the Carboniferous rocks of the same region !

(2) The most abundant and typical genus of plants in the Carboniferous rocks of Tasmania and Australia, is a *Glossopteris* (several species). The genus is not represented in the rocks of the same age in Europe, but a representation sparingly occurs in the Upper Mesozoic beds of that region.

(3) The genera *Phyllotheca*, *Podozamites*, *Pterophyllum*, *Salisburia*, *Ginkgophyllum*, *Baiera*, *Zeugophyllites*, *Sagenopteris*, *Thinnfeldia*, *Rhacophyllum*, are very characteristic in what is deemed, on the evidence of local stratigraphic succession, to be the lowest division of the Mesozoic rocks of Tasmania. Seven of these are equally characteristic of the middle or upper division of the Mesozoic rocks of Europe.

(4) The fauna and flora of the Tertiary period in Europe, are in many important respects more akin to the existing floras and faunas of Australia and Tasmania than are the existing floras and faunas of both regions ; and conversely :—

(5) The flora of the Tertiary period in Australia and Tasmania is in many important respects more akin to the existing flora of Europe than are the existing floras of these distant regions.

Many other striking examples, unmistakeable in their character and in the order of their appearance, might be cited to prove :—

That the order of the appearance of genera or other affinities in plants in the strata of any one region, affords no reliable clue to the order in which plants of similar genera or other affinity make their appearance in the strata of far distant regions ; and that the known history of the order of appearance of characteristic genera of plants in Australasia and Europe, leads us to expect that inversion of the order after an epoch of interval is more likely to occur, than homotaxial, harmonious, and progressive parallelism.

If these considerations are admitted, and I do not see how they can be disputed from facts, it follows that theories of the succession of rocks in Australia and of their relationship with the known subdivisions of far distant regions, based upon the study of the order of appearance and generic affinities with fossil plants of these distant regions, must inevitably lead to error and confusion, as it has done in the past.*

In further support of these statements I have prepared a comparative table (Pl. XVII.) showing approximately the order of the appearance of characteristic genera of plants in Europe and Tasmania, the latter closely corresponding to the order in Australia. If we examine this table carefully we are compelled to admit the following conclusions:—

(1) That similarity in the characteristic genera, solely of the rocks of two far distant regions, forms *primâ facie* evidence,—not of their correspondence as regards contemporaneity or homotaxis or parallelism of biological, or stratigraphic progression—but of the reverse of these.

(2) That such gaps, inversions, and lack of parallelism in the biological progression in separate far distant regions, supports the Darwinian hypothesis of single specific centres of origin; for if plant life passed through similar stages of development from similar independent specific pairs in every region of the earth, beginning at the same homotaxial stage, we should certainly fail to find such gaps, inversions, and lack of parallelism in biological progression, as those referred to in the table of comparative order of the appearance of plant life in Europe and Australasia.

The only reasonable conclusions to be drawn from these considerations are such as have already been advocated by the author in a paper read before the Royal Society of Tasmania in the year 1886,† viz:—

(1) It is most probable that all the higher specific forms of life, including even those of the known genera of ferns, sprung from one centre and from one pair.

(2) It is improbable that all species had their origin in one particular hemisphere, but rather:—

(3) It is probable that some species originated in the Northern Hemisphere, while others had their origin in the Southern.

(4) It is reasonable to assume where species or genera have spread from the centre of origin, or from a subsequent station to another hemisphere, that a very considerable period of time may have elapsed.

(5) Where such world-wide destribution of forms has taken place, it is perfectly admissible to conceive that the particular assemblage of organisms in any point or division of a vertical series in either hemisphere, would embrace forms some of which originated locally within the age of the system of formation, while other were immigrants from an opposite hemisphere, dating their original appearance on the globe in a former epoch among

* See the controversy regarding the age of the *Glossopteris*-bearing beds of N.S. Wales.
† Papers and Proc. R. Soc. Tas. 1886, pp. 164-182.

associates differing widely in character from those met with in the last station reached by them, in their long process of migration.

For my own part, I do not see what other explanation can be given which would satisfactorily account for the gaps, inversions, and lack of biological progression in any one regional centre, when viewed in relation to the order and grouping of organism in far distant regions.

The acceptance of separate centres of specific origin from one independent pair in conjunction with time consumed in migration, does of necessity involve such inharmonious relationships, when the view is restricted to any one spot on the earth's surface; but it is perfectly compatable with orderly relative biological progression when concerned in relation to all centres, of the globe.

Let it be firmly borne in mind that the principles contained in these reflections are neither new nor fanciful. They flow naturally and consistently from conceptions regarding the doctrine of single specific centres, firmly held and advocated by Sir Henry De la Beche nearly fifty years ago. Edward Forbes, according to Huxley, firmly held to this view, for he was in the habit of asserting that the similarity of the organic contents of distant formations was *primâ facia* evidence, not of their similarity, but of their difference of age, and Huxley himself, whose name is always associated with Darwin, has long devoted his clear reasoning mind to establish the same ideas. Similarly, the writings of Sir Roderick Murchison, Jukes, Blandford, Ettingshausen, Starkey Gardner, Feistmantel, Daintree, Prof. Hutton, Prof. Judd, and many others could furnish strong support in favour of the conceptions now brought specially under the consideration of this Association for the purpose of evoking discussion.

In making use of the phrases "stages of biological progression," and "stages of stratigraphic succession," there is also much danger.

We can conceive of the development of the lower to the higher formsof life occ urring in a broad harmonius order as under :—

	1.	2.	3.	4
Plants—	Thallogens.	Ferns, Mosses, and Lycopods.	Cycads, and Conifers.	Angiosperms.

	Invertebrates.		*Vertebrates.*	
Animals—	Protozoa;	Molluscs, etc.	Gill-breathers;	Lung-breathers.

Whatever gaps are found in the simple series, it is conceivable that the order might be found without inversion in all regions, and so far it is possible for stages of stratigraphic succession being recognised, which would in any country, broadly correspond with such stages of biological progression. But if the correspondence between orderly biological progression, and orderly strategraphic succession, is expected to coincide in regions far apart, beyond these general lines I am convinced the results would be anomalous and confusing. To expect this would pre-suppose that organic development went on at a corresponding rate with *time*, no matter how the local environment was conditioned. This would be expecting too much, and hence I am of opinion that even homotaxial relationships, based upon relative biological progression, must be received with the greatest caution when dealing with the comparison of rocks of widely separated regions. However unpleasant it may be to relinquish convenient time-honoured methods, it must be allowed that in science as in morals, the desire to have them *true* is preferable to the desire to have them *sustained.* In science as in religion, our reverence for the great names of a past age exerts a powerful enslaving influence, tending almost as powerfully to induce us to bolster up uneliminated error, as to sustain and expand the great truths which were originally unfolded. If on the one hand, as recently pointed out by Prof. Judd, there is danger that impatience at the rate of progress of geological knowledge, leads many to attempt "to cut the tangled skein of research by hasty and ill-considered speculation," there is an equal, if not a greater danger, with others, to become enslaved to time honoured generalizations based originally upon limited observation; a tendency moreover which often causes many to overlook the express limitations of the earlier authorities.

Generalisations which may be of much value within certain limits, may be absolutely false, and widely misleading, when applied beyond the limits originally ordained. Thus, as pointed out thirty-four years ago by Sir Roderick Murchison,* "however, certain distinctions may be clear and good in typical tracts of Siluria and Wales, there are many parts even of the British Isles, and numberless foreign localities, where separation into the formation of Llandeilo and Caradoc is absolutely impracticable either by mineral distinctions or by dislocations," and accordingly he announced his conviction then—a conviction, by the way, of the fullest signification to Australian geologists—"that in many regions of the earth, the geologist will find it impossible to classify by the means of such smaller divisions."

If these facts be duly weighed we may well ask:—Of what value is any classification of Australian rocks which follows too slavishly the nomenclature of the sub-divisions of great Periods or Systems as adopted in Europe upon the mere evidence of two or three genera whose association in the rocks of a particular horizon in Europe has been proved to be only of local value?

It is also of the greatest significance that Prof. Judd admits this in his recent interesting articles in "Nature."† He distinctly affirms that recent knowledge indicates that "attempts to establish a universal system of nomenclature or classification of sedimentary

* Siluria, p. 51.
† The Relations between Geology and the Biological Sciences, *Nature*, March 1, 1888.

rocks are indeed greatly to be deprecated, for if the zoological and botanical distribution of past geological times were at all comparable to that of the present day any such universal system *must be impossible.*" The italics are mine.

Moreover, the generic groupings of the flora and fauna of any one region, as in Australia, often affords in themselves contradictory evidence, when comparisons with distant regions are attempted on the lines laid down by Prof. Prestwich, viz: "*the presence of the same characteristic genera.*" Thus, in the Upper Palæozoic division, out of a list of three hundred and eleven species of marine organisms in Australasia, there are fully twenty-three per cent. specifically identical with those of the Carboniferous marine beds of Europe; while the typical plants associated with the Carboniferous marine beds in Australasia do not show the faintest correspondence with the corresponding typical plants of Europe. Both species and genera are altogether different.* This also is borne out by Prof. Judd's† statement that "the growth of our knowledge concerning the terrestial floras and faunas of ancient geological periods since 1869 has constantly forced upon the minds of many geologists the necessity of a duplicate classification of geological periods based on the study of marine and terrestial organisms respectively." I do not, however, think that a "*duplicate classification*" would be of much value. The evidence rather points to the conclusion that the assemblage of typical organisms of any one region, owing to the inter-weaving at any one point of emigrants from many independent distant centres of origin, *affords no satisfactory clue to the order, relationship, or succession of the strata of a distant region.*

It is, however, a great satisfaction to me to know that the main contention upheld in my paper to the Royal Society of Tasmania, in October, 1886,* has the support of such a distinguished observer as Prof. Judd.

There is, it appears to me, no royal road for establishing the relationship of the rocks of opposite hemispheres. We must be content to work out the true association of local stratigraphy and local biology unimpeded by references to such associates elsewhere. In short we must establish the relationship between the successive formations and their contained fossil remains exactly on the lines begun by the great English pioneer, William Smith, and we must not, in our eagerness for geological progress, expect to establish at once in Australasia such close harmonious relationships as have been determined in Europe by the accumulated labours of several generations of distinguished workers.

Slightly altering a phrase used by Prof. Huxley, I am of opinion—"All that *Palæontology* can prove is *local order of succession,*" and

* See Table (Pl. xvii.)
† *Loc. cit.* p. 427.

therefore the work before the Australian geologist, however slow in progress, will be more satisfactorily advanced if we stick close to the evidences afforded by the unmistakable observed order of succession of local stratigraphy in the *first* place; and *afterwards*, by carefully observing the nature of the contained fossils in each succeeding horizon, gradually build up the *locally true order of biological succession.* The dependence upon the succession of rocks of distant regions, as based upon the affinities of organic remains, though temptingly convenient, must assuredly prove to be a Will-o'-the-Wisp chase leading to geological disaster.

The order of biological progression depends largely upon local external conditions, and unless we assume what is impossible, that environment varies in every separate region at the same time and in the same degree, the rate of biological variation or development must almost of necessity vary with the locality.

This helps to explain the greater differences exhibited by the contemporary floras of two widely separated regions, than is shown by the contemporary faunas of the same regions.

As already suggested by me,* the closer parallelism between the marine remains of two widely separated regions is probably due to the greater facilities for more rapid diffusion of types among the marine inhabitants of a continuous sea, as compared with the slower diffusion of terrestrial organisms, barred as it must often have been by wide tracts of sea, and other physical obstructions. This conclusion is borne out by the illustrious Darwin,* who states, "The process of diffusion would often be very slow, depending on climatal and geographical changes, on strange accidents, and on the gradual acclimitisation of new species to the various climates through which they might have to pass, but in the course of time the dominant forms would generally succeed in spreading and would ultimately prevail. The diffusion would, it is probable, be slower with the terrestrial inhabitants of distinct continents, than with the marine inhabitants of the continuous sea. We might therefore expect to find, as we do find, a less strict degree of parallelism in the succession of the productions of the land, than with those of the sea."

In summing up the various considerations touched upon in this paper, I anticipate your verdict will be, that Australian geologists cannot safely rely upon the order of succession of the characteristic genera of fossil plants of a far distant region in the determination of the order and relationship of Australian terrestrial formations; and that even within its own wide borders, covering an area nearly equal to that of the whole of Europe, considerable differences may be expected in the biology and minor subdivision of systems, as developed in some of its widely separated colonies.

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* Papers and Proc. R. Soc. Tas. 1886, p. 166.
† Origin of Species, pp. 229-230.

Ideal Distribution of Genera from independent or widely-separated geographical centres.

On the hypotheses that all organic genera did not arise and radiate repeatedly from one geographical centre only, and that a considerable space of time would be consumed in the greater extremes of distribution as regards terrestrial plants of higher organisation, a diagram has been designed,* roughly to illustrate the possible complication and inversion of order arising out of the radiating distribution of genera from widely-separated centres; and also illustrating the different nature of the possible associates to be met with at different stations should the survivals succeed in reaching a middle station or the antipodes of the place of their generic origin.

The cross dotted lines indicate the possible lapse of geological time between the commencement and close of the migration of each genus, and also the curious interweaving of different genera which originated in centres widely apart.

*Papers and Proc. R. Soc. Tas. 1886, p. 182 (to face).

Section D.—BIOLOGY.

President of the Section: Ralph Tate, F.L.S., F.G.S., Professor of Natural Science in the University of Adelaide.

Wednesday, August 29.

The President delivered the following Address:—

ON THE INFLUENCE OF PHYSIOGRAPHIC CHANGES IN THE DISTRIBUTION OF LIFE IN AUSTRALIA.

Custom has sanctioned for occasions like the present, a review of the history of the progress of our knowledge on some branch of study, or an exposition of marked advances in some line of research, but it has also permitted a broad and comprehensive survey of a phenomenon, or group of phenomena, which summarises results rather than submits details of proof. To conform with usage and to confine myself within the limits of our Science have been difficulties that were not discovered till too late to withdraw from my position; however, my theme, "The Influence of Physiographic Changes in the Distribution of Life in Australia," fulfils the prescribed conditions, but how far my treatment of the subject comes up to the requirements expected from the occupant of this Chair is for you to judge. The subject especially concerns us as biologists in Australia; and it moreover admits of development on so many subordinate lines of investigation, that I am hopeful to awaken some little enthusiasm in respect of it.

I have partly been led to this selection through the following statement made by Baron Sir F. von Mueller:—"To draw the species into physiographic and regional complexes must be the work of future periods, when climatic and geologic circumstances throughout Australia shall have become more extensively known."* I propose to make a beginning in the direction indicated by the foregoing citation, which of necessity concerns the geologist equally well as the botanist; believing, that however crude and imperfect our first efforts may be, they may nevertheless incite to further enquiry into all the circumstances involved and thereby advance to the attainment of our object more rapidly than if we permit the subject to be dormant until the said circumstances have been fully mastered independently.

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*Systematic Census of Australian Plants, 1882, p. 8.

By way of introduction I have to traverse ground that has been substantially prepared, which may be summarised briefly as follows :—

The flora of Australia consists of the following constituent elements :—

I.—An immigrant portion, derived from at least two separate sources.

(a) Oriental, which is dominant in the littoral tracts of tropical Australia ; but despite the large assemblage of Asiatic species, the Australian character is deeply impressed by numbers, specifically and individually, of *Eucalyptus*, *Grevillea*, Phyllodineous *Acacia*, and others.

(b) Andean (including also certain species of the cool and temporate regions of the North Hemisphere). For the most part this type of vegetation is restricted to the high mountains of Tasmania, Victoria and New South Wales. The peculiarity of the Tasmanian flora is only in its alpine types.

II.—An endemic portion, a localised type of which occupies the extreme south-west of the continent.

It is conceded that the large and varied flora of the south-west, specifically, almost totally so, and largely generically different, implies long continued isolation. Much speculation has been indulged in as to the physical causes which have brought about and maintained that isolation. The whole question, seems to me, to resolve itself to this :—Is there independent of the peculiarities of the distribution of the flora, and incidentally of the fauna, any evidences of alteration in our continental physiography which may account for the biological phenomena. I answer, yes !

The chief factors influencing the geographic distribution of plants are those of temperature and moisture, because they are indispensable ; of the two, so far as Australia is concerned the latter is by very far the more important. Petrological conditions are of secondary value only, though giving rise within limited areas to great floral contrasts ; this is exhibited on a rather extensive scale by the vegetation of tropical South Australia. If we pass from the coast inland in a southerly direction, a very abrupt change is encountered on gaining the escarpment which terminates the plateau of the Desert Sandstone. In the basin of the rivers of Arnheim Land, we have a retentive soil and copious rainfall contrasting with the highly absorbent soil and diminished rainfall of the Table-land ; it is to the superior hygrometric property of the soil of the latter, rather than to any chemical properties of the formation, that is due the great differences in the floral productions. In the same region, there occur basaltic patches, which also have certain distinctive botanical features, as pointed out by Baron Sir F. von Mueller as far back as 1855.

From lists of species of tropical South Australia, which I have compiled and drawn up according to the occurrences within the area of the northern rivers, and on the table land and its southern extension, I present a few summarisations.

Total Species—1,405; in Arnheim Land 1,221, 780 of which, or 63.9 per cent. are endemic; in the Table-land 614, of which 491, or 80 per cent. are endemic.

Sequence of the orders according to the number of species:—

Arnheim Land. Orders.	No. Species.	Table Land. Orders.	No. Species.
Leguminosæ...	158	Leguminosæ...	102
Gramineæ	106	Gramineæ	54
Cyperaceæ	87	Myrtaceæ	33
Euphorbiaceæ	54	Compositæ	30
Myrtaceæ	43	Cyperaceæ	25
Compositæ	35	Amarantaceæ	26
Rubiaceæ	32	Goodeniaceæ	24
Convolvulaceæ	30	Malvaceæ	22
Filices	26	Convolvulaceæ	19
Malvaceæ	23	Proteaceæ	16
Urticaceæ	20	Boragineæ	13
Amarantaceæ	20	Scrophularineæ	12
Tiliaceæ	19	Sterculiaceæ	11
Asclepiadeæ	19	Chenopodiaceæ	11
Proteaceæ	18	Rubiaceæ	10
Sterculiaceæ	16	Euphorbiaceæ	10
Boragineæ	16	Myoporineæ	9
Verbenaceæ...	14	Tiliaceæ	8
Goodeniaceæ	14	Verbenaceæ	8

On proceeding from the coast line towards the interior of the Continent, the following phytographic characteristics are observable:—The littoral region in its lower level is a savana, that is timbered grass-lands, and in its higher level is sylvan or forest-land; as we pass inland the timber growth on both zones becomes less and less, one species after another altogether ceasing; and finally a grass growth with some shrubs dominate the surface. Beyond this latter belt, the vegetation is strikingly dissimilar, and shrubby salsolaceous plants, Eremophilas and Cassias are in the ascendant in this so-called "salt-bush" country. This variation in the botany is co-ordinate with a decreasing rainfall, and though there is no line of demarcation between one type and another, yet in certain localities the transition is rapidly coincident with an abrupt diminution in the rainfall as a consequence of some physiographic conformation, such as a mountain range trending transversely to the direction of the prevailing wind, and bounded on its inner side by a depressed area.

The vegetation of the salt-bush country presents such contrasts with the other Australian floras, and has originated through distinct climatic causes, that it may well be studied *sui generis*. I will divide the Australian Endemic Flora into three types, to which for convenience of reference I apply distinctive names. (Pl. XVIII.)

1. Euronotian (lit. south-east wind) dominant in the south and east parts of the Continent.

2. Autochthonian (lit. of the original race) restricted to the south-west corner of West Australia, and approximately coinciding with the rain-fall limit of twenty inches.

3. Eremian (lit. desert) dominant in the dry region, which has its centre in the Lake Eyre Basin. It corresponds with the salt-bush country, and approximately coincides with the area having less than ten inches of rainfall per annum. It is bounded on the north and north-east by the Indo-Australian vegetation; on the east and south-east by the typical Euronotian Flora, and on the extreme south-west by the Autochthonian.

The characteristics and peculiarities of the Euronotian and Autochthonian Floras have been treated fully, as far as materials were available by Sir Joseph D. Hooker in his Essay on the Australian Flora, and repeated by Wallace in several of his contributions on the geographical distribution of animals, and Sir Ferdinand von Mueller has intensified the differences between the two floras by subsequent discoveries. The disemberment of the Eremian Flora from the Euronotian will not materially disturb the salient characteristics which separate the Euronotian from the Autochthonian, but if we eliminate from the Autochthonian such species as properly belong to the Eremian Flora, by narrowing the geographic limits of the former in accordance with the botanical affinities and environment we shall greatly augment the dissimilarities of the two extreme floras.

As to where the determinating line for the Autochthonian Region should be drawn, is a question of great difficulty in the absence of personal knowledge of the various circumstances that must be taken into consideration. Already, Sir Joseph Hooker had indicated, that the vicinity of Shark Bay marked the blending of the tropical with the Autochthonian Floras; but I recognise in the florula of Gascoigne River nothing more than an admixture of subtropical forms mingled with the more prominent types of the same Eremian Region, though it is certainly true that a few characteristic Autochthonian species extend so far northward. The plants from the Murchison River show the same general facies, though with a larger blending of Autochthonian species, as might be expected from its more southerly situation.

On the south coast, the Autochthonian type of vegetation extends in a narrow strip certainly to Lacapede Bay, and perhaps to Cape Arid; whilst the main mass is located in the triangle formed by a line joining Doubtful Bay and Bunbury.

Mr. F. T. Gregory* has made known the leading physical and geological features of this corner of Australia, which are shortly as follows :—The principal portion consists of an undulating table-land of granite, the western edge of which forms an abrupt escarpment of from eight hundred to twelve hundred feet above the sea; its inland slopes are occupied with salt lakes. "Between the western escarpment of the table-land, or Darling Range, and the sea, lies a low belt of country from twenty to sixty miles in width, the upper portion of which is evidently of very recent formation." Near King George Sound, and along the south coast near Mount Barren, are detached ranges up to three thousand feet elevation.

The same observer has further shown that the area occupied by the principal forest trees corresponds with that of the littoral tract, whilst the range of Xanthorrhæae is still more contracted. The line marking the 20-inch rainfall is one which embraces the distinctive features botanically and physically of the tract exterior to the granite table land, and is here employed as setting off the Autochthonian Region from the Eremian, the transition from one to the other being remarkably rapid in a medial line, whilst the blending of the two types is more prolonged on the west and south coast, more so in the latter than in the former.

As will hereafter be shown, the Autochthonian Region was greatly extended in Pliocene times, and through the rainfall lines of twenty-five and ten inches are narrowly separated, yet it is highly probable that the Autochthonian types which occupy this intervening space are remnants of the former extension of the main flora.

The maximum rainfall is 46.67 (average of twenty years) at Augusta, near Cape Leuwin, diminishing to 35 at Perth, 19 at Geraldton, and 5.5 at Carnarvon, increasing to 9.37 at Cossack, and 32 at Derby. On the south coast, the chief rcords are—at Albany, 32; at Esperance, 24.3; at Eucla, 9. From Perth, the rainfall rapidly diminishes in an easterly direction, and at York (sixty miles off), the average of eleven years is 17.77.

CHARACTERISTICS OF THE EREMIAN REGION.

This botanic region has its centre at Lake Eyre, where the average annual rainfall does not exceed five inches. This almost rainless portion extends through four degrees of latitude; the rainfall is, moreover, very intermittent; thus, at Charlotte Waters the rainfall for 1881 was only 2.495 inches, whilst the average for seven years is 7.064. But despite the high temperature and limited rainfall, the region is not a desert as may be judged from the large numher of plant species which occur; and in this

* Quart. Journ. Geol. Soc. 1861, xvii., p. 475, et seq.

particular I have selected for illustration the florula of the depressed country surrounding Lake Eyre, within which the conditions are the most unfavourable to maintain life.

The following table gives the number of species in each botanical class, and the number of those which are endemic and extra Australasian :—

	Endemic	Extra Australasian.	Total.
Exogens	263 ...	42 ...	305
Endogens	42 ...	16 ...	58
Vascular cryptogams ...	...	5 ...	5
	305	63	368

All the extra-Australasian species belong to the Oriental Province, and the majority of them inhabit the sandstone table-lands of the Western Peninsula of India, and even to Northern Baluchistan, where the climate becomes dry for a considerable portion of the year. This type of the Oriental vegetation is largely interspersed throughout the tropical tracts of the Eremian Region, and imparts a facies which is absent in the tropical portions of the Euronotian Region where lowland and maritime types of the Indo-Malay Sub-Province predominate.

As I am not yet prepared to analyse the whole Eremian floras, I will substitute in its stead that of the Extratropical South Australian portion, with which I have some personal acquaintance, and which I believe to be fairly representative of the entire flora.

Within this region, diversity of soil exercises a great influence on the botanical physiognomy, particularly as regards the perennial constituents of the flora, and taken in conjunction with their gregarious habits originates a high degree of monotony. Indeed, the vegetation is sharply defined into that of the hills, and on rock formations, that on the sandhills, that on the clay-plains and dry beds of water-courses.

The total number of species catalogued for that portion of the Eremian Region within Extra-tropical South Australia is 813, of these 470 are peculiar, and 343 extra limital, but of the latter 46 are essentially Eremian, so that more than half the species are limited to this region. Of the extra-limital species, 137 are extra-Australasian, 108 of which are Oriental, and the remainder are Palæarctic, Andean, or cosmopolitan types. There remains 206 endemic species which are common to this region and neighbouring ones, 80 of them are migrants from the tropical parts of the Euronotian Region, but the bulk of the remainder have immigrated from the temperate parts of the same region ; whilst with the Autochthonian Region the interchanges do not exceed seven.

A brief survey of the Eremian Flora as a whole in respect to its ordinal and generic features, offers, as regards the first, no very positive characters, if we except Zygophylleæ, Ficoideæ, Salsolaceæ, Amarantaceæ, Verbenaceæ, which are more largely represented in this region than in the rest of Australia, whilst the Order Myoporineæ, which is essentially Australian, has its head-quarters within this region. Of negative characters, perhaps the most striking is the absence of Epacrids, one extra-limital species, however, just reaches the outskirts of the region.

As to genera the following are either peculiar or attain their greatest development in the Region.

I.—Those of Endemic origin.

Stenopetalum, Geococcus (monotypic), Menkea, Hannafordia, Diplopeltis, Macregoria (monotypic), Ptilotus, Dysphania, Didymanthus (monotypic), Babbagia, Gunnia, Templetonia, Ptychosema Ctianthus, Petalostylis (monotypic), Swainsonia, Stylobasium, Calotis, Pterigeron, Erodiophyllum (monotypic), Dimorphocoma (monotypic), Catosperma, Notonerium (monotypic), Dicrastyles, Newcastlia, Gnephosis, Cephalipterum (monotypic), Chthonocephalus, Millotia, Myoporum, Eremophila, Neurachne, Astrebla.

II.—Those of Exotic origin.

Sida, Abutilon, Tribulus, Abriplex, Bassia, Kochia, Crotalaria, Cassia, Helipterum, Eragrostis, Triodia.

Whatever value we may assign to the Eremian Flora in respect of its exoteric relations, there cannot be a doubt that it occupies an excessively dry region which is an impassable barrier to the interchange of Autochthonian and Euronotian types. The nature of the barrier which isolates the Autochthonian Region has hitherto been overlooked. The only way of migration between two extreme regions may possibly have been by the former extension of the southern coast line, during Post-Miocene times, indications of which are afforded by the truncation of the Old Tertiary beds of the Great Australian Bight, which present a perpendicular front to the sea, varying from two hundred and fifty to one hundred and fifty feet elevation, for a length of three hundred miles, *i.e.*, from the Head of the Bight to Point Calver. This suggestion that the Autochthonian Region may have extended southward and westward of its present limits, seems to be demanded by certain analogies which Kangaroo Island and Port Lincoln present with it.*

Has this climatic barrier always existed during the epoch of the existing floras or their immediate ancestors? The answer is, no; though a barrier of some sort has intervened from Pre-Cretaceous times till an absolutely recent period.

Firstly.—Marine Cretaceous beds are widely distributed in Central Australia, they occupy a very large portion of the eastern section of the Eremian Region, probably underlie the Desert

*Though the depth of water about the Great Australian Bight is generally twenty fathoms at from one to two miles off shore, and thirty fathoms at five or six miles, yet Yatala Reef thirty-eight miles seaward from Fowler Bay, affords soundings at ten fathoms; other reefs and islets occur to the south-east of this place which may be regarded as remnants of an old coast line.

Sandstone of North Australia, stretching across from the Victoria River to the country south of the Gulf of Carpentaria, they wrap round Lake Eyre on its east, south and west sides, extending westerly so far as known to beyond Mt. Paisley in lat. 135°. The existence of this upraised Cretaceous bed, though probably of inconsiderable elevation, implies during the period of its deposition the submergence of a large extent of country. The Autochthonian Region would be reduced to the condition of an archipelago widely separated from another chain of islands in what is now the meridianal elevation in South Australia, whilst a larger body of dry land existed on the east coinciding with the Cordilleras of the Euronotian Region.

Secondly.—Following close on the extinction of the Cretaceous Epoch was another submergence during the deposition of our Old Tertiary beds, but which did not involve so large an area as the former one, inasmuch as the general elevation above sea level of marine beds of this age is only about three hundred feet, and their extension inland does not exceed fifty miles, except around the Great Australian Bight, and in the Murray Desert. During this period of submergence much of the Eremian Region must have been dry land, and may have afforded a way of intercommunication between the floras on either side, but not so, if present climatic conditions were as actively repellant then as now; of this we have not actual evidence though it may be reasonably deduced from the facts bearing on oscillations of climate that it may so have been.

Professor Martin Duncan* and Mr. Alfred Wallace† have each assumed that the Old Tertiary sea extended in a wide gulf from north to south through Central Australia. I know not on what foundation these authors had based their assumption; possibly Mr. Brough Smyth's Geological Map of Australia may have been to them a Will-o'-the-Wisp, as the Tertiary rocks are indicated on it by one colour only. Now the beds of this period which cover an extensive area in the medial portion of Australia are of lacustrine origin and belong to a comparatively modern epoch.

Whether or not the circumstance that several maritime species re-appear in the Eremian Region, and which count among some of its most characteristic plants, had influenced the forenamed speculative minds I cannot say; that it has not escaped the notice of local observers is well known, who are to some extent answerable for the propagation of a popular fallacy that the lake region of Central Australia has recently been cut off from Oceanic waters.

The maritime plants are *Lepidium ruderale*, *Nitraria Schoberi*, *Frankenia lævis*, *Plumbago zeylanica*, *Salsola Kali*, *Mesembryanthemum equilaterale*, *M. australe*, *Cressa cretica* of exotic origin;

* Quart. Journ. Geol. Soc. 1870.
† Island Life, 1880.

and *Polycnemon diandrum*, *Threlkeldia diffusa*, *Kochia oppositifolia*, *K. brevifolia*, *Salicornia arbuscula*, *S. australis*, *Templetonia retusa*, and *Festuca littoralis* among endemic species.

Captain Sturt was the first to suggest, that the Basin of Lake Eyre was once a fresh-water sea, and Mr. Etheridge has speculated on the lacustrine origin of the Desert Sandstone, which occupies so large an area in Central Australia; I arrived at the same conclusions quite independently and brought forward facts of the former existence of a vast inland sea centering about Lake Eyre.

The Pliocene Tertiary loams and sands have yielded and at several distant localities within the basin of Lake Eyre, the following palæontological proofs of their lacustrine origin—a species of crocodile comparable in size with the living *C. porosus*, plates of a turtle indicating a carapace of at least a yard in diameter, the vertebræ of large fish, the mandibular teeth of *Ceratodus*, extinct species of *Unio*, bones of *Diprotodon*, of several extinct Kangaroos, and of an Emu-like bird.

Elsewhere* I have sought to claim for this region during the accumulation of the Pliocene drifts, a very much larger rainfall than it now has—this pluvial condition being contemporaneous with that which gave rise to the glacial phenomena at places in more southern latitudes in Australia, and as other evidences in addition to the palæontological ones first mentioned, I appeal to the waterless large river channels, to the contracted and saline like basins, and to the nature and disposition of the sand ridges which form one of the most characteristice and wide spread physical feature in Central Australia.

The Pliocene drifts, which partially conceal the Cretaceous beds over a very extensive area in Central Australia, show their fluviatile origin in the form of fossil Unios as far south as Leigh Creek, one hundred miles from the present margin of Lake Eyre, and situated nearly four hundred feet above the sea level, and thirty-nine feet more above Lake Eyre.† Such a water level would connect Lake Eyre with Lake Torrens by way of the broad gap, which interrupts the Aroona Range on the south of Termination Hill, and would unite in a vast inland sea the whole of the lake region around Lake Eyre, and to the westward of Lake Torrens, A very much less addition to the present height of water level would connect Lake Eyre and Lake Frome, connecting a large depressed region into a continuous inland sea. Much of the Murray Desert to the eastward of Overland Corner, and perhaps embracing the whole Riverine region, was at this time a lacustrine area, though probably disconnected from that of Lakes Eyre and Torrens.

* Trans. Roy. Soc. S. Aust. Vol. VIII., pp. 49 et Seq.

† The north end of Lake Torrens is one hundred and eleven feet above sea level, and the south end of Lake Eyre is thirty-nine feet below it.

Whatever may have been the cause, which brought about these very opposite climatic conditions, the facts are incontestable and point to one conclusion, that since Pliocene times Central Australia has been drying up—that the present barrier to the migration of plants has simply replaced one different in kind—an arid waste by a vast area of inland drainage.

As the aridity of Central Australia is a consequence of its geographical position in reference to the equatorial region of low barometric pressure, being the co-ordinate region of high barometric pressure, it is not illogical to suggest that a secondary cause of the pluvial conditions in Pliocene times over Central Australia was the northerly shift of the whole system of winds, by which the dry region moved to the north, and effectually acted there as a barrier to migration, whilst in more southern latitudes the inland sea operated in a like manner.

The oscillation of climate through long periods of time as evinced by floral features, has been generally accepted for the Northern Hemisphere, and it is not unreasonable to insist that corresponding climatic vicissitudes had been experienced in this hemisphere; but on the hypothesis of Dr. Croll, the maxima and minima would alternate in the two hemispheres. The temperate conditions which prevailed over the arctic regions in Mid-Tertiary times, and clothed them in a forest vegetation, had come to be replaced in the Glacial Epoch by the extremest rigour of a long continued arctic winter, which involved the present cold temperate belt of the old world in a high condition of refrigeration; since then the climate has ameliorated. An analagous sequence of phenomena, differing in intensity but not in kind, has been witnessed in these latitudes; the northerly advance of the region of high barometric pressure brought the now arid region into the belt of summer rains, whilst in more southern latitudes a mild glacial epoch prevailed.

Thus, whilst the Eremian Region has been a land surface since Cretaceous times, it has been subjected to such varying climatic and physical changes that must have materially affected the permanency of its plants. We cannot wonder, therefore, that in comparison with the Autochthonian and Euronotian floras, its plants should present less of an Australian facies than its neighbour, consisting virtually of emigrants from surrounding provinces, though sufficient time has elapsed to have developed within itself some new generic types and evolved many new species.

The more modern facies of the Eremian flora is partly shown by the wide disposal of a large number of exotic species, which thus evince a quality of accommodating themselves to a great variety of climatic and physical influences. This colonising power has had freer scope to exercise itself in the comparatively pre-occupied tract of the Eremian Region, than was possible in the more stable external regions.

Another feature pointing in the same directions is the high state of specific luxuriance in many of its genera, twenty of which in the extra-tropical part of South Australia contain two hundred and forty-one species, twelve to a genus, or more than one-fourth of the flora. Nevertheless, for the whole flora the number of species per genus is low, namely 2.7, and is actually the same for the exotic as for the endemic genera. Thus three hundred and ninety-six exotic genera contain five hundred and sixty species, and one hundred and forty-four endemic genera contain two hundred and seven species.

A process of differentiation seems to be in progress because of the local racial characters exhibited in some genera and species.

Of the latter of these may be mentioned as noteworthy :—

Arbutilon oxycarpum, var. malvæfolium.
Salsola kali, var. strobolifera.
Crotalaria dissitiflora, var. eremœa.
Darwinia micropetala, var. cicatricosa.
Cassia circinita, var. glaucescens.
Panicum divaricatissimum, var. amnophilum.
Panicum pauciflorum, var. fastigiatum.
Panicum Mitchelli, var.
Eriachne ovata, var.

Further, the many monotypic genera which are for the most part offsets of Australian types, altered by new surroundings, show no singularity which may be attributed to a high antiquity.

An indispensable property of the Eremian plants is that of rapid germination so as to take advantage of the rare opportunities when the physical and hygrometric conditions of the soil are favourable, and quite irrespective of temperature. Moreover, the long periods of droughts intervening between the favourable periods necessitates another quality in their seeds, that of resistance to long exposure. The protection necessary to ensure a long suspended vitality reacts adversely by increasing the difficulty of rapid germination ; but in extreme cases at least, this seems to be met by the fruit and seed eating propensities of certain animals. In this connection, we may have an explanation of the wide dispersal of some species of plants by the agency of migratory animals.

Individual tenacity of life is another essential condition of maintaining a foothold in the Eremian Region. To one who has seen this country for the first time during a severe drought will wonder that the shrubby growth, reduced to a mass of dry twigs and withered leaves can by any possibility recover, but on the first copious rains the transformation is marvellous. Now and again a few agral weeds reach the outskirts of the Eremain Region, but they have not succeeded in permanently establishing themselves.

The Autochthonian flora, after elimination of the emigrant species of exotic origin, consists of species belonging, for the most part, to genera endemic in Australia, whilst, on the other hand, the endemic species of the Euronotian and Eremian floras belong to a relatively large number of extra-Australasian genera, but the Euronotian flora contains a few representatives of that primitive flora which marks the close of the Cretaceous and the early stages of the Tertiary Period, the existence of which in Pre-Pliocene times in Australia. has been made known chiefly by the researches of Baron von Ettingshausen. The forms belonging to this type of vegetation, which still linger with us, are *Cinnamomum*, *Ulmus*, *Fagus*, *Araucaria*, *Cassia*, *Sapindus*, *Panax*, *Litsæa*, *Zizyphus*, *Callitris*, and in an extension to New Guinea, *Quercus*.

In association with the fossil representatives of these genera, are progenitors of such genera as *Dryandra*, *Lomaria*, *Casuarina*, *Eucalyptus*, *Dammara* and others, which indicate that the early flora of this Continent had then impressed on it those botanical features which make it so conspicuous in living vegetation. These Australian types are mingled with the Old World forms in the Eocene-Cretaceous floras of North America and Europe, as they are in Australia, and renders it difficult to assign an earlier date to the one in preference to the other.

Keeping in mind the fact of the absence of primitive types of the Old World flora* in the Autochthonian Region, its highly specialised Australian types, and its long continued isolation from the rest of Australia, which I have endeavoured to establish on physical evidences, may not the Autochthonian flora be regarded as of greater antiquity; and that the modification of the Australian flora in the Euronotian Region by an equally primitive flora of European type, was subsequently acquired chiefly by reason of less remoteness of this part of Australia, and for the same reason has it continued into recent times to receive greater accessions of Asiatic races.

It is to be deplored that we have no knowledge of the Tertiary flora of the Autochthonian Region, but I hope that some effort will be made to eliminate this desideratum, and would call particular attention to the gorge of the Fitzgerald River as affording a field of investigation, the lignitiferous bed at which place is, in the opinion of Mr. S. Dixon,† contemporaneus with the Old Tertiary.

The history of the Australian floras, viewed chronologically, may be summarized as follows:—

The Australian flora is of high antiquity.

The Autochthonian constituent was dismembered in Cretaceous times.

The Euronotian constituent was modified during very early Tertiary times by a primitive cosmopolitan flora.

That it was further modified during the Glacial Epoch of the Southern Hemisphere by an incursion of Andean types.

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* *Dryandra* has one Eocene species, and *Adenanthos* has one species Senonien.

† Trans. Roy. Soc. South Australia, 1884, Vol. VII., p. 9.

That since the Glacial Epoch, the Eremian flora has been developed from Autochthonian and Euronotian elements, largely modified by an incursion of Indian types; and co-temporneously the Euronotian gained accessions from the Indo-Malay Province though it is not improbable that migrants have been received at all times since the flora of the Indo-Malay Province acquired a specialized character.

In concluding the botanical portion of my Essay, I express the desire that the enormous mass of facts summarised by Baron Sir F. von Mueller in his "Census of Australian Plants" should be tabulated and compared so as to exhibit the various relations of our flora in the same manner as was done by Sir Joseph D. Hooker, in his Essay on the Flora of Australia with the materials available thirty years ago. It is not that vast accessions have been made to the list of species during this long interval; but that the limits of the majority of the genera and species are better defined and their distribution better known, whilst a greatly extended knowledge of climatic, physiographic, and geologic conditions has been gained.

It is my belief that we have sufficient data to co-ordinate the botanical features with certain physical phenomena, and from which we may determine the relations of the respective floras; obviously the task of dismembering our provincial floras, of relegating their constituent species to their natural provinces will absorb many weeks of labour, demanding so accurate a topographical knowledge, and of other kindred subjects, as it is hardly possible for any one man to possess. Hence my sketch may seem crude and imperfect because it has not been possible for me to compile all the facts bearing on the distinctive features of each floral region, but at the same time I claim that it is not from a consideration of specific details that the problem of the relations of our floras and their origin will ever be solved, though these details must eventually supply the proofs of the solutions.

It is a trite saying of those familiar with the life of the Eremian Region—"No rain, no flowers; no flowers, no insects." Thus implying a co-ordination between physical phenomena and life, and an interpendency between the plant and the animal—an interpendency so pronounced as to suggest morphological adaptations for permanent establishment in this region subject to great climatic vicissitudes. Correspondingly therefore we are lead to expect that not only in the Eremian Region but in the others, that the fauna of each will exhibit, though perhaps in a less degree, similar relationship to one another as the floras.

In all classes of terrestrial animals morphological variety is at a maximum in the Euronotian—the converse of the vegetation. It is richer in Oriental types than the other Provinces, and in some classes partakes of a tropical character common to the rest of the world.

The Autochthonian Province is without distinctive features other than specific.

The Eremian Province has many specific and some generic peculiarities, but is essentially Australian.

By the same agency that introduced the Andean Flora, we owe a few animal forms of identical genera whose species are either similar or modified. Among fish, there are *Galaxias*, *Geotria*, *Mordacia*, *Haplochiton*, *Prototroctes*, and *Aphritis*: and *Gundlachia* among Mollusca.

The extinct land mammalia, which in point of time immediately preceded the living, consists of the peculiar marsupial type, and under dimensions as varied as are the placental wild beasts of larger continents. Creatures nearest of kin to them have lived and bred on land which forms part of Great Britain anterior to the Chalk. And the marsupials, like the flora, had a common ancestry in the Secondary Period.

The elaboration of such generalisations in the several departments of Zoology I must leave to each specialist. In such investigations we must keep well in mind the degree of facility that each plant or animal offers to migration, and the mutual relationship of certain species of the two kingdoms. How far the wide distribution of the Emu is correlated with that of *Fusanus*, of certain parrots with particular species of *Acacia*, of *Dicæum horundinaceum* with the miseltoes, of the procumbent *Styphelias* with the stump-tailed lizard, are examples of suggested interpendency, in a wide and interesting field observation which may well occupy the attention of those who have knowledge of the habits of the animals.

In conclusion, I beg to suggest that this Section imitate a scheme for the investigation of the Fauna of this Continent on those lines which seem best to fuse the species into geographic groups, as dependent on—(1) physical features of surface and climate, and—(2) the era of introduction.

The following papers were read:—

1.—ON THE ACTION OF METALLIC SALTS IN THE DEVELOPMENT OF *ASPERGILLUS NIGRESCENS*.

By William M. Hamlet, F.I.C., F.C.S., Analyst to the New South Wales Government, Sydney.

Some months ago a very curious sample of bread came into my hands for analysis. The specimen consisted of a slice about half an inch thick and presented a strange appearance; the whole of the interstices, forming the well-known honeycombed character of properly baked bread, being full of a rusty-black powder or dust, so much so that the bread was sent for analysis, the sender being under the impression that it was poisonous.

Some of the black dust was placed under the microscope, and the conidia of penicillium were found in great quantities and well-developed; the mycelia, with their aerial hyphæ, having spread over the whole of the bread, penetrating the piece from one side to the other.

Of the *Ascomycetes*, *Aspergilus glaucus*, and *A. flavescens*, are the most commonly met with in Sydney, whereas *A. nigrescens* is somewhat rare.

Remembering that Raulin, in his researches on moulds, found that this particular organism developed enormously whenever salts of iron or zinc were added to the cultivating media, I made an analysis of the bread and found the sample to yield 2.43 per cent. of ash. The composition of the ash was found to be abnormal, inasmuch as when examined in the usual way for metals of the iron group, a small quantity of zinc was found.

Minute traces of zinc were also found in the brownish-black powder.

Some of the powder containing conidia was placed in Raulin's solution and grown in a cultivating chamber with the result that a speedy growth of *A. nigrescens* was obtained.

Some of the same powder sown in Pasteur's solution, in which neither zinc nor iron salts were present, produced scarcely any effect. Duclaux noted the absence of colouring matter in the growth of *A. nigrescens*, and its power of readily assimilating small quantities of iron and zinc. He instances an experiment* where 32 m.g.m. of zinc in 25 grams of culture solution, reduces the growth enormously, $\frac{1}{50,000}$th part reducing the crop to ten per cent.

Speaking of the action of the trace of iron in a plant destitute of chlorophyll as the Aspergillæ, he says (*loc. cit.* p. 47):—

"On peut être surpris de voir le fer au nombre de ses éléments nutritifs. Ce métal paraît, en effet jouer un rôle spécial. M. Raulin pense et, quand on lit les raisons q'uil eu donne il est difficile de ne pas partager son opinion que le fer n'est utile que parce q'uil detruit au fur et à mesure de sa production, un poison secreté par la plante, et qui en s'accumulant dans le liquide, finirait par la tuer. C'est ainsi q'un animal perit quand il n'elimine plus l'urée produite dans ses tissus. Le fer ne serait donc pas mis physiologiquement en æuvre par la plante, il lui seriorait seulement de contrepoison."

These results show that salts of zinc and iron have a peculiarly stimulating effect upon the development of this fungus, even if it is not absolutely necessary to its growth.

The actual growth on this sample of bread was probably owing to the use of galvanised iron tubs or vessels in the preparation of the bread.

* Ferments et Maladies, p. 46, Duclaux, Paris, 1882.

2.—RESPIRATION IN THE ROOTS OF SHORE-PLANTS.

By Dr. J. Bancroft, &c., of Brisbane.

The following results of a series of observations on the respiration of plants may tend to the better understanding of that function in the bark of trees. (Pls. XIX.-XXVII[a].)

There is much obscurity on the subject, and as no work, as far as I am aware, supplies any clear account of the matter, I may be pardoned for encroaching on the labours of the botanist proper, by supplying some data that may help future observers in their efforts in elucidating plant respiration.

I have spoken to Baron von Mueller, of Melbourne, recently as to his views, and am encouraged thereby to bring forward what forms of vegetation have fallen into my hands in Queensland that bear on the subject.

In the first place, in the year 1881, I made various experiments with an organ which grows from the submerged roots of *Avicennia officinalis*, a tree that is common on the shores of Queensland, extending up the rivers as far as salt water passes.

This organ, often over a foot long, has not hitherto been described by botanists, and if we turn to the notice of the tree in the "Flora Australiensis,"* no mention of it will be found. My examination of this organ led to the writing of a paper which was sent to the late Professor Balfour, from whom I have a letter of acknowledgment, stating that he was in feeble health and might be unable to do justice to the communication.

The paper was submitted to the Royal Society of Edinburgh by Professor Dickson, but was not published so far as I am aware. A notice appears of the reading of it in "*Nature*."†

Both these botanists having died, I now place the original communication before you.

On May 25th, 1881, being detained by a lady patient, I took a walk on the banks of a salt-water creek botanising. Amongst various things that interested me, a white powder floating on the brackish water, presented itself as an object of inquiry. This powder looked at a distance like the male *Vallisneria* flower, but on closer inspection it was observed to issue from openings in the aerial roots of neighbouring *Avicennia* trees, the habitat of which is restricted to the muddy banks of salt waters. Some of these upright roots in rapid growth, found casting off the white powder, I drew up, together with the horizontal white pithy parts that

* Vol. V.

† Vol. XXV., p. 404.

were in process of extension to an unoccupied mudbank. Having secured a number of specimens I carried them home for further examination. This powder by the aid of a microscope was found to consist of cells, iodine tinting them brown. This substance could have no relation to the reproductive system of the *Avicennia* tree as the flowers are high up on the branches, followed by fruits like garden-beans.

The aerial roots of *Avicennia* are from a foot to eighteen inches long, covered with green epidermis, on which the tides deposit mud and confervas. They never throw out leaves, but occasionally become forked. The muddy bank around the *Avicennia* stem is covered by a brush of these roots to a distance of from four to six yards from the bole of the tree.

This brush, by entangling *débris*, protects the bank from destruction by stream or tide. The roots are as thick as a penholder, and are covered with pores, five hundred or more to be counted on a single specimen. The pores just opened are surrounded by broken epiderm, looking like the sepals of a flower, but having no regularity. The horizontal portions of the root system to which the aerial upright parts just described are attached, are white, pithy, and full of air, and though living in undrained mud are quite free from any waterlogged condition. As the upright roots appear to rise out of the mud to obtain air, could the powder-discharging pores contribute anything towards aeration? Might they be mouths to admit air? After considering how this could be determined, I attached the indiarubber head of a pipette used for eye-drops to the cut part of a root, tied it, and immersed the aerial portion in water, On compressing the rubber cap, air was found to issue freely from the pores, and at no other parts.

This, then, seems to me to be the function of the pores, to supply air to the root system of the mud-inhabiting *Avicennia* tree; the office of the discharged powder being to establish a communication between the air vessels of the plant and the outer atmosphere, by bursting open the cuticle of the root.

Some time later I made an excursion to the estuary of the Brisbane River, and examined other shore plants.

Rhizophora mucronata, a true mangrove, throws up no aerial roots, but on those sent downwards tripod like apertures are seen with elevated edges, circular, one-twentieth of an inch in diameter, and filled with reddish-brown powder.

Ægiceras majus, a small shrub, has white spots on the roots and stems extending up among the leaves.

Excœcaria agallocha, has a large well-formed aperture, in which a brown powder is to be seen. I can blow air by the mouth applied to the cut stem, through all these apertures, but find the bellows of Paquelin's thermo-cautery a very convenient instrument for such experiments.

The roots that show the greatest resistance to the passage of air, are those of the *Excœcaria*. The habitat of this tree is not in such close proximity to the shore as that of *Avicennia*, *Rhizophora*, or *Ægiceras*.

The same organ I saw on dried stems of *Acanthus ilicifolia*, another shore plant.

Guided by the appearances on the roots of *Ægiceras* and *Excœcaria*, the pores of which are found to extend also higher up among the foliage, the conclusion is forced on me that these root-pores are only modifications of the organs called lenticels.

The lenticels of the generality of trees differ somewhat from the root-pore in having no cup-like margins, and the corky mass does not fall freely in the form of powder, as is found in the root of *Avicennia*. Yet air can be blown through these organs among the foliage of *Ægiceras*, less freely in *Excœcaria*. With Paquelin's bellows and patience, it may be seen to issue from the lenticels on the young shoots of the peach, and by the same apparatus can be made to pass through the stomata near the midrib of the common *Oleander*. So far, I have seen air issue through the stomata of no other leaf, though experimenting with many.

Examining all my botanic authorities, I observe no account of the root organs of these plants, and the function of the lenticel is not laid down with certainty. The only botanist, whose writings I have perused, who has given a correct theory for the function of the lenticel, is our esteemed Professor Balfour, who says: "Lenticels keep up a connection between the air and the inner bark, and probably perform the function of stomata in the advanced period of the growth of the plant."

One might suppose that in deciduous exogens the lenticels perform important duties before the leaves are unfolded in the spring.

Turning over Leunis' "Botanic Synopsis," lenticels are there called Korkwarzen and Kinderhoeckerchen, and Mohl believes them to be the first indication of cork formation. No mention is made of any function in this work.

Decandolle conjectured they were points developed for the emission of roots.

The microscopic structure of the lenticel is similar to the root-pore of the shore plants, and its functions must be that of respiration. Root-pores then may not inappropriately be called *foramina purumatica*.

The microscopic appearance of the foramen of the root of the mangrove being larger than the others mentioned, is worthy of attention. Air passes through it with the greatest freedom. The colour of the corky powder is reddish-brown. The cells are in regular layers which, when observed *in situ* from above, shew a honeycomb-like surface. The cells peel off in layers, and when undisturbed from the tubes, each cell appears to have a ring-like margin, which is closed at the bottom by a thin membrane causing it to look like a cup. One might suppose air to traverse the tubes, as some of the membranous centres appear ruptured.

The longitudinal air vessels of the bark communicate with the base of this honeycomb-like cell work.

Herewith I have forwarded roots of the shore plants referred to assist in the elucidation of the subject.

Immersed in water many days the corky-cell work of the root-pores does not become water-logged. Turpentine and alcohol close up the structure so that air no longer comes through the pore touched with these fluids.

Since the original paper of 1881 was written several additional observations have been made.

Some years ago, my son, Dr. Thos. Bancroft, brought from the Johnston River, in North Queensland, a large breathing organ which grows from the submerged roots of *Sonneratia acida*, Willd., of the natural family Lythrarieæ, a tree not before known to inhabit this colony, but entered in the "Flora Australiensis"* as frequent in bogs on the N. N.W. coast of Australia, observed by A. Cunningham. No mention is made of breathing organs springing from the roots. In the "System of Botany" by Maout and Decaisne, *Sonneratia acida* is considered to furnish the best substitute for coal on the Indus steamers.

In Lindley and Moore's "Treasury of Botany," the tree is said, among other things, to be "exclusively confined to sea-coasts, where it grows together in large masses, being what is called a littoral and sociable plant," and that the acid fruits are eaten as a condiment by the Malays. Roxburgh, in the "Flora Indica," says of it:—"a native of the delta of the Ganges; flowering time the hot and rainy seasons." No one appears to mention the breathers, which are of variable size up to six feet high, one of which I now shew.

In the *American Agriculturist* of December, 1886, will be seen a woodcut of the "Deciduous Cypress" (Pl. XXVII.[a]), and description which reads as follows:—

"The Deciduous or Bald Cypress, probably because it is a native of the Southern States, has been strangely neglected by the tree planters at the North. Though naturally growing in moist places and in a warm climate, it will grow on high ground, and proves hardy in localities much farther north than those in which it is native. The northern limits of its spontaneous growth are Delaware and Southern Illinois, and it extends throughout the Southern States, through Texas to Mexico. It grows upon river banks, especially in those localities subject to annual overflow. In

* Vol. III.

favourable localities it attains the height of one hundred, and one hundred and twenty-five feet; its trunk is straight, clean, destitute of branches for the greater part of its height, with a flat, spreading top. The diameter varies from four to ten feet. There was, a few years ago, in the Bartram garden, near Philadelphia, a cypress tree one hundred and twenty-five feet high, and twenty feet in circumference. It is a peculiarity of this tree that when it gets large its roots throw up conical protruberances, known in the South as "Cypress knees." These are from one to two feet high, and four or five feet across at the base, and always hollow. They are covered, like the roots, with a small reddish bark. What use these are to the tree, or what causes them, is not known. Michaux states that he never succeeded in causing them to throw out shoots by wounding them. They appear in great abundance on trees subject to annual inundation, and begin to appear when the tree is about twenty-five feet high. The "knees" are sometimes produced on cultivated trees. A notable case has occurred at Sion House, England. In this case the knees extend sixty feet from the trunk. The base of this tree, and the numerous "knees" which have sprung up about, are shown in the engraving (Pl. XXVII[a]) The "knees" are cut off and used by the negroes at the South for bee-hives, buckets, and, when provided with covers, they serve as boxes in which to store various articles. The trunk in large trees is often hollow for some distance above the ground, and in felling the trees it is customary to build a scaffold, upon which the choppers stand to cut the trunk above the hollow portion."

It is difficult to say confidently that these "knees," one to two feet high, have the same function as the breathers of our shore-plants.

On comparing the roots of *Bruguiera Rheedii*, a photograph of which I show, we notice a great resemblance. This mangrove throws up at a distance from the stem of the tree, "knees" which are covered with lenticels, and no doubt serve the same function as the breathers of *Avicennia* and *Sonneratia*.

They are hard woody projections, seldom above a foot high on the roots of trees growing at the mouth of the Brisbane River, with the bark frequently abraded at the highest point of the "knee" by drift-wood.

Dead "knees" when the bark is decayed away, may be kicked over and are much of the form of the head of the Cassowary.

I cannot detain you with any further description of these organs. The study of them is to be commended to botanists and may establish the respiratory value of the lenticels, and the necessity of keeping these organs open and free from lichenous incrustations in our peaches and apple-trees.

Friday, August 31.

The President, Mr. Ralph Tate, F.L.S., F.G.S., Professor of Natural Science in the University of Adelaide, in the Chair.

The following papers were read :—

1.—PRELIMINARY NOTES ON THE STRUCTURE AND DEVELOPMENT OF A HORNY SPONGE (*STELOSPONGUS FLABELLIFORMIS*).

By Arthur Dendy, M.Sc., F.L.S.

2.—PRELIMINARY OBSERVATIONS ON THE MINUTE ANATOMY OF AN AUSTRALIAN PLANARIAN.

By Arthur Dendy, M.Sc., F.L.S.

3.—ON THE DEVELOPMENT AND STRUCTURE OF THE PINEAL EYE IN *HINULIA* AND *GRAMMATOPHORA*.

By William J. McKay, B.Sc., Sydney.

[*Abstract.*]

The observations contained in this paper were made at the Biological Laboratory of the Sydney University, through the kindness of Dr. W. A. Haswell, whom I have to thank for directing my attention to the subject, and for a portion of my material.

The material I have had, has been various stages in the development of *Hinulia* (*Lygosoma*) *tæniolata*, *Hinulia* sp., and *Grammatophora* (*Amphibolurus*) *muricata*. In the embyros of *Hinulia*, the pineal eye stands out as a prominent projection in the region of the thalamencephalon; while a smaller projection immediately behind it is the curved end of the epiphysis. In *Grammatophora* the epiphysis is seen in the first stage as a simple evagination of the wall of the thalamencephalon, being composed of a single row of columnar cells. In the next stage the outer wall begins to grow forward and leads to the formation of a second evagination in the wall of the primary one. There are thus formed two

vesicles, an anterior larger one, destined to become the pineal eye, and a posterior smaller one, the end of the epiphisis. In this stage the nuclei of the columnar cells undergo karyokinesis, and a second layer of cells is formed. In the next stage the anterior vesicle becomes constricted off to form the Pineal eye. The further changes in the eye are unknown, beyond the fact that it becomes densely pigmented, and that an external modification of the scale above forms the so-called cornea.

The stages of *Hinulia* that I have had, have been from the time when the eye is becoming differentiated from the epiphysis. In the first stage the eye was seen lying close to the surface, being separated from it only by a thin layer of connective tissue. The eye is ovate in longitudinal vertical section, its long axis being placed parallel to the long axis of the head of the lizard, and it is slightly dorso-ventrally compressed. The lens is concavo-convex in shape, the convexity being on the superior side. It is nearly the same thickness throughout, but slightly thinner where it joins the retina. It is cellular in structure, and composed of two layers of columnar cells. The retina is composed of seven layers.

The first layer is composed of rods occupying about one-third of the whole thickness. They have a distinct oval nucleus, and taper at their inferior extremities. In the second layer are spherical nucleated bodies, which do not stain deeply. They have processes which run up to join the rods.

Third layer.—Spindle-shaped bodies staining very deeply. No nucleus could be detected, but they have processes which run up to the rods and to the second layer of cells. Fourth layer.—A layer of spherical cells similar to those of the second layer; and also triangular-shaped elements that stain very deeply; these have processes. Fifth layer.—Spherical cells as in the second and fourth layers; and a layer of spindle bodies similar to, though more elongated than the third layer. Sixth layer.—A clear region devoid of cellular elements, and having only a few cell processes running across it. It may correspond to Spencer's molecular layer. The Seventh layer is composed of connective tissue and small nucleated bodies. The optic vesicle contains a humour. In the next stage pigment is developed in the rods, and then in the lower parts of the retina. No connection exists between the eye in the later stages and the end of the epiphysis. On comparing the forms which I have described, with those described by Spencer,* the following are some of the points which are similar, or dissimilar:—

(1) A scale is modified to form a cornea in *Grammatophora*, this being similar to such forms as *Calotes*, *Varanus*, etc.

(2) The lens is doubly convex in outline, a point which appears to be common to all the forms in which the eye is known.

* Quart. Journ. Micro. Science, Oct., 1886.

(3) The shape of the lens in the youngest stages of *Hinulia* is similar to the lens in *Cyclodus*, the eye in the latter being in a transitional state.

(4) As in some of the forms (*Varanus*, etc.), pigment is developed in the lens, so also in *Hinulia* is slight pigmentation present.

(5) The lens is composed of columnar nucleated cells.

(6) In the retina, the columnar cells called rods are present.

(7) Nuclei are present in the rods in the later stages, a point not ascertained by Spencer in his highest forms.

(8) The pigment is disposed in horizontal layers in the rods, and where the rods join the lens the pigment reaches through the whole thickness of the retina.

(9) The humour exists in the optic vesicle, which appears in prepared specimens as fibrillæ lining the vesicle.

(10) The rods have processes attached to their lower extremities.

(11) Spherical nucleated cells similar to the *(N')* layer of the *Hatteria* exist in *Hinulia*.

(12) The molecular layer (if it be such) of *Hinulia* is placed in a very different position to the molecular layer of *Hatteria* and *Varanus*.

(13) No such bodies as cones exist in *Hinulia*.

(14) Layers of spindle-shaped elements exist, which have no correspondence to any of the elements in *Hinulia* or *Varanus*.

(15) Layers of triangular-shaped elements exist, which have no correspondence to anything in Spencer's forms.

(16) The epiphysis as in *Calotes*, *Seps*, etc., is separated from the eye, and no such structure as the pineal stalk is present in either of the forms examined.

4.—CENSUS OF THE AUSTRALIAN MOLLUSCA.

By Ralph Tate, F.L.S., F.G.S., Professor of Natural Science in the University of Adelaide.

5.—NEW AUSTRALIAN SPECIES OF NOTABLE GENERA OF MOLLUSCA.

By Ralph Tate, F.L.S., F.G.S., Professor of Natural Science in the University of Adelaide.

6.—ON SOME NEW OR LITTLE KNOWN GENERA OF AUSTRALIAN MOLLUSCA.*

By RALPH TATE, F.L.S., F.G.S., Professor of Natural Science in the University of Adelaide.

CŒLODON.

C. patulus, n.sp., dredged in life in St. Vincent Gulf. This genus, separated by Carpenter in 1864 from *Pandora*, has been recorded in one Oriental species (*C. elongatus*, Carpenter) from North Australia by Mr. E. A. Smith in the "Zoology of the Challenger Expedition."

RÆTA.

R. meridionalis, n.sp., St. Vincent Gulf. A *Mya*-like *Lutraria*, hitherto unrecorded from Australia, though represented in New Zealand by *R. perspicua*, Hutton.

EPHIPPODONTA.

A new genus founded on *Scintilla lunata*, Tate, and *E. McDougalli*, n.sp., inhabiting St. Vincent Gulf. It differs from *Scintilla* and *Galeomma* by possessing two erect cardinal teeth in each valve, which are opposed to each other by their bifid ends and not alternating. The animal has the creeping habit of *Galeomma*; the valves are flexible and spread out flat, indeed while in life they cannot be brought into near proximity. Both species live on the mud-formed burrows of the shrimp (*Axus* sp.), sheltering beneath large stones and overhanging rock-ledges. Mr. McDougall, the discoverer of both species, who has kept them in confinement, informs me, when the animal is in motion the anterior margins of the mantle are largely expanded in a funnel form.

SACCHIA.

I venture to attach to this genus, the following species described by Angas under *Felania*, a sub-genus of *Mysia* (or *Diplodonta*), as *F. Adamsi*, and *F. jacksoniensis*, both from New South Wales, though the former is now known to extend to St. Vincent Gulf. The well-developed dental plate, deeply and largely excavated for the cartilage, particularly distinguishes the genus from *Diplodonta*. The genus has hitherto been known by a few species, living and

* The new species are described and figured in the Trans. Roy. Soc. S. Australia for 1888, issued May, 1889.

Pliocene, in the Mediterranean Region, but I have already announced its occurrence in our Old Tertiary, in an antecedent species to *S. Adamsi*, and the present determinations are therefore less unexpected.

LOBIGER.

L. Wilsoni, n.sp., taken in life at Port Philip Bay by Mr. J. B. Wilson, F.L.S. The genus includes four species inhabiting the Atlantic Province, and is characterised by the foot developed into four-paddle-like natatory appendages. The Australian species in respect of animal and shell is readily separable from its congeners.

UMBRELLA.

U. corticalis, n.sp., dredged in life in Port Philip Bay by Mr. J. B. Wilson, and has been taken in a few individuals in St. Vincent Gulf. This genus contains six tropical and sub-tropical species one of which, *U. indica*, extends to New South Wales. The new species, by the possession of a largely developed epidermis, differs from all others; in no conchological work which I have consulted is any reference made to an epidermal covering to the shell, and though not positively stated, yet its absence is implied. Messrs. Adams give a drawing of the animal and its shell, as in life, but the latter is represented as smooth and shining.

MESALIA.

A genus of *Melania*-like Turritellæ containing two recent species and several from the American and European Eocene. I have taken, in South Australian waters, a few examples of what may be *Mesalia melanioides*, Reeve, the habitat of which was unknown.

STENOPUS.

After repeated examinations of the animals of *Helix subangulata*, Cox, and the southern representative of *H. rustica*, Pfeiffer, I find that the anatomical characters are proper to *Stenopus* (*Guppya*, Tate, 1867 ; *Habroconus*, Crosse and Fischer, 1872.)

Our heliciform pulmonates are not yet anatomically known to permit of their generic groupings with any degree of certainty. Tryon, in his "Manual of Conchology," has ventured to distribute them into various families and genera, in many instances quite contrary to our actual knowledge, and at times he is singularly unfortunate in his guesses. Some species referred to *Rhytida* prove, on dissection, to be correctly placed ; whilst a few included therein by Tryon do not belong to the same family.

7.—ON A MYXOSPORIDIUM INFESTING AUSTRALIAN FROGS.

By A. W. Fletcher, B.A., B. Sc., Sydney.

[*Abstract.*]

This organism is a parasite Sporozoan, and was first observed in the testes of a considerable proportion of the male specimens of *Hyla aurea* dissected in the Biological Laboratory of the Sydney University. It is found to have its seat in the urinary bladder of male and female under the peritoneum, and in the testes. When well developed, it presents a large oolitic mass of encysted myxosporidia, the presence of which causes the pleuro-peritoneal cavity, especially that of a female charged with ova, to be distended to an abnormal extent. The myxosporidium of the Australian Frog is found to infect, as yet, only one species, viz., *Hyla aurea.*

Hitherto, the myxosporidia have only been found parasitic in fresh-water fish and certain Elasmobranchs. But they have not previously been observed in any of the Australian fauna. Bütschli has described an amœboid myxosporidium from the pike's urinary bladder, and an encysted myxosporidium from the gills of the Cyprinoidea, this latter bearing a striking resemblance to that of the Australian frog. The myxosporidium from the frog presents a number of cysts containing myriads of microscopic spores. Each spore is flattened, oval, bivalvular, $\frac{1}{1500}$th. inch in its greatest length. It contains a nucleated mass of protoplasm and two polar bodies or germs, each having coiled up within it a spiral thread which is shot out on the application of alkalis or concentrated H_2So_4

By the use of iodine the internal contents and firm capsule of the spore are well differentiated, while the nucleus is stained a bright red. Several free germs with attached threads were observed; they were probably released by pressure. Different abnormal adult forms were seen, one spore being pointed; also several intermediate stages between germs and spores. As regards the life-history, the myxosporidium probably develops in the endoplasm a trinucleate protoplasmic globule, two of the nuclei becoming eventually the germs, while the third forms the general protoplasmic contents of the spore. But the actual successive steps in the development of the germs from these nuclei have not yet been fully worked out either by Bütschli in the myxosporidium of the Cyprinoidea, or in the case of the Australian Frog.

8.—ON THE PROTECTION OF NATIVE BIRDS.

By A. J. Campbell, H. M. Customs, Melbourne.

9.—NOTE ON THE NOMENCLATURE OF THE SEXUAL ORGANS IN PLANTS AND ANIMALS.

By F. Jeffery Parker, B.Sc., F.R.S,, Professor of Biology in the University of Otago, New Zealand.

In a recent paper* Mr. R. J. Harvey Gibson makes some very useful suggestions as to the nomenclature of the reproductive organs and their products in plants. The leading idea of this paper is, that the time is now ripe for abolishing the existing multitudinous and confusing terminology of the sexual organs of plants, and for adopting names which shall be applicable to the whole of living things, whether plants or animals, in which such organs occur. The author would get rid of all such terms as oogonium, archegonium, archicarp, procarp, carpogone, and ascogone, and call the female sexual organ an *ovarium* whatever the details of its structure: in the same way he would drop the names antheridium, spermogonium, pollinodium, and antheridial branch, for the male organ, and call it uniformly a *spermarium*. In correspondence with this he suggests the universal application of the name *ovum* to the essential female element, the egg-cell, oosphere, or female gamete; and of the name *sperm* to the essential male element, the spermatozoid, antherozoid, spermatium, or male gamete.

The advantage both to the teacher and to the student of Biology of some such uniform nomenclature would be immense. As Mr. Gibson remarks, the union of the sub-sciences of Botany and Zoology under the one heading of Biology, is the outward and visible sign of a unity of treatment: he instances the adoption of the word *protoplasm* by both geologists and botanists as a notable case in which the "biological" treatment of the two sister sciences has resulted in a simplication of nomenclature of equal advantage to each. I may also adduce the adoption of the word *metabolism* by both vegetable and animal physiologists as another striking example of the same tendency, a tendency which none but a "scarabæist" of the first magnitude will regret. When once the homology of two structures, hitherto known by different names, whether in plants and animals, or in different

* "On the Terminology of the Reproductive Organs of Plants." Read before the Liverpool Biological Society, 10th December, 1887.

groups of plants or of animals, is established beyond all reasonable doubt, the victory should be signalized by a simplification of terminology.

The most serious question which occurs to one in connection with Mr. Gibson's proposals, is whether it will be possible to persuade botanists to drop the use of the words ovary and ovule, in their present incorrect and misleading sense. If only morphologists were as strict as systematists in questions of nomenclature this would have to be done: the morphology of the parts in question being now thoroughly understood, to call a macrosporange an ovule, or part of a sporophyll an ovary, is, and ought to be considered, as great a misdemeanour as it would be for the discoverer of a new beetle to name it *Canis familiaris* or *Quercus robur*. Neither botanists nor zoologists, as such, appreciate the mischievous nature of errors embalmed in words such as those referred to: it is only when animals and plants are studied from the common, or "biological" standpoint, that the pressure is felt, and a teacher feels that he would give a great deal not to be obliged to confuse the already overburdened memories of his students by using the same word for two structures, which have no possible connections with one another, or, by using different words for structures the undoubted homology of which he has to insist on.

Although I should like to see most of Mr. Gibson's suggestions adopted, there are certain objections which occur to me. In the first place I would retain the terms *gonad* (= reproductive organ), *gamete* (= conjugating body), and *zygote* (= product of conjugation) as general terms, using the names *spermary* and *ovary* for differentiated male and female gonads; *sperm* and *ovum* for male and female gametes; *zygospore* for a resting cell or non-motile zygote formed by the conjugation of equal and similar gametes; *zygozoospore* for a similarly formed motile zygote; and *oosperm* for a zygote formed by the union of ovum and sperm.

In the second place I object to Mr. Gibson's use of the word *embryo* as the equivalent of oospore (= *oosperm*: this word is applicable to the young organism up to the time of hatching or of germination, and it is certainly convenient to have the means of distinguishing the fertilized egg-cell or unicellular embryo (*oosperm*) from the multicellular embryo formed from its division, and known as morula, gastrula, embryo of a ripe seed, &c.

In the case of plants exhibiting onetagenesis, Mr. Gibson proposes the term *gamophyte* for the sexual generation, on the ground that the words oophyte and oophore suggest the production of ova, and not of reproductive products of either sex, which is the real point to emphasize. But here it appears to me that Mr. Gibson is not true to the leading idea of his paper. If the terminology in the case in question is to be reformed, what we want is names which will apply equally to animals and plants.

From this point of view the termination *phyte* is obviously inapplicable, as well as the whole name *sporophyte*, since what we wish to express is the fact that the asexual generation multiplies by budding; the fact of the bud being in some cases unicellular (spores), and in others multicellular (zooids) is of quite secondary importance. I, therefore, venture to suggest *blastobium* for the asexual, and *gamobium* for the sexual generation: the former is equally applicable to a fern-plant or a hydroid colony, the latter to a prothallus or a medusa.

The following table, giving a classification of the chief methods of sexual reproduction, will serve to illustrate the applications of the terms proposed, and to show how far they differ from those ordinarily used, and from those proposed by Mr. Harvey Gibson.

Sexual reproduction consists in the conjugation of two cells (*gametes*), the essential part of the process being usually the union of their nuclei. The following are the chief variations in the process:—

A. The union is temporary, accompanied (probably) by an exchange of nuclear material, and followed by increased activity in fissive multiplication: gametes equal and similar, and co-extensive with the conjugating organisms.
Paramœcium, *Stylonychia*, &c.

B. The union is a permanent one, resulting in the formation of a zygote, the nucleus of which is (? always) formed by the fusion of the nuclei of the two gametes.

I. The gametes are equal and similar.

a. The gamete is co-extensive with the organism, the two unicellular sexual individuals undergoing total fusion.

α. The protoplasm of the zygote undergoes multiple fusion, producing numerous flagellullæ or swarm spores.
Heteromita, *Dallingeria*, &c.

β. The zygote is a *zygozoospore*, or free-swimming flagellate cell. *Protococcaceæ*.

b. The gamete is co-extensive with the cell-body of the organism, or is formed by its division into two: the cell-wall or its outer layer takes no part in conjugation. In this case the entire cell may be looked upon as a gonad. Zygote, a *zygospore*, which after a period of rest gives rise to one or more individuals of the ordinary kind. *Desmids*, some *Diatoms*.

c. Gametes produced each from a single cell (*gonad*) of the organism, the greater part of which takes no part in conjugation. Zygote, a *zygospore*, or resting cell.
Mucor, *Mesocarpus*, &c.

d. The gonads take the form of very numerous ellipsoidal spores, each producing numerous ciliated gametes. Zygote, a *zygospore*. *Acetacularia.*

II. The gametes are of equal size, but one (*ovum* or *egg-cell*) is either altogether non-motile or becomes so before conjugation, while the other (*sperm* or *sperm-cell*) is motile. With the differentiation of the gametes the gonads may be distinguished as *ovary* and *spermary* respectively. Zygote, a *zygospore.*

a. Ovum wholly non-motile : sperm amœboid. *Spirogyra.*

b. Ovum ciliated at first, but coming to rest and losing its cilia before conjugation : sperm ciliated. *Ectocarpus.*

III. Gametes dissimilar both in form and size, one the *micro-gamete,* being relatively small and active ; the other, or *macrogamete* relatively larger and passive.

a. The gamete is co-extensive with the organism.

α. A free-swimming micro-gamete conjugates with an action, but fixed macro-gamete. The zygote is active, and indeed is indistinguishable from the macro-gamete, and the only result of the process is increased activity in fissive multiplication. *Vorticella.*

β. A free-swimming micro-gamete or *sperm* conjugates with a macro-gamete or *ovum,* which is a single unicellular zooid of a free-swimming colony. The zygote is an *oosperm,* which, by repeated fission, give rise to a new colony. *Eudorina, Volvox.*

b. The gamete is not co-extensive with the organism : the male and female gonads take the forms of spermary and ovary respectively.

α. Ovary produces one or more macro-gametes or *ova,* spermary one or more micro-gametes or *sperms.* Zygote an *oosperm.*

1. Ovary and spermary multicellular; sperms ciliate: ova ciliate at first but come to rest before fertilization. *Cutleria.*

2. Ovary unicellular, producing one or more ova by rejuvenescence ; spermary unicellular, producing one or more sperms.

i. Two or more ova to each ovary : fertilization extra-ovarian. *Fucus, &c.*

ii. One ovum to each ovary : fertilization intra-ovarian.

a. The oosperm produces the adult organism by direct germination. *Vaucheria.*

b. The oosperm undergoes fission, forming flagellulæ (swarm cells) which afterwards germinate. *Coleochæte.*

3. Ovum produced by rejuvenescence of part, or the whole of the protoplasm of a unicellular ovary. No sperms developed, but the micro-gamete is represented by part of the unicellular spermary. *Peronosporeæ.*

4. Ovary multicellular producing one or more ova by differentiation of one or more of its cells. Spermary multicellular, sperms formed from the nucleus and a portion of the protoplasm of certain of its cells. Zygote gives rise to the adult, or to the blastobium in cases of meta-genesis, by repeated fission.

i. One ovum to each ovary: sperms always ciliate. *Characeæ, Muscineæ, Vascular Cryptoganes.*

ii. Ovary usually produces more than one ovum: sperms usually ciliate, but may be amœboid or non-motile. *Metazoa.*

β. Ovary more or less degenerate, producing a single ovum. Spermary degenerate, producing no sperms, but effecting fertilization by one of the products of division of its nucleus. Zygote an oosperm, forming the adult organism (blastobium) by repeated fission. *Phanerogams.*

γ. The protoplasm of the ovary does not become differentiated into an ovum, and in consequence the zygote never assumes the form of a distinct oosperm.

1. The ovary is provided with a reception portion (trichogyne): the spermary gives rise to non-motile sperms.

i. Ovary and spermary unicellular: zygote divides into amœbulæ which come to rest and germinate. *Bangiaceæ.*

ii. Ovary and spermary unicellular: zygote divides repeatedly forming spores. *Nemalion.*

iii. Ovary multicellular: after fertilization two of its cells become zygotes, which divide forming spores. *Spermothamnium.*

iv. Ovaries dimorphic, some being provided with trichogynes and receptive, others devoid of trichogynes and non-receptive; fertilization of the latter takes place by their fusion either with a receptive ovary, or with a conducting tube given out from it. Zygotes are formed by the non-receptive ovaries only: they undergo division forming spores. *Corallina, Dudresnaya.*

v. Ovary multicellular. Zygote branches and gives rise to numerous asci, in which spores are developed. *Lichens.*

2. Ovary has no special receptive portion and may be unicellular or multicellular. Protoplasm of spermary does not divide into sperms. Zygote branches, giving rise to one or more asci. *Erysipheæ, Discomycetes.*

10.—ON THE ROLE OF SILICA IN THE WHEAT-PLANT, IN DETERMINING A COMPARATIVE IMMUNITY FROM THE ATTACKS OF THE RUST FUNGUS.

By Henry Tryon, of the Queensland Museum, Brisbane.

It is well known that silica is one of the components of the inorganic skeleton of the cell wall of plants, and that though this is so, its total amount in any plant may vary to a large extent without the normal structure of that plant being departed from, and this is especially so in the case of cereals. But though this variation, within certain limits, in the quantity of silica may have little or no influence in enabling a plant to retain its physical structure, it may to some extent determine its capacity or otherwise for withstanding disease, and thus the opinion has been expressed that wheats which are poor in silica are especially subject to the attacks of rust, and more frequently than other wheats, succumb to that disease. Mons. M. Gneymard, in 1859, even went so far as to attribute to this deficiency in silica the cause of the rust, at the same time stating that the wheat-plant should contain as much as sixty per cent. of this mineral.* Again, more than twenty years since (as we are informed in the *Queenslander*, of the 30th May, 1887) there was a pamphlet published, by J. J. Moore, of Sydney, the title of which was "Rust in Wheat." The theory presented by the author was, that the development of the disease was attributable in part to the deficiency in silica—such an important element in the straw.

The reason which lead in either case to the expression of this opinion, as to the influence of silica, is not forthcoming, but it was probably founded on the observation that wheats in which this mineral was deficient, were more subject to rust than were those in which it was largely represented as a constituent body.

In the case of M. Gneymard, this view received confirmation from M. Bouquet, an agriculturist of great experience, who recorded as the result of his own observation that—in the

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* Comptes Rendus, 1859, xlix. p. 547.

province of Marn, where—as in the neighbouring arrondisements—the soil reposed on a great bed of chalk, and though rich in nitrogenous matter, was accordingly largely composed of carbonate of lime, the wheat crop was always very subject to rust. With M. Gneymard's opinion before him, he was now able to explain this, as also the fact, which he too had noticed, that all varieties of wheat did better on land which contained silica, that all wheats seemed to require this mineral—even the short-bearded varieties which could do with the least amount of any; and lastly, that when wheat growing in such a soil as he had described, was manured with compost rich in nitrogenous plant food-substances, the crop, as far as immunity from rust was concerned, did best which received the manure which, though in other respects the poorest, contained the largest amount of silica.

The opinion too receives further corroboration from the experience that, of so-called rust-resisting wheats, the hard wheats, *i.e.* the pericarp of whose seed contain an unusually large amount of silica, are those which withstand the attacks of this fungus in the greatest degree, and the unusually large amount of silica contained in the skin of these hard wheats is indicative of the fact that the whole plant is unusually rich in this mineral also.

No attempt to arrive at an explanation of the rôle performed by silica in this connection has, as far as we can learn, ever been made. Now it may be assumed that the rust-fungus lives and grows at the expense of bodies genetically related to sugar, *i.e.* the glucosides, or soluble forms of starch, which it finds in the perrenchymatous tissue of the leaf, where it is located either within the cells, or the cell walls, or as most frequently, in the intercellular spaces. And that it does so subsist at the expense of the soluble forms of starch and gluten, is plainly indicated by the fact that these bodies are almost absent in "rusted" wheat plants. This food-material is derived from the starch of the neighbouring chlorophyl-containing tissue, from which it passes by a process of osmosis, glucosides possessing the greatest power of endosmosis of all vegetable substances of equal density with them. The degree of osmosis, however, for the same body, varies with the same composition or nature of the membrane through which it takes place, and nothing so much determines its amount as the presence of silica to a greater or less extent, vegetable substances especially, as is a well ascertained fact—being permeable by osmosis in indirect proportion to the amount of silica which they contain. The formative substance then of the cell walls of the tissue of a wheat-plant when largely composed of silica, would, therefore, form a much greater hinderance to the passage of these food materials of the *Puccinia* to the tissue in which this fungus grows, than would one in which silica was little developed; in other words, non-siliceous wheats would be those which were most favourable for the support of the Rust-fungus.

This explanation amounting to the establishment of an *a priori* probability as to the siliceous wheats being comparatively rust-proof is corroborative of the experience that they possess this character, and we can only point then to the desirability of growing wheats of this class. It is not merely necessary for us to sow hard wheats, for the character of the succeeding generations derived from this seed will possess this character, or not, according to the nature of the soil on which they are raised. That wheats may be made to, and do, differ in this respect might be regarded as certain, even if it had not been demonstrated to be the case by actual experiment, when it is considered that all the varieties of wheat have arisen from a few—at most—different kinds, and chiefly under the influence of change of soil. We are, however, enabled by way of making this appear more evident, to state, on the authority of Lyon Playfair, F.R.S., and by reference to a "Table showing the Composition of the Ashes of Wheat," which he quotes as follows:—The grain of a wheat — "Hopetoun Wheat"—on analysis by Messrs. Way and Ogden was found to contain 5.91 per cent. of silica, and on being used as seed gave, when grown on one soil, 1.42 per cent. of silica, and 2.84 per cent. (or just double the amount) on another; finally the same Hopetoun Wheat when grown on a sandy soil became so siliceous that the silica in its grain amounted then to 5.63 per cent. Analyses of the grain of another wheat, viz.: "Red straw White Wheat," showed that the silica in it ranged from 2.05 to 9.71 per cent., according as it was grown on "loamy soil in the Greensand" or "calcaseous soil in the Magnesian Limestone formation.* From this it may be seen that wheat originally rich in silica, on cultivation, may become poor in that mineral, and that the proportion in which silica is present depends on the nature of the soil—a nature which can be modified by ordinary agricultural processes.

The manner, however, in which a soil poor in assimilable silica, may be rendered well endowed with respect to this mineral will be best indicated on consideration of the process by which the plant obtains its silica component from the ground. The direct assimilation of soluble silicates being as a theory dismissed for reasons which I shall immediately adduce, we may state that it is now usually held that silicon is taken up by plants in the form of a very dilute solution of silicic acid, or as gelatinous or colloidal silica, and not directly in that of the soluble silicates of soda or potash. These salts, even if they could exist in a soil poor in uncombined silicic acid, being decomposed at the points of contact of the root hairs with the soil and by the carbon dioxide which they inhale. This is the view taken by the justly celebrated plant physiologist, Julius Sachs, Professor of Botany in the University of Würzburg. He adds, that by far the larger part of

* "A Cyclopedia of Agriculture," edited by John C. Morton, s.v. "Ashes," Vol. I., p. 143.

this silicic acid passes into the insoluble state within the cell walls; but he does not, however, refer at all to the soluble alkaline silicate.

That silica is also taken up directly by the roots in a minutely divided state, and by some process unrecognised by vegetable physiologists, seems also probable in view of a discovery announced by Prof. P. B. Wilson, of the Washington University, that Diatoms, *i.e.*, microscopic organisms whose pustules are almost wholly siliceous, are present within the tissues of the straw of wheat, grown under circumstances favourable for their obtainment, and to adopt the title of his memoir on this subject, that "Silica of grasses and other plants (are) carried up as diatoms or other siliceous grains and not in a solution as soluble silicates.* In this record of his researches, Prof. Wilson states that he found generally that the silica in the ash of plants, obtained by slow incineration, had different properties from "silicates soluble in acid or those decomposed with sodium and potassium carbonates," and that its appearance showed that it had been assimilated in a free state. Further, that the straw of wheat grown in infusorial earth, contained under this circumstance siliceous matter wholly composed of the siliceous shields of Diatomaceæ in their original form and identical with those contained in this earth—the larger discs only of the species being absent. The question of how these siliceous grains do, as it seems they do, effect an entrance into the plant-structure, through the medium of its roots, is not discussed by Prof. Wilson, but it would seem to us that some light is thrown upon the subject by the quite recent researches of H. Marshall Ward, M.A., F.L.S., relating to the entrance of some germinal elements of a particular fungus into the root hairs of the vetch.†

We may next consider the value of the Darling Downs soils in respect to their possession of assimilable silica. Are they rich or poor in this desideratum of the properly constituted wheat plant? Some light may be thrown on the subject by an examination of its soils, but it would seem that our immediate inquiry will best be answered if attention is confined to wheat plants raised there. What amount of silica then do they contain?

Unfortunately, however, we have no data which will supply this information. The constitution of the straw of wheat raised in the wheat-growing districts of the colony, and especially on the Darling Downs, has not been made the subject of scientific investigation, but that the wheat raised in the latter district is poor in silica is a very prevalent opinion. Thus, "A Farmer's Friend" in the *Queenslander*, 30th May, 1887, states, "If any of your readers will compare the wheat straw which they will remember

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* American Journ. Sc. 1876, XI. pp. 373-4.

† *Vide* "The Tubercular Swellings in the Roots of the Leguminoseæ." Proc. R. Soc., London, XLII., No. 255, p. 331.

to have seen in Britain with that grown on this side of the world, I think they will find a great difference, the latter being much softer than the former."

We fare little better when we come to investigate what is known concerning the physical or chemical nature of the Darling Downs soils. An analysis made in England by T. Hughes, F.C.S., of a soil from Killarney, which the late Mr. R. Daintree described as being "a fair average sample of the black soil" of the Darling and Peak Downs, and of the Volcanic Districts of Queensland generally," showed that this soil yielded on analysis 49.416 per cent of insoluble, and 17.944 per cent. of silica soluble in alkali, or a total of 67.360 per cent. of silica.*

Again from analysis made by Mr. K. T. Staiger, of nine samples of what he designates "dark rich chocolate brown soil . . . . . especially adapted for wheat-growing," and procured by this chemist from the northern Darling Downs, near Jimbour, we find that they contain on an average 17.411 per cent. of silica soluble in alkalies, and 51.317 per cent of insoluble residue, or a total of 68.728 of silica and clay.†

According to an analysis made by Professor May, we find, on calculation, that the amount of silica removed from the soil by wheat, taking the average of twenty crops, was 80 per cent. of the total quantity of material obtained by it from this source of 12 per cent. more than M. Gueymard (*Vide* p. 343) stated should be the proper amount of this mineral present in the same cereal. According to investigations of Professor Wilson, to which we have alluded, the state of the division in which the silica exists in soils when testing their capability of growing siliceous, and so perhaps rust resisting wheat becomes a matter of great importance. As far as we are aware no mechanical examination of Darling Downs soils has been made, and in the absence of the information derivable from such examination the mere chemical estimation of its constituent elements becomes of subordinate importance only.

11.—ON THE NEPHRIDIA OF EARTHWORMS.

By W. Baldwin Spencer, B.A., Professor of Biology in the University of Melbourne.

12.—ON SUCCESSFUL RABBIT-SUPPRESSION IN NEW ZEALAND.

By Coleman Phillips, of Wairarapa, New Zealand.

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*Analysis of Queensland Wheat and Sugar Soils, with Dr. Völcker's Report on their fertility, 1874. p. 17.

†Report to Queensland Investment and Land Mortgage Co. Limited, 28th April, 1887.

13.—A COMPARATIVE STUDY OF STRIATED MUSCLE.

By WILLIAM A. HASWELL, M.A., D.Sc., Lecturer on Biology, University of Sydney.

[*Abstract.*]

A CONSIDERABLE proportion of the discrepancies to be observed between the statements of different authors as to the distribution of striated muscle are to be ascribed to a confusion between two perfectly distinct tissues—simple striated muscular fibres and compound striated muscular fibres — the former comprising a number of very distinct kinds differing from one another in the nature of the transverse markings, the latter all conforming to one general type.

Of the compound striated fibres (with which alone the present paper deals in detail) examples are to be found only in the Chætopoda (*Syllis*, *Nephthys*), in the Arthropoda, and in the Vertebrata. A detailed account is given of the structure of these fibres in *Syllis*, where it is shewn that the number of transverse networks in a fibre varies in the case of different species from one to twenty. In the simplest form—as it occurs in the wall of the gizzard of *Syllis nigropunctata*—the compound striated fibre consists of a hollow cylinder, the walls of which are composed of fibrils, readily distinguishable in the fresh condition, and bound together in the middle by a single transverse network crossing a median isotropous zone of the fibre with anisotropous zones on either side of it. In a second species (*S. kinbergiana*), there is an increase in the number of transverse networks to three, with a corresponding increase in the number of isotropous and anistropous segments. In *S. schmardiana* there are about seven transverse networks, and in *S. corruscans* there are fifteen to twenty. In the last-named species the fibres are in all essential respects identical with the striated fibres of the Arthropoda and Vertebrata, differing from these only in the greater distinctness of the constituent fibrils and the greater coarseness of the "striations"—the distance between successive transverse networks being as much as 0·03mm.

Evidence is adduced in support of the view that each of those compound striated fibres is the equivalent not of a single non-striated fibre, but of a bundle of the latter connected together, first by a single transverse network, afterwards by several; and in the case of certain species of *Polynoë* it is shewn that each of the simple fibres which take the place occupied in the same organ

by the striated fibres of *Syllis* is made up of an outer isotropous and an inner anisotropous segment. The formation of the first transverse network in such a form is supposed to have taken place by the establishing of communications between the intra-nuclear filaments of the internal nuclei found in the middle of the isotropous segments; this communication having been brought about owing to a necessity for simultaneous contraction.

14.—ON SACCULINA INFESTING CRABS IN PORT JACKSON.

By William A. Haswell, M.A., D. Sc., Lecturer on Biology, in the University of Sydney.

15.—PRELIMINARY NOTE ON THE BELL PIG.

By T. P. Anderson Stuart, M.D., C.M., Edin., Professor of Anatomy and Physïology, in the University of Sydney.

16.—ON A NEW AUSTRALIAN MAMMAL.

By E. C. Stirling. M.A., M.D., Cantab., Lecturer on Physiology in the University of Adelaide.

Through the kindness of Mr. A. Molineux, of Adelaide, a small mole-like animal, which appears to be new to science, was forwarded to the South Australian Museum, Adelaide.

It was found on the Idracowie Cattle Station, at a distance, I understand, of about one hundred miles from the Charlotte Waters Telegraph Station, on the overland line from Adelaide to Port Darwin, but the exact circumstances of its capture are not yet to hand. The collector, however, reports that it must be of rare occurrence, as on questioning the aboriginals of the locality, there was only one old woman who said she had seen it before, and that upon a single occasion.

It is evidently an underground burrowing animal, resembling somewhat the Cape Mole (*Chrysochloris*) in its general external appearance, but differing in many respects.

The total length is 13 cm., inclusive of the tail, which is 2 cm. long. The head, relatively shorter than in *Chrysochloris*, has a rounded muzzle, the dorsal surface of which is covered by a horny shield. Nostrils transversely slit-like. No eyes visible, the skin passing uninterruptedly over the ocular region, but on reflecting the skin on one side of the face a small circular pigment spot is visible in the position of the eye. No apparent bony orbit. Tongue fleshy, broad at the base and tapering to a blunt point. No external ears, but the ear-openings distinct, 1 mm. wide, and covered over with fur.

The fore-limbs are short, resembling somewhat those of a mole, but the manus is folded, so that the large nails of the fourth and fifth digits only are visible in the natural position of the limbs. Of these nails the fourth is 15 mm. long, and of a uniform width of 4 mm., ending very bluntly; the fifth is very slightly shorter than the fourth, broad at the base (8 mm.), tapering rapidly to a blunt point, the two together forming an outline rather like that of a goose-mussel *(Lepas)*. The nails of the third, second, and first digits, very much smaller, form a series gradually diminishing in size, in the order named, and constitute a second row on the inside of the fourth and fifth, by which, as stated, they are completely concealed from view. What corresponds to the palm is the cleft between the two rows of digits.

The hind-limbs are also short, with the soles turned outwards. What appears to be the fifth (anterior) digit, is very short, with a short, broad and strong nail; the fourth is armed with a long (7 mm.) narrow, curved and sharp claw, while the claws of the third, second, and first are broad, flat, rounded at their points, and joined together by a membrane which extends nearly to their points. On the sole there is a hard, elongated, horny tubercle crossing it transversely.

The tail 2 cm. long and 5 mm. wide at the insertion, tapers to 3 mm. and terminates in a knob-like tip.

About 15 mm. in front of the vent *(cloaca)* there is a pouch in the integument about 4 mm. wide, with the opening directed backwards, and having a depth in a forward direction of from 4-5 mm. The surface of this pouch is devoid of hair, but the bare area is surrounded by thick fawn-coloured fur with a slightly reddish tint; it is possible, however, that this reddish tint is due wholly or in part to some ferruginous-looking sand, which is much mixed up with the fur. The body generally, with the exception of the lower two-thirds of the tail, which is bare, is covered with fur of a rather lighter tint.

With regard to the internal parts it is unfortunate that the specimen came to us completely eviscerated, and in a bad state of preservation generally, but in a small part of the lower bowel which was left, remains of ants were found. The bowel terminates at a wide vent (*? cloaca*), and I can find no trace of a separate genital aperture, nor of such openings into the supposed *cloaca*.

I have not yet had time to examine with minuteness the skeleton, which unfortunately is also considerably damaged, especially about the occipital region, but from a cursory examination of the recently skinned body I can note the following points. with I believe accuracy. Cranium relatively large. No bony orbits. Zygomatic arches present. Well developed shoulder girdles with slender clavicles. Pectoral muscles large. Pelvis large and strong with a rather wide symphysis, but no epipubic bones either actual or rudimentary. Ribs fourteen. Angle of lower jaw markedly inflected.

The teeth are peculiar, and require a more extended description than I can give at present, but the formula appears to be

$$i\,\tfrac{3}{3}\;c\,\tfrac{1}{1}\;m\,\tfrac{6}{5}\;\left(?\,\frac{\text{p. 2 m 4}}{\text{p. 1 m 4}}\right);$$

this, however, may require some modification as just posterior and external to the præmolar (or first molar) of the right ramus of the mandible, there is a small rudimentary conical tooth which is not to be found on the opposite side, or at corresponding positions in the maxilla.

I cannot help being struck with the resemblance both of the lower jaw, and of the general characters of the teeth, to figures of the jaws of *Amphitherium*, as figured in various osteological works.

SECTION E.—GEOGRAPHY.

President of the Section, The Hon. John Forrest, C.M.G., F.R.G.S., &c., Surveyor-General of Western Australia, &c.

THURSDAY, AUGUST 30.

The President delivered the following Address:—

I DO not think it advisable on this occasion to confine my remarks to a particular subject, as is usual in old established societies, as I think a few general observations on subjects within the wide scope of the Geographical Section of the Association will be more useful on the present occasion.

The map of Australia, which you see before you, must be familiar to all persons who claim Australia as their home. It is a vast territory, being about thirty-three times as large as England and Scotland, about the same size as the United States of America, and about two-thirds the size of the continent of Europe.

The present territorial divisions are five, viz., New South Wales, Victoria, Queensland, South Australia, and Western Australia, and each of these divisions has its own independent government, though the laws of each differ but slightly from one another.

There is not time on this occasion, nor do I think it is either necessary or advisable that I should place before you how Australia has been little by little discovered, how its coasts have been carefully examined, and its interior has been traversed and mapped. for these things should be known to all who claim Australia as the land of their birth, or of their adoption. It is not given to many to be the means of opening up new territories, to describe for the first time new districts, and to be the first to gaze upon lands hitherto only known to the savage, and of the list of explorers who have indelibly inscribed their names on the map of Australia, but few now remain amongst us. They have, however, left us their journals and their maps, and these have been collected by able hands, and form a most interesting and complete history of the early days of our civilisation and progress.

To the young these records must always prove interesting and fascinating, and I should like to see the history of Australian exploration introduced into our schools, and carefully taught: for what more useful work can there be than the history of the way the continent we live in, and which we love so well, has gradually been opened up to the enterprise and commerce of the world.

Australian exploration of the adventurous kind is fast becoming a thing of the past, within but a few years Australia has been changed from a *terra incognita* to a country whose coasts are traversed by the world's steam ships, whose central interior has been crossed by the electric telegraph wire, and whose broad pastures have been stocked with cattle and sheep. What a wonderful change has taken place during the past one hundred years. No one, I venture to think, of those who first landed at Sydney one hundred years ago, even in the wildest flight of his imagination, could have imagined that the change would have come so soon. And the question arises, what will Australia be like in another hundred years? It is scarcely possible to imagine, and no great good can arise from such thoughts, except to stimulate us to greater exertion.

The old way of travelling by cart and coach, which is familiar to many of us, has given way to the railway; the old way of shepherding our stock is fast disappearing; the old way of tilling and reaping has been superseded; in fact, our present ways are not the old ways, and so it must be in the work of exploration also—the old way must be superseded by the new. No longer must it be the love of adventure, and the fascination of discovering new mountains and new rivers, but our aim must be to examine and map the treasures of the earth. The man of science must now with care, and with skill, and with slow but sure steps follow in the path of the early geographical traveller, and to the prosecution and accomplishment of this great work, I would commend the government and people of this great country.

The Geographical Section of this Association has a great work before it, not perhaps so much in adventurous travel or in the discovery of great natural features, but in scientific research and minute and careful observation. The outside superficial work has to a certain extent been accomplished, but the real scientific investigation remains to be completed.

I hope it may not happen in the future, as it has happened in the past, that this great work is to be carried out under difficulties for want of encouragement and support.

Although the work of exploration and discovery has, to some extent, been accomplished, it has been done under the greatest difficulties, and the governments of the different colonies have never assisted the exploration of the continent in the way it deserved.

As a rule, expeditions have been badly provided, have received but scant encouragement, and have had but small governmental support. Those in power have been unable to realise the position, and have, as a general rule, not seen far enough ahead.

It has therefore happened that fertile tracts of country have remained unknown and unutilised for years, just because a government has not had sufficient knowledge and enterprise to have it examined and reported upon.

Many instances could be given of this want of enterprise, I might even say neglect of duty, by the different governments of Australia. Surely the first duty of a State is to find out what its territory consists of, and any government which neglects this duty is not worthy to be entrusted with the care of such territory.

Even at the present time we are not doing as much as we should do. How much a year does Australia expend on its scientific departments? Are we anxious to obtain the services of the best scientific men, or are we not rather trying to confine the scientific departments to the narrowest limits? How often do we hear the representatives of the people insult and decry the man who has made science the study of his life, entirely forgetting that the scientific man alone can give us the information we require, and that even the practical miner is dependent for what knowledge he possesses to some smattering of the science, the students of which he sometimes pretends to despise.

When it is considered what a great advantage it would be to Australia as a continent not only to have its topography accurately established, but also to have its geological, botanical, and zoological characteristics clearly and faithfully described, it should not be difficult to convince the governments and people of the continent that this is a great national work, and that the sooner it is completed the better it will be for the progress and prosperity of us all.

The cost will be as nothing compared to the results to be anticipated, and I look forward, most earnestly, to the further and more active prosecution of this great work, and in the prosecution of such a work this Association should take an active part and have great influence.

This Association, which I confidently believe will do a great work in the future, has a splendid field for its duties. A continent lies before it the treasures of which have yet to be discovered, and it is quite certain that the mineral wealth of Australia is known only to a very slight extent indeed. Many millions of square miles have never yet been seen by the white man, and, consequently, their character is almost if not entirely unknown.

Surely, in the present state of our progress, this condition of things should not be allowed to continue, and the foundation of the Association will, I trust, give new life and energy to the people of Australia to begin at once the great national work of scientifically examining the whole of the continent.

As far as pastoral pursuits are concerned the enterprise of the squatter has done good and lasting work, and the settling of stock on the available lands of the continent may with safety be left to the energy of this able and intelligent class, but, in order to enable Australia to become the home of millions of our race, there are two things which must receive our immediate and continued attention.

The first is the conservation of water for the irrigation of the soil, and the other is the systematic and careful survey of the mineral character of the continent. The first will enable Australia to produce sufficient to support a large population, and the other will produce sufficient for wealth and comfort.

The subject of irrigation is one that is most important to our future, for there is no denying the fact that, taken as a whole, Australia is a country in which permanent surface water is scarce. As a general rule there is a sufficient rainfall, and in many places there are running rivers and springs, and therefore the work of irrigation will not be very difficult, and must be productive of great benefits. Hitherto, however, want of means and ample scope for ourselves and our flocks and herds, has either prevented or has obviated the necessity for turning our attention to this most necessary and beneficial work, but enough has been done to show us what a change will take place in Australia when our population has increased even say tenfold, and our resources are correspondingly developed by the means of irrigation. Necessity must force the matter forward, for by no means of irrigation alone, can Australia be made to support the population which in a few years will inhabit it.

In considering the question of irrigation, it is interesting to examine the drainage, or river systems of Australia, and on the map before you I have sketched the six distinct systems, viz. :—

1. The Western coast rivers.
2. The Northern ,, ,,
3. The Eastern ,, ,,
4. The Murray River.
5. The rivers emptying into Lake Eyre.
6. The area without any extensive drainage system.

The western coast rivers drain a large extent of country, but as a rule the watershed is low, and except in the case of the rivers on the N.W. coast the alluvial lands are not very extensive. In the S.W. corner the climate is excellent, the soil productive, and the rainfall ample, and this corner of Australia will, in the future, I believe, be the home of a large population.

The northern river system is extensive, though the rivers are as a rule short, and owing to the height of the watershed the alluvial plains are generally extensive. This portion may be considered to comprise tropical Australia, and is destined to be a large producing territory in the future.

The system of drainage on the eastern coast is not very extensive, and the watershed is of considerable elevation, and not far distant from the coast, consequently the rivers are short, and, owing to the rapidity of the descent, the alluvial lands are very extensive and rich, and owing to its many advantages will always be the most productive and most populous portion of Australia.

The Murray River system is most important and most extensive. This is one of the principal drainage systems of the continent, and will no doubt be largely utilised in the future for irrigation. It drains a fertile territory, has a temperate climate, and must therefore always be an important producing district of Australia.

The system of drainage into Lake Eyre is one of the most extraordinary, as this lake receives the drainage of an immense area, and has at present no outlet, though no doubt at one time there must have been an outlet by Lake Torrens to the sea at Port Augusta.

The large area colored yellow on the map has no river system, and no drainage into the sea, as between Cape Arid and Port Lincoln, a distance of nearly 1000 miles, there is not even a rivulet running into the sea. The rainfall over this immense area is absorbed in the ground, or forms short watercourses leading into depressions. This is caused by the low elevation of the interior, the absence of any extensive mountain ranges, and the limited and uncertain rainfall of the interior forming marshes which are invariably salt.

A careful study of these different drainage systems I have referred to, and of the rainfall throughout the continent, will, I think, show that there is generally no lack of water if means were devised for conserving it, and that immense areas now altogether unutilised can be made productive by the judicious expenditure upon waterworks of a permanent character.

The present divisions of Australia cannot but be a subject of great interest well worthy of consideration, and in dealing with the question it is necessary that we should ascertain by what rule or method the existing boundaries were determined upon. I fear we must admit that the method pursued was a haphazard cne, arrived at without any knowledge or regard for the natural features or the climates of the different territories.

The boundaries were, as a rule, certain lines of latitude and longitude, and as Australia has progressed these lines have been made to divide the people of one colony from another. The question naturally arises whether it is reasonable that these divisions can or should be maintained in the future.

Take, for instance, the Murray River, which divides New South Wales from Victoria. On either side we find the same people, the same language, the same religion, the same occupations, and the same interests. Are these people likely to be content to live under different laws, to be pestered by different tariffs, and to be made antagonistic to one another by having a different government? The same may be said of Victoria and the southern part of South Australia, and of New South Wales and the southern portion of Queensland, and to some lesser extent of the southern portions of South and Western Australia, though in this last case they are at present divided by a considerable extent of unoccupied country. When we come to Northern, or tropical Australia, the case is more unreasonable still. Is it likely that Northern Queensland, Northern South Australia, and Northern Western Australia, all of which have the same climate. and are snitable to the same productions and industries, are for long to be content to be divided from one another by lines fixed in a haphazard manner, by different laws, different tariffs, and different governments, with but little if any voice in their local self-government? And this brings me to another subject of great importance, viz., the question of the Federation of the Anstralian Colonies.

The question of federation must occur to every one who thinks of the future of Australia, and the problem we have to face is, how far we are to regard ourselves as the people of one, or of different countries.

One of the charms of visiting the United States, or Canada, is the feeling that you are under one flag and one law, and after visiting those countries, as I have recently, the fact that Australia is divided into five divisions is forcibly brought before me. Our tariffs wage war against one another, and even our laws are dissimilar, and in many respects we are to one another but as the people of foreign nations.

No doubt there are great difficulties and great prejudices to be overcome before federation takes place, for the different colonies and their different governments will lose their prominence, and the Dominion Government will alone be known in the world. This is a very serious obstacle to the ambitions of each colony, and will play an important part in preventing the federation of Australia.

For instance, we may all know who is the President and Ministers of the United States, or the Governor-General and Ministers of Canada, but how few of us know anything, for instance, of the local governments of the State of California, or of the Province of British Columbia? The states and provinces are merged in the Central Government and Legislature, and it will be difficult to convince the colonies of Australia that it is desirable to sink their individual prominence and become merely a facter in the central government. Yet if we can overcome these selfish or ambitious feelings we will, I think, be convinced that to be federated will be to our material advantage.

If Australia could speak with one voice, how much more important would she be? If her tariffs were identical what a market within herself for free competition would there be? If Australia were federated how long would the different colonies remain separated for want of railway communication? We should have a railway from west to east and from south to north, we would be able to enter a railway carriage at Fremantle and in a few days step out of the same carriage at Sydney, in the same way as you may enter a carriage on every Tuesday evening at Montreal, and at midday next Tuesday step out of the same carriage on the shores of the Pacific Ocean at Vancouver.

But a few years ago it was not considered as practicable that the Atlantic and Pacific Oceans would be connected by the iron road, but in these few years a large number of routes have been opened by which you may cross from New York to San Francisco.

Again, the Canadian Pacific Railway, connecting as it does the eastern and western provinces of Canada, was for a long time looked upon as impracticable, but it is now completed, and has resulted in the federation of Canada, the Western State of British Columbia only entering into the Dominion, on the condition that daily railway communication should be established between the Atlantic and Pacific Oceans. In a similar manner federation in Australia would require, as an indispensable condition, daily communication by railway between the colonies of the continent. To be an Australian will then be a prouder title than to be a New South Welshman, a Queenslander, a Victorian, a South Australian, or a West Australian, and so much is this even now felt that it is becoming the practice for persons hailing from any of the colonies to call themselves Australians, feeling no doubt that the title of continental Australia sinks all other minor divisions.

If we are to become a nation, to be the great power in the southern hemisphere, it can only be by being federated, to be allied to one another, not only by the ties of nationality and kindred, but also by all those material bonds which operate so strongly in our dealings with one another.

Our aim should be to make Australia another Britain, another home for the Anglo-Saxon race.

In our prosperity, however, I trust we will never forget the land of our fathers, the dear old mother country, to which we owe our existence as a people, from which we derive our laws and our liberties, and from which we have a right to a glorious heritage.

In conclusion I may express a hope that this Association, which has made a good beginning, may continue and prosper, and may follow in the paths of its great progenitor, the British Association. We may be certain of receiving every encouragement from the learned societies at home and abroad, and we have before us a great work and a great future.

If in my address I have wandered away in some measure from what may be considered the subject of geography, if at one moment I have treated of early travel, at another of future scientific research, at another of the conservation of water and the irrigation of the soil, while at another time I have touched upon the subject of Australian federation, it is because I consider that the term geography covers a very wide area, and embraces or is allied to so many questions of great importance to us, and in which colonial history and colonial enterprise are connected, that it was necessary or desirable that I should, on this occasion, treat the subject from a purely scientific point of view.

The following papers were read :—

1.—EMIN BEY AND HIS SURROUNDINGS.

By Sir Edward Strickland, K.C.B., F.R.G.S., Treasurer of the Association.

2.—THE PHYSIOGRAPHY OF THE AUSTRALIAN ALPS.

By James Stirling, F.G.S., F.L.S., Geological Survey of Victoria.

[*Abridged.*]

Topography.

The highest altitudes in Australia are to be found in the south-east portion of the continent. On the Main Dividing Range parallel to the south-east coast line, and on the lateral spurs proceeding from it, are the highest mountain peaks and most elevated plateaux, embracing an area of unique interest to the student of Physiography.

Here are to be found climatic zones wherein to study important meteorological phenomena ; the endemic vegetation is necessarily varied, depending on such climatic conditions ; while in the character and composition of the great rock masses of which the mountains are built up we have in the words of an able writer*—" An unrivalled field wherein to study the mutual relations of the sedimentary, metamorphic, and igneous rocks."

As a mountain system the Australian Alps are undoubtedly older than the European, African, or Himalayan.† The lava flows of the Tertiary period have not partaken of the folding process which characterize the European Tertiary formations. Long

* A. W. Howitt, Devonian Rocks of North Gippsland. Progress Report, Geol. Surv. Victoria, No. 4, p. 75.

† R. von Lendenfeld, Exploration of Victorian Alps. Gold-fields of Victoria, March, 1886, p. 71.

continued sub-aerial denudation had sculptured the upturned Silurian and Devonian systems into mountain and valley during the period when the ranges forming the higher elevations of much of the European Alps were being deposited on the sea floor as fine and coarse sediment. The Mesozoic formations are entirely absent in the Australian Alps.

Although locally deflected round the Livingstone Creek sources from Mount Hotham, the Main Dividing Range trends north-easterly from Mount Howitt at its western, to Mount Kosciusko at its eastern extremity. It presents a diversity of surface contour, rising into coned peaks at the Twins, 5,575 feet; into a rounded height at Mount Hotham, 6,100 feet; spreading into minor table-lands at the Paw Paw and Ormpin Plains, 4,000 to 4,500 feet; falling in low gaps as Tongio Gap, 2,600 feet (which afford the readiest access from the northern areas to the coast region); rising into escarped peaks, as Mount Tambo, 4,700 feet; into rugged terraced mountains like the Cobberas, 6,025 feet; to another coned peak, Mount Pilot, 6,020 feet; and finally culminating in a series of elevations at the Kosciusko plateau, 7,256 feet above sea level—the highest altitudes in all Australia.

The contours of the natural watershed lines dividing the principal streams, as the Ovens, Kiewa, Mitta Mitta, and Hume, flowing northerly into the Murray; and the Mitchell, Tambo, and Snowy Rivers flowing southerly into the Gippsland Lakes and Southern Ocean, are also extremely varied, as on these the loftiest plateaux occur—notably the Bogong High Plains to the north, and the Snowy, Dargo, and Nuninyong plateaux to the south.

Starting from the western extremity of the area at Mount Howitt we find the watershed line between the Mitchell and Macalister Rivers traversing an elevated table-land—the Snowy High Plains, at an altitude of 5,000 feet—and connected further south by a ridge with Mount Wellington, near which has recently been discovered a morainic lake, and from the summit of which a magnificent view of the lacustrine area of Gippsland is obtained.

Further to the eastward a ridge proceeds from Mount Selwyn in a northerly direction between the Buckland and Buffalo Rivers (both tributaries of the Ovens), and rises to the bold Buffalo Mountains.

From Mount Hotham, still further east, several main watershed lines radiate. One narrow and serrated ridge proceeding northerly between the Ovens and Kiewa Rivers culminates some seven miles distant in Mount Feathertop, 6,303 feet. Another, bearing north-easterly, and dividing the Kiewa and western tributaries of the Mitta (as the Cobungra, Bundarrah, Big River, and Snowy Creek) rises within three miles of Mount Hotham to a rounded peak, Mount Lock, 6,175 feet, falls away to a low gap at the head of the Cobungra River, 4,000 feet; then rises to the Bogong high plains table-land, 6,000 feet. This plateau, the highest in Victoria, is further connected by a narrow, low, and sinuous ridge, with Mount Bogong, the highest mountain in Victoria, at an elevation of 6,508 feet above sea level. South from Mount Hotham, an undulatory and sinuous ridge, separating the waters falling into the Wongungarra and the Dargo Rivers (both tributaries of the Mitchell), rises some eight miles distant from the Dargo High Plains, 4,000 to 5,000 feet above sea level.

An extension of the western watershed line of the Mitta Mitta forms the picturesque Omeo Plains, a depressed table-land 2,000 to 3,000 feet, with a small lake, the Omeo lake, on its western margin.

Easterly from the Omeo Plains and on the watershed line between the Tambo and Buchan Rivers (the latter a tributary of the Snowy River), is situate the Nuninyong table-lands, 4,500 feet; while still further easterly on the divide between the main Snowy River and the Buchan, is found the Gelantipy table-land, These elevated and now disconnected plateaux of basaltic rocks would appear to have been united during Middle Tertiary times as one vast mountain plateau.

The physical features and scenery of the higher table-lands are distinctively Alpine, and whether we examine the Kosciusko plateau, or the Bogong High Plains, the surface features and physiognomy of the vegetation are the same.

PHYSICAL FEATURES OF THE MAIN VALLEYS.

It follows from the remarks already made concerning the former existence of a once vast extent of table-land throughout the area now occupied by the Australian Alps, that the valleys are mainly valleys of excavation. And that many of the higher points within their catchment basins, are made up of those harder rock masses which have longest resisted the detritive agencies by which the softer rock masses were abraded.

At the same time it is in the plutonic disturbances which characterised the close of the Silurian, and extended through the Devonian periods, that we must recognize the influences which dominated in the evolution of existing contours by the conversion of the softer sedimentary rock masses into crystalline schists, or the intrusion of molten masses, which on subsequent cooling acquired a hard crystalline aspect. Similarly in Tertiary times the Miocene lava flows, sealing up the valleys, have left dense sheets of basalt which have resisted the denuding action of the atmosphere while the softer adjoining ranges have been degraded. The contours of the valleys there necessarily depend on the character of the rock masses out of which they have been excavated.

Above the township of Harrietville, the upper affluents of the Ovens are torrential, and have sculptured deep hollows in the flanks of Mounts Hotham and Feathertop; below it, the main stream winds through alluvial flats which vary from one to two miles in width. The boundary ridges form steep sidelings rising suddenly from the flats.

The Kiewa rises at Mount Hotham (Diamantina spring),* and draining the eastern slopes of Mount Feathertop, and the western slopes of the Bogong High Plains, its upper affluents form a series of cataracts, where the source runnells fall rapidly away from the table lands. Huge boulders occupy the valley, many of them shewing evidences of glacier transportation.

Below the Mountain Creek settlements at the base of Mount Bogong, wherein the Mountain Creek heaped up masses of morainic debris occur, the valley widens and the hills undulate, and fine alluvial flats, from one to two miles in width, bounded by extensive terrace deposits are found. The latter present indisputable evidences of the wide spread deposition of materials during the pluviatile period which succeeded the breaking up of the glaciers occupying the higher valleys of the Australian Alps since Miocene times.

The source affluents of the Mitta Mitta comprise the following:—The Cobungra, Bundarrah, Wombat Creek, and Big River, on the west; the Victoria and Livingstone Creek on the south; and the Benambra Creek, and Gibbo and Dark Rivers, on the east.

Owing to the western affluents draining the Bogong High Plains, and to the general altitude of the western watershed line, the volume of water brought down by these affluents constitute the source supply of the Mitta Mitta. As an instance of the effect which such higher plateaux have in regard to the collecting capacity of a source basin, it is interesting to note that, although the Victoria River only drains an area of about eighty-one square miles, while the Livingstone Creek drains an area of one hundred and thirty-eight square miles, yet the former empties almost as great a volume of water into its recipient, the Cobungra, as the latter does into its recipient, the main Mitta Mitta River. The Victoria rises in the Paw Paw Plains table-land, 5,000 feet above sea level, while the highest point drained by the Livingstone Creek, hardly exceeds 4,000 feet.

The general configuration of the minor watershed lines dividing the western affluents, is that of gradually sloping terraces and shelves, open grassy flats, with thickly timbered rises, occasionally rocky. The steepest slopes prevail on the southern sides of the watershed lines, being frequently precipitous. The southern affluents, the Livingstone Creek and Victoria River, are partly encircled by the Main Dividing Range, the character of the country along the courses being much more open and undulating than the principal tracts of country intersected by the western

* R. B. Smythe and O. S. Skene. The Physical Resources of North Gippsland.

affluents ; in short the Livingstone Valley, and the greater part of the Victoria Valley, includes rich pasture lands, more open and gently undulating along the eastern and south-eastern watersheds of these streams; the former comprising the rolling pasture hills stretching from Omeo township towards the Tongio gap, and north-easterly towards the Omeo plains, and the latter the still more open, and gentle grassy slopes of Parslow's Plains. Of the eastern affluents of the Mitta Mitta, the Benambra Creek is by far the most important, embracing an area of two hundred and thirty-three square miles, its upper courses open out into some fine upland flats, marsh lands now partially drained, consisting of flats, averaging one mile in width, and treeless except on their margins. The lower part of the Benambra Creek skirts the northern margin of the Omeo plains. The Gibbo and Dark Rivers on the east, and the Wombat Creek on the west are torrential streams intersecting rugged mountains, with flats of limited extent on their lower courses, as at Dartmouth on the former, and Quartpot on the latter. Below the Gibbo River junction the main Mitta Mitta falls into a gorge-like valley formed by the near approach to the Gibbo mountains on the east, and the Wombat Creek ranges on the west. Here the course is difficult to follow, steep bluffs and rocky sidelings render it difficult to proceed even on foot. Below the junction of Snowy Creek (which drains the northern slopes of Mount Bogong and enters the Mitta Mitta from the west), the Mitta Mitta winds through a continuous series of pine flats, from one to three miles in width, right down to its junction with the Murray.

I have given rather detailed descriptions of the Mitta Mitta Valley for the purpose of assisting the reader in following my subsequent remarks on the metamorphic rocks which characterise the area.

The eastern tributaries of the Hume River, which may be called the source affluent of the Murray, drain the Kosciusko range, and the nearest divide towards Mount Pilot, as well as the rugged Cobberas mountains. As might be anticipated, there are numerous waterfalls and cataracts along these courses. On the most southern affluent of the Limestone Creek are some fine caves and marble beds to be hereafter referred to ; some flats of moderate extent occur ; and on the western watershed some fine grassy uplands. Below the junction of Limestone Creek and the Hume, the latter passes through a narrow gorge towards Tom Groggin, where some undulatory foot-hills on the western watershed serve to break the continuity of the otherwise rock-bound valley. It is not until the fine flats and rolling foot-hills near Towong station are reached, that the valley widens, and the Murray becomes a distinctive stream.

The tributaries of the Mitchell River drain a large area of country. The most westerly affluent, the Wonnangatta, finds its source runnells at Mount Howitt and on the Snowy Plains. An eastern tributary rises at Mount Selwyn, and traverses wild mountain country at present comparatively unexplored. On the west, another important tributary, the Moroka, has excavated a picturesque valley, in which are found spots of wild and rugged grandeur. Bold fortress-like outlines, as at Snowy Bluff, give place at higher levels to escarped heights, as Mount Kent and Castle-hill; while deep chasm-like valleys stretch back into dim and unvisited recesses, down which the source runnells fall headlong thousands of feet from the upland summits of the Snowy Plains table-land and adjoining mountains. Below the Moroka River junction, some moderate sized flats replace the steep sidelings of the upper valley; among the former may be mentioned the Eagle Vale flats. The Wongungarra River, rising at Mount Twins, winds through mountain defiles to its junction with the Wonnangatta below Eagle Vale, receiving from the east the interesting mountain torrent, known as the Crooked River, which drains the western margin of the Dargo High Plains.

The Dargo, rising at Mount Hotham, and draining the eastern portion of the Dargo High Plains as well as the western portion of the Main Dividing Range, also winds between the terminal spurs of steep ranges until near its junction with the Mitchell; where at Dargo Flat the valley widens and some fine flats and undulating foot-hills mark the area occupied by the Dargo Agricultural Settlement. Another tributary further to the east, rising at the main divide opposite, head of the Livingstone Creek, and draining a bold range to the east on which Mount Baldhead is situated, presents similar features. This is the Wentworth River. Below the Wentworth junction, the Mitchell River is hemmed in by high mountain ridges for many miles, until the rich alluvial flats near Lindenow are reached. This portion of the valley has been ably described by my friend Mr. Howitt, in his admirable description of a voyage down stream in a blackfellow's canoe.*

The physiography of the Tambo River Valley has been elsewhere described in each detail by the writer,† that a brief reference to the leading topographical features is all that is necessary here. The upper sources intersect the charming area of limestone hills known as Bindi; the middle portion, the alluvial flats of Tongio and Swift's Creek junction, an eastern tributary intersecting fine pasture hills at Ensay—this is the Little River Settlement. At lower levels the Tambo receives its most important affluent from the east of the Timbarra, while at still lower levels the valley narrows to a gorge-like canon, until the fine alluvial flats near Brenthen are reached.

* Progress Reports, Geological Survey Victoria. (Notes on the Devonian Rock of North Gippsland.)

† The Physiography of the Tambo Valley. Trans. Geol. Soc. Australasia, 1887.

The Snowy River is the most important of all the streams draining the higher regions of the Australian Alps. Traversing the fine Monaro Table-land, its course becomes torrential east of the Kosciusko plateau, and has excavated a valley at lower levels, which presents features of great interest. To attempt anything like a fair description of the leading topographical features of this magnificient valley would extend the scope of this paper to too great a length. A few remarks concerning the principal affluents of the stream can only be offered here.

Leaving out of consideration the many important eastern and northern affluents which flow through the fine Monaro Plains, the first alpine stream is the Crackenbac River, rising at Mount Kosciusko. At first traversing the grassy and mossy uplands abounding in sphagnum beds, as at the Boggy plain (where the writer has recollections of sudden and somewhat ungraceful movements over his horse's head during youthful days, when the latter almost disappeared underneath a treacherous moss bed), the Crackenbac afterwards flows over rocky ledges forming numerous cataracts of great beauty to lower levels.

From Mount Kosciusko to Mount Pilot, several similar mountain torrents presenting similar features enter the main Snowy River from the west. Rising at Mount Pilot and draining the Cobboras, the Toonginbooka and its affluent the Ingeegoobee, forms a deep valley excavated from the eastern slopes of these important mountains. The difference between the apperance of the lower and upper valleys of this during midsummer has been eloquently described by Mr. Howitt.* From the Toonginbooka junction the Snowy River forms a deeply excavated valley past the Gelantipy plateau for over forty miles. From Turnback Peak over which the road to Bendock passes a magnificient view of the upper valley is obtained. A number of unimportant affluents such as the Mountain Creek, Broadbent or Yalmy, and Rodgers Rivers enter from the east. The principal affluent is the Buchan, entering from the west. This stream rising in the Cobboras mountains, winds through the interesting area of Buchan, where a belt of Middle Devonian limestone country is found—to be hereafter more particularly referred to.

METEOROLOGY.

The importance of obtaining meteorological observations from the highest elevations over South-east Australia, can, I think, hardly be over estimated, from the fact that there is probably no other country where the necessary conditions for studying weather phenomena are more favourable. Surrounded by oceanic expanses, and with just sufficient vertical relief to cause obstruction to wind

* Devonian Rocks of North Gippsland, p. 185.

and water circulation, the higher regions of Australia offer a splendid area for investigating many meterological changes. The movements of circo-felum* in advance of cyclonic disturbances, could be observed with greater clearness from the Alpine stations free from the influence of smoke and other obstructions incidental to large cities in the lowlands. The causes which predominate in the deflection of extensive aerial currents, and the consequent condensation and precipitation of rain, snow, &c., over the alps—whether such be due to ascensional movements of moisture-laden air,† to other thermal influences, or to the complex actions arising from the irregular barometric depressions and nulic cyclones, which are constantly moving over the earth's surface in the temperate zones,‡ the protrusion of areas of high and low pressures, &c., or other causes of like nature—would doubtless be more satisfactorily determined by establishing a chain of high-level observations on the Western Australian ranges, across South Australia and the summits of the Australian Alps, to the Blue Mountains in New South Wales. These might be expected to furnish data of sufficient scientific importance to enable our able Australian astronomers to establish some valuable weather laws, or in addition to determining more fully the laws of Meteorology prevailing over our Australian continent, and enable them to reduce the already formulated theories of Europe and America to general laws.§

That the primary condition of earth sculpture is to be found in the intensity of the denuding agencies is, I think, obvious; but in areas where the sub-aerial denuding agencies are equal in intensity, then the different waste resisting powers of the different rock masses gradually evolve these surface contours, which afterwards modify the action over certain areas of the original climatic conditions. Thus, where the hard crystalline rock-masses resisting sub-aerial decay, form ridges, while the softer rock-masses are degraded. The circulation of vapour and the influences of such ridges in the vertical protrusion of moisture-laden winds causing secondary influences which produce inequalities of rainfall and other hygrometric and thermal conditions. The latter again exert a modifying effect on the vegetation, so that from the time when a vast table-land existed in South-east Australia, until the present contours were formed by the erosion of the existing valleys, the gradually changing climatic conditions would slowly evolve corresponding changes in the physiogonomy of the native vegetation, and tend to constant, yet imperceptable, variation in specific forms.

* Rev. Clement Ley. Quart. Journ. Met. Soc. 1883, IX.

† Rainfall at Charrapenyi. Quart. Journ. Met. Soc. 1882, VII.

‡ Scott's Meteorology, p. 332.

§ Stirling. Notes on the Meteorology of the Australian Alps. Trans. R. Soc. Victoria

That the amount of rainfall is greatest at the normal line of cloud flotation, approximately 3,000 to 4,000 feet in the Australian Alps, will be seen by comparing the records from those stations, such as Grant, 4,000 feet, in the Mitchell River, with those at Dargo, 1,000 feet, in the same basin, only fourteen miles distant. Thus, during three or four years the average rainfall at Grant is probably fifty inches, at Dargo not more than thirty inches. Independently of the elevation, the situation of the station largely affects the precipitation of rain, which helps to increase the difference. For instance—the trend of the Dargo River Valley from Dargo is southerly, and although partly exposed to the moisture-laden winds from the Pacific, it is nearly surrounded by high ranges. Grant, on the contrary, is on the crest of a high range fully exposed to the influence of south-westerly moisture-laden winds which sweep up the Dargo and Wongungarra Rivers, and to the north-western winds, which are carried across the Dargo High Plains from the valley of the Ovens and its tributaries.

The record from Mount St. Bernard, near Mount Hotham, where I erected instruments some years since, also offers conclusive evidence that the situation of the recording station is important. Dr. von Lendenfeld in his interesting notes on the "Meteorology of Mount Kosciusko," remarks—* "The amountof water precipitated from mist without the formation of regular rain is much greater than one generally assumes." This is no doubt true, but it by no means follows that the total amount of water produced on the summits of the Alps, is greater than at the levels I have suggested. An instance shewing that the sub-alpine slopes on the weather side of the ranges receives a greater actual supply of rain than the summits of the mountain occurred during our joint expedition to Mount Bogong, when we were camped on the summit, the wind blowing from the north strongly, while clouds were creeping slowly up from the south. On top of the mountain there was at length a calm, and shortly the rain commenced falling in the valley to the north, but before the rain reached the summit of the mountain, the moisture-laden clouds from the south forced up into a higher region of the atmosphere would have precipitated the greater part of their moisture on the northern slopes of the mountain, so that the actual quantity of vapour converted into water would be less on the summit than on the slopes.

Snow falls at heights above 2,000 feet, but at the lower levels seldom remains longer than a few days, thawing quickly as it falls, unless on the shaded hill sides, where the frost hardens the crust. The distribution of snow seems to be affected by many complex causes; it is noticed that at similar elevations, in the same locality, the depth of snow after a fall is very unequal. It is

* Proc. Linn. Soc. N. S. Wales, X. p. 40.

possible that different radiating properties of various soils or rock-masses* may exert some influence in the more rapid congelation or thawing of snow-flakes, or that parallel air currents may be different degrees of moisture or of temperature. It is not unusual after a snow-storm to find at night that the snow which has fallen in the open is more luminous than that which has fallen in the shade of timber trees. This peculiar phosphorescence is no doubt due to exposure during the day of the many reflecting surfaces of the small speculæ of ice to the sun's rays, and to their retaining the light after the sun has set. I have observed, near the ummit of Mount Kosciusko, at an elevation of 7,200 feet, masses of consolidated snow fully thirty feet deep—maiden glaciers—resting in the hollows of verdant slopes during mid-summer. And as the huge masses of tabular granite which form the rocky crests of this important mountain chain (presenting in many places escarpments fully forty feet above the gentle slopes which surround them), are covered with snow early in June of each year, it is not improbable that the annual fall at this elevation amounts to fifty feet coresponding to an annual rainfall of from fifty to sixty inches. I am not aware that there is any rule for an increase in the fall of snow with elevation. I am inclined to believe that there are vapour palnes, and that upon the percentage of moisture present in any of these zones, or the degrees of temperature—which are no doubt governed by many complex causes at present little understood—the fall of snow depends.

The manner in which snow accumulates in certain situations in the higher elevations is admirably described by Dr. von Lendenfeld in his "Notes on the Meteorology of Mount Kosciusko."†

Often when the sky is clear during the morning, towards afternoon dense masses of vapour are seen floating up the valleys of the Tambo and other streams from the sea board, at a mean elevation of 3,000 feet, and settling on the ranges round Omeo, causing a rapid fall of the temperature. These fogs are, according to old residents, generally the forerunner of dry seasons, and are altogether distinct from the ordinary radiation fogs of Sir M. Herschel. Whilst botanising on Mount Kosciusko some years ago, an opportunity was afforded the writer of watching the progress of one of these southern fogs coming from the sea board. A warm cloudless morning, with the thermometer at 92° in the sun, at 1 p.m., at an elevation of 7,000 feet, was followed by a warm cloudless afternoon until 5 p.m., when large masses of what appeared to be dense nimbus clouds were seen on the southern horizon, which gradually enlarged, and could be seen surging up the valleys. At last the temperature sank to 43° F., when a dense fog suddenly enveloped the summit of the mountain, and in a few minutes began to clear off again, sinking to a level of about

* Loomis' Meteorology, p. 26.
† Proc. Linn. Soc. N. S. Wales, X. p. 41.

6,000 feet, and there remained like a wide expanse of silvery ocean during the clear moonlight night, until dissipated by the warm golden rays of the rising sun. A peculiar feature of such fogs is that the upper part is cooler than the lower, *i.e.*, when the fog-masses are rising radiation of heat is greater at the upper than at the lower part.

As a rule, the number of cloudy days is in excess of the clear days for the entire year, and the cloudiness is greater during summer and winter than in spring or autumn. The beautifully clear days of winter are a noticeable feature in the climate of the Australian Alps, although frequently preceded by hard frosts, and occasionally followed by heavy snow falls.

The month of July is one of severe frosts in the Australian Alps. At elevations of 2,000 feet, the frosts range from May to September, but as the seasons are later at the sub-alpine habitats than in the lowlands, the September frosts, which might prove injurious to vegetation in the lowlands, are not so much so at these elevations.

It is only in the valleys that the severest frosts take place. I have observed lowland exotic plants flourishing on the ridges, which perished under the extreme frosts in the valleys, the temperature being more equal at the former habitat than in the latter.

The range of temperature at sub-alpine elevations, as at Omeo, 2,200 feet, is apparently large and increases with the elevation. The annual mean temperature at Omeo, deduced from observations extending over six years, gave 53.34°. The highest recorded temperature in the shade, on 21st January, 1880, was 105° ; and the lowest in July, 1883, 19° Fahrenheit, or 13° below freezing point ; or an absolute range of 128° ; nearly as large as Chicago, Illinois.*

The mean annual temperature in the sun at Omeo was 63.38°, a little over 10° higher than in the shade.

The variation to which the law of decrease of temperature with elevation is subject, is well shown by many localities in the Australian Alps, particularly by the presence of many tropical types of vegetation in the humid soils on the most southern slopes, at elevations of 3,000 feet ; and the mean temperature is probably greater at similar elevations on the northern sunny slopes, than on the moist southern slopes ; and the absolute range of temperature is also greater on the former than on the latter at similar elevations. Again, those localities open to the cooling influence of polar winds, would doubtless show a lower mean annual temperature than those localities on the same latitude, at the same elevation, although exposed to the warming influence of equatorial winds.

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* Loomis' Meteorology, p. 274.

A noticeable instance of evaporation over a large surface is furnished by Lake Omeo, which in 1882 was a sheet of water two miles long by one mile broad, and with an average depth of probably two feet six inches, or less. The lake became dry in 1884, and this accords with the following approximate results from the evaporator at Omeo, viz., thirty and a-half inches per annum. It must be borne in mind, however, that the evaporation from a sheet of water freely exposed to the accelerating influenceof summer winds, would be greater than that from a situation sheltered by high ranges.

There are not wanting evidences that spontaneous evaporation is in excess of rainfall over many areas at sub-alpine localities in the Australian Alps.

Hailstones, although frequent in the higher regions of the Australian Alps during summer and autumn, are not so at sub-alpine latitudes, although it is somewhat remarkable that the size of the hailstones is frequently much larger at elevations of 2,000 to 4,000 feet, than at higher levels. I have noted hailstones fully half-an-inch to three-quarters of-an-inch diameter. As a rule, the hailstones come from the westward, and are generally accompanied by electric discharges, or strong wind.

The higher points of the Australian Alps are noted for the excessive dew which is deposited every evening during midsummer. Dr. von Lendenfeld remarks, that he never experienced in any part of the world, at any height between 10,000 and 15,000 feet, such dews as occurred every night at his camp on the Kosciusko plateau. I have experienced similar phenonema on all the higher points over 5,000 feet.

The lowest mean temperature of the dew-point is reached during the month of July, and highest during February, corresponding in this respect to the temperature of the air. It may be interesting to note that the humidity of the air varies greatly during the summer months, especially at the higher elevations; and at the lower levels, as at Omeo, the shifting of the wind from north to south-west and south, sometimes causes an excessive humidity, as shown by the dense fogs which frequently envelope the higher points over 4,000 feet; during summer a feature connected with such hygrometric conditions arewhat is locally termed southern fogs.

The greatest mean velocity of the wind occurs during spring and summer, and principally with north-westerly currents of air. On the whole, westerly winds may be said to predominate in the Australian Alps, although local influences at lower sub-alpine altitudes, cause deflection and obstruction to aerial currents. A remarkable phenomenon connected with the temperature of wind which has been frequently noticed in the sub-alpine valleys of the Australian Alps, is the occasional whiffs, during frosty mornings, of warm currents of air, producing an irritation of the throat and nose, similar to that felt when ozone is largely present in the atmosphere. How far these peculiar abnormal air-movements are due to electrical agencies, or to the actual presence of isolated masses of warm dry air, which have come to us from the heated interior of Australia, I am unable to suggest; I simply note the fact as one which requires some explanation.

The mean barometric pressure during winter is greatest, and during summer least.

The rule for decrease of pressure with altitude, would seem to be subject to slight variations caused by lateral pressures, aerial currents sweeping up the narrow valleys, and by thermal influences of a local character, so that the difference of surface configuration and surroundings of two stations on the same parallels of latitude, and at the same altitude, may differ slightly in their barometric pressures.

The mean winter temperature at Mount St. Bernard, 5,060 feet, would appear to be 33.91 Fahr., or about two degress above freezing point. The lowest temperature recorded from ten a.m. observations is 29°, the maximum 70° in the shade, and 90° in the sun. July and August are the coldest months, February and March the warmest. The seasons of maximum cold for the past thirteen years appear to have been 1876, 1881, and 1882; and the season of greatest heat, 1882. The fall of snow sometimes commences as early as April—although May is the usual month—and begins to disappear during September, sometimes October. April is frequently a rainy month, and during January and February thunderstorms are prevalent, invariably from the westward. As a rule the prevailing winds are from south-west to north-west during summer; south-west to south-east during autumn; north west during winter; west to north-west during spring.

The wind blows with great force at these elevations, and the changes are very rapid. Mr. Bonsted informs me that he has had thick fogs with rain all day at Mount St. Bernard, while three miles lower down, or at an elevation of 4,000 feet, the sun has been shining in a clear sky. He also remarks that it is an unusual thing to have a Christmas without snow.

BOTANY.

The Flora of the Australian Alps includes many heterogeneous elements, and thus it presents some interesting botanical features, among which may be mentioned the Antarctic character of the endemic alpine species, and their affinity with the Tasmanian flora as pointed out first by Baron von Mueller. This identity of species may be fairly said to unite those now isolated alpine areas to some extent, into one botanical region, or would, at least in some respects, suggest a community of origin; and, although there are no apparent proofs of a continuity of land surface uniting Tasmania to Australia proper during Tertiary times, yet a comparison of the sequence of the great rock-masses in both areas would certainly suggest that Tasmania forms part of the Australian continent geologically. With reference to the date of the introduction of the present endemic alpine species, this may be safely centred in the glacial movements which I think, took place in the Southern Hemisphere during Post-Miocene times. By the light which these glacial movements throw upon the subject, it is not difficult to understand how a tropical flora, extending during Miocene, or even early Pliocene times throughout Eastern Australia, was gradually replaced by the present remnants of an Antarctic flora at the higher elevations, and the mixed forms which prevail at sub-alpine habitats. During the refrigeration which culminated in a glacial period, those tropical forms which were able to accommodate themselves to the decreasing temperature, might survive as stunted varieties, which have differentiated under the changing climatic conditions, while a large number of genera and species unable to withstand the intense cold, would doubtless perish.

The immigration and dissemination of antarctic types would, in all probability, increase in proportion to the extinction of many of the tropical types; and it is at least conceivable that commingling of species took place, and the cross fertilisation of an altered tropical with an antarctic species produced forms able to withstand greater extremes of temperature, and that prolonged periods of slowly changing climatic conditions might result in the differentiation of varieties so distinct from the original species, as to claim true specific rank.

The breaking up of the glaciers, and the gradual raising of temperature to the present time, with the varying oscillations of land-surface by sub-aerial denudation affecting different geological formations in respect to ratios of denudation and erosion, &c., might also produce analagous effects, as, by immigration, the tropical, or extra-tropical forms began to commingle with, or replace, the antarctic forms in the lowlands, until the latter became restricted to the higher elevations, where they now occur. The presence of many extra-tropical northern species is, no doubt, peculiar, although, as remarked by Sir J. W. Hooker, "if as complete evidence of such a proportionally cooled state of the inter-tropical regions were forthcoming as there is of a glacial condition of the temperate zones it would amply suffice to account for the presence of European and arctic species in the antarctic."

Comparison with Tasmania.—Of the five hundred and eighty-three species collected by the author, at elevations exceeding 2,000 feet, in the Australian Alps, not more than fifty-four are truly endemic, while no less than eighty-nine are restricted to Tasmania and the Australian Alps.

Contrasting the orders richest in species we find :—

Australian Alps. (Restricted.)					Australian Alps and Tasmania. (Endemic in both regions.)			
Compositæ...	5 genera and	8 species.			8 genera and		14 species.	
Leguminosæ.	4	,,	6	,,	5	,,	8	,,
Umbelliferæ.	3	,,	5	,,	2	,,	2	,,
Proteaceæ....	3	,,	4	,,	2	,,	2	,,
Cyperaceæ ...	1	,,	6	,,	4	,,	5	,,
Gramineæ....	1	,,	3	,,	6	,,	6	,,

In a paper on the Phanerogamia of the Mitta Mitta* I suggested that meteorological conditions would probably be found to have exerted a dominating influence in the evolution of varieties of plants. Further observations not only tend to confirm that suggestion, but point to the probability of physical causes prevailing over geological causes of distribution, or in other words sub-aerial influences being the most important factors in plant distribution.

It would be impossible, within the scope of this paper, to deal satisfactorily with the facts which lend support to this theory. The evidences may form the subject matter for another paper for the Association at some future time.

Remarks on the most prevalent Genera.—The extensive orders Compositæ and Leguminosæ first claim attention as being the richest in species. Bentham remarks,† "that the Compositæ are the most extensive of flowering plants, and represented in every quarter of the globe in every variety of station," and that there are five hundred species indigenous to Australia. I have noted great variation in the growths of many composite herbs in the Australian Alps during different seasons, sports being abundant in dry seasons, and the reversion to foliaceous growths very remarkable. I have observed the florets in *Microceris Forsteri* becoming pedicellate and assuming the form of an Umbellifer. Among Compositæ, such as *Brachycome*, *Aster*, *Senecio* and *Helichrysum* are most abundant, *Brachycome* by the herbaceous species *B. decipiens*, *B. diversifolia*, &c., which yield a fine carpeting of flowers on the open grassy ridges and flats during early summer, ascending to the alpine regions at the higher plateaux—6,000 feet elevation.

Aster includes, among other arboreous forms, the ever-scented Native Musk (*A. argophyllus*), which attains its greatest luxuriance among the deeply-vegetated and shaded glens on the sub-alpine littoral slopes where humidity prevails.

Shrubs as *A. stellulata*, *A. myrsinoides*, are more evenly distributed in open northern areas along the banks of streams, although the latter is represented by dwarfed forms on the lower ridges of the higher plateaux. Such herbs as *A. Celmisia* are

* Phanerogamia of the Mitta Mitta. Trans. R. Soc. Victoria.

† Flora Australiensis, Vol. iii. p. 449.

apparently restricted to the grassy alpine stations where the hygrometric conditions are suited to their growth. The *Helichrysæ*, like the *Brachycomæ*, are principally herbaceous, represented both by species on the lower sunny areas of undulating country, as *H. semipapposum*, *H. apiculatum ;* and by the larger flowered *H. bracteatum*, on the higher table-lands, and as remarked in a previous paper,—" Covering these highlands with fields of bright golden yellow flowers, giving character to the landscape, while at similar elevations the diffuse *H. baccharoides* covers acres with dense undergrowth."

At lower levels, 2,000 to 3,000 feet, along the courses of some of the principal streams, is met with the shrubby species *H. rosmarinifolia* ; which when drying emits a delightful fragrance. Among many genera of Leguminosæ, the well known Acacias are in greatest profusion, comprising among others the interesting shrubs *A. vomeriformis*, *A. myrtifolia*, *A. siculiformis*, the first two being more abundant on open heathy stony northern areas, and the latter on the sands and gravels of the different streams. The arboreous species such as *A. decurrens*, *A. melanoxylon*, *A. penninervis* and others are distributed in open forest lands throughout the area, nowhere gregariously, unless in the heads of gullies with southern aspect. It may be remarked, however, that the general habit and form of the species *A. decurrens* and *A. melanoxylon*, when occurring on the stony northern slopes are essentially different from that which they assume in the most shaded localities of southern littoral aspect. In the former stations the general form of *A. decurrens*, for instance, is that of a rounded, short and thick-stemmed tree, the foliage dense, and the bark somewhat rugose, while in the shaded glens it assumes the form of an erect tall-stemmed tree, frequently obtaining a height of eighty feet, smooth barked and lightly foliaged. Nearly the whole of the different species of the genera *Daviesia*, *Pultenæa*, *Bossiæa*, and *Oxylobium*, are prolific on dry northern areas, especially the two latter. Like the Acacias, many species of *Daviesia*, as *D. corymbosa* and *D. ulicina*, are greatly affected by hygrometric conditions in their forms and habit ; and similarly species of *Pultenæa* and *Oxylobium* thrive in rocky situations amid the snow regions where other less hardy Leguminosæ perish. Next in importance are the hardy "native heaths" or Epacrideæ. The plants of this order, although numerically less as regards species than the Compositeæ or Leguminoseæ, are still, owing to their extensive distribution over the whole area, more frequently met with—the principal genus being *Styphelia*, with which Baron von Mueller has now included a number of previously formed separate genera.*

The species of *Styphelia* herein referred to consist principally of shrubs and undershrubs of heath-like form, from the robust and

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* Systematic Census of the Plants of Australia, 1883, p. 105.

erect *S. lanceolata*, *S. scoparia*, etc., which attain their most luxurious growth on the wooded sub-alpine ranges, near and on the Great Dividing Range—where condensation and precipitation of vapour is greatest and most continuous—to the decumbent, and diffuse *S. serrulata*, flourishing on the drier stony northern areas at lower elevations. Another genus, *Epacris*, is represented on sandy soils by the lovely crimson and white *E. impressa*, and struggling to higher elevations along courses of streams are seen dwarfed forms of the otherwise erect *E. heteronema* of lower levels, while abundant on the damp upland marsh lands are seen varieties of *E. microphylla*, and on the stony crests of ridges, the alpine species *E. paludosa* and *E. petrophila*. Among Rutaceous plants none are more generally distributed than the Native Fuschia, *Correa Lawrenciana*, especially on the sub-alpine littoral slopes, where it is frequently gregarious.

The genus *Eriostemon* contains a number of hardy species, apparently endemic to our Australian highlands, including the sparsely distributed *C. ozothamnoides*, a robust shrub on rocky situations. The Order Ranunculaceæ is also represented by a number of alpine herbs, among which are the species *Ranunculus anemonius*, *R. Muelleri*, and the apparently endemic *Caltha introloba*, so closely resembling a New Zealand species.

Among the Labiatæ, an order consisting principally of herbs and shrubs, occurs the perhaps solitary arboreous form *Prostanthera lasianthos*, an inhabitant of most densely vegetated gullies of littoral aspect. At sub-alpine altitudes of 2,000 to 4,000 feet, an apparently alpine species, *P. cuneata* may be found growing from the crevices of rocks at the highest elevations. In the Proteaceæ, an order whose maximum of species is reached in Western Australia, we have a few apparently endemic forms, as *Grevillea Miqueliana*, *G. alpina*, etc. The valuable notes given by the Government Botanist in his examination of the "Vegetable Fossils of the Auriferous Drifts of Victoria," (p. 10), appear to indicate some resemblance between exisiting forms of tropical *Grevillea*, and the vegetation of the Pliocene era. It is to be hoped that further palæontological researches may yet be available for correlation purposes, enabling the pre-existing flora to be more satisfactorily compared with the present, and by this means trace out the successive changes which have taken place not only in the surface configuration, but in the Flora and Fauna of our present Alpine regions. One species of Proteaceæ herein referred to, viz.:—*Persoonia juniperina* is suggested by Professor Tate of South Australia, as a probable survival of an alpine flora of Pliocene date.*

One species of Proteaceæ, the handsome *Orites lancifolia* is an inhabitant, almost exceptionally, of the higher and colder regions,

* *Vide* discussion on a paper submitted by the writer to Royal Soc. of South Australia, on the Proteaceæ of the Victorian Alps, p. 8.

not descending in this area below 3,000 feet. The extensively distributed order Scrophularinæ is represented principally by herbs and undershrubs of the genera *Euphrasia* and *Veronica.* Among the former the species *E. Brownii* and *E. antarctica*, cover the grassy highlands during midsummer, with their beautiful flowers, whilst on the grassy ridges at lower levels *E. speciosa* predominates along with *E. scabra.*

Among Veronicas, *V. Derwentia* is common on shaded hillsides, *V. perfoliata* on rocky bluffs, and *V. gracilis* on damp grassy flats.

Among Umbelliferæ are a few herbs which may yet become valuable through cultivation as culinary esculents, as *Aciphylla glacialis*, flourishing at the higher and colder zone. The Santalaceæ, including the well-known species *Exocarpus cupressiformis*, or "Native Cherry-tree," is represented also by shrubs with pleasantly acidulous edible berries, and *Leptomeria aphylla* and *Exocarpus stricta*, common on stony and heathy sub-alpine areas.

Among Thymelaceæ, the most extensive genus here represented is that of *Pimelea*, containing several species known as possessing valuable industrial properties, as *P. axiflora* and others, which yield a fine brown dye and superior bast of great tenacity, and the more compact bush, *P. ligustrina* of medicinal value, the former more abundant on shaded hill-sides at the lower levels, and the latter on the wooded depressions on the high table-lands. The order to which our noble Eucalypts belong, that of the Myrtaceæ is represented not only by the arboreous forms of the genus *Eucalyptus*, but by a number of shrubs of the genera *Callistemon*, *Leptospermum*, *Bæckea*, and others. Of the latter, *Callistemon salignus*, var. *Sieberi*, is met with, not only margining the principal streams of 2,000 feet, but ascending to the source runnels intersecting the higher plateux, where, along with *Bæckea Gunniana* and dwarfed varieties of *Leptospermum* and *Kunzea*, it forms dense undergrowths in the neighbourhood of *Sphagnum* beds.

Among Eucalypts, the species *E. Gunnii* and *E. pauciflora*, are perhaps the most generally distributed on the undulating ranges near Omeo, both, however, ascend to the edge of the snowy plateaux as dwarfed, stunted, and gnarled gum-scrub. In the humid, shaded slopes at lower elevations of 1,000 to 2,000 feet are met with lofty forms of *E. globulus*, &c., while on the opposite side of the ranges or spurs is seen a species of stringybark, and the change in some places is so marked as to exhibit a distinct line of demarcation from the blue and white gums to the stringybarks. On the heathy spurs are met with *E. piperita* and *E. pulverulenta*, the latter towards Omeo Plains, while on damp flats and on the rich soil of upland gullies are seen varieties of *E. Stuartiana.*

In the division Monocotyledoneæ the orders more largely represented by genera and species include the Orchidaceæ, Liliaceæ, Cyperaceæ, and Gramineæ, the two first-named, although containing many interesting species, have none which are exclusively endemic, all having a wide territorial range over the Australian continent.

Among the Cyperaceæ, however, there appears to be a few species of the extensive genus *Carex*, which are restricted to the alpine regions of Victoria and Tasmania, as *C. acicularis*, *C. Buxbaumii*, &c., although some of these species are even represented in Europe and North America, and also in North Asia. The important order Gramineæ which, as regards number of species, stands next to the Leguminosæ throughout the world, is here represented principally as regards number of species by the genera *Danthonia*, *Poa*, *Festuca* and others, but in respect to territorial range of single species none are more extensively distributed than the well-known "Kangaroo grass," *Anthistiria ciliata*. The Poas are the tallest grasses to be met with in these regions. Culms of *P. dives* are frequently seen to attain a height of twelve feet in shaded hillsides, the whole plant being succulent and nutritious, and may hereafter repay cultivation. All the local Danthonias and Festucas are good fodder grasses. A species of *Trisetum*, *T. subspicatum*, is apparently restricted to the higher mountain regions of Victoria, New South Wales, and Tasmania.

GEOLOGICAL STRUCTURE.

The greater part of the rock-masses which constitute the Australian Alps, may be described as Palæozoic sediments which have been tilted, folded, compressed, and completely metamorphosed over large areas into crystalline schists. The lower curves of the folded and compressed sediments have been melted off into granite masses. Numerous porphyritic bosses and igneous dykes, now bared by denudation, shew plainly the result of powerful plutonic action, while certain fragmental porphyries and massive felsites remain as a record of intense volcanic activity. The whole complex of sedimentary plutonic and igneous rocks of Palæozoic age are in parts overlain by Tertiary lava flows (sheets of basalt), which form the principal plateau and elevated table-lands, along whose margin some of the present river valleys have been eroded, and the adjoining hills degraded. As previously stated, the Mesozoic rocks—so far as known—are entirely absent in the Australian Alps.

There are apparently no pre-Silurian rocks in the Australian Alps, but the oldest sediments are referable to the Lower Silurian, and consist of a recurring series of highly inclined, and in most areas slightly metamorphosed slates and sandstones, which are intersected by auriferous quartz veins. In the Mitta Mitta source basin, and in the Upper Tambo basin, these sediments are metamorphosed into crystalline schists — nodular schist, mica-schist, and gneiss—in some localities the gradual transition from the argillaceous members of the series into dense granitoid masses is traceable—as on the Mayford spur—from the Dargo River over the main divide towards the Cobungra River.

The less altered beds, vary from argillaceous to arenaceous in composition, with slaty cleavage. The preponderating dip is to the east (although the dip varies from 70° to the vertical), from which we may infer that the whole of the beds were tilted over to the west. The strike varies between north-north-east and N. 60° W., although in some localities where certain plutonic masses have invaded the sediments, the latter have been thrust out of the normal line of strike. On the whole the strike is at an angle with the axial line of the main divide.

On the surface the argillaceous rock masses are yellowish and brownish, but in all the mines they are of a bluish or greenish-cast of colour, and of a slaty structure. The arenaceous beds are varied in structure from soft and friable sandstones to coarse quartzose grits. I am not aware that any conglomerate beds which might be considered as representing the base of the series have yet been discovered.

There is a noticeable absence of fossils from which the actual age of the beds might be determined. They present lithographical resemblances to the normal Lower Silurian sediments elsewhere. On the eastern watershed of the Snowy River, as at Deddick and Goongerah, are certain black slates, apparently part of the series which contain undoubted Lower Silurian organic remains, such as *Diplograptus rectangularis*, M'Coy; *Didymograptus caduceus*, and *Diplograptus foliaceus*.* The author has recently found similar Graptolites on the Yalma River in similar black slates.†

Whatever may have been the character of the rocks upon which these Silurian sediments were laid down, there are abundant evidences that a granitiform mass underlies the whole of the sedimentary rocks over the greater part of the area known as the Australian Alps, and, as has been remarked, "were the whole of the granite stripped of the superior strata, without being itself denuded, it would present an extremely uneven and irregular surface, for we find on examining the streams, that in places the Silurian strata descend below the general surface of the granite and are much contorted and fold back on themselves, while in other places we find bosses of granite appearing through the Silurian ridges of slate." On the whole those sediments classed as Lower Silurian are more indurated and slaty, and present a higher angle of dip than similar sediments in which undoubted Upper Silurian fossils exist. It is doubtful if the classification of a considerable area in the Mitta Mitta and Ovens River valleys as

* M'Coy, Prodomus Pal. Victoria, Decade I., p. 12.

† Stirling, On Prospecting Parties, County Croajingolong. Reports, Mining Registrars, Victoria, March, 1888.

Lower Silurian can be maintained, recent examinations by the author on the Gibbo Ranges in the former, and the ranges south of Mandiliging in the latter, yielding obscure stems and leaves of a fuciod of probably Upper Silurian facies.

The British equivalents of the Lower Silurian sediments of the Australian Alps are the Llandeilo Flags and Bala rocks in Wales, according to the palæontological determinations of Prof. McCoy.

As regards the Upper Silurian, the great folding and alteration to which the whole of the Lower and Upper Silurian sediments have been subjected, renders the determination of a true stratigraphical horizon a work of difficulty. There are certain limestone bands, conglomerates, and shales, presenting such well-marked lithological characters, and also containing such distinctive fossils that their position in the series can readily be determined. There are two localities where such distinctive rock-masses occur—one in the Mitta Mitta valley at Gibbo River, and the other in the Hume valley at Limestone Creek.

In the Mitta Mitta valley, between the Gibbo River and the Wombat Creek, there are extensive beds of conglomerate, shale and bands of hard blue crystalline limestone—the Gibbo River beds—which contain fossils of an Upper Silurian facies.

The limestone bands form lenticular masses representing hollows in the ancient sea floor. The adjoining shales are very much corrugated in places, and where they adjoin certain intrusive porphyrics are converted into hornfels.

The accompanying Section A.-B. (Pl. XXX.) across a limestone 'cliff' from the Morass Creek, explains the sequence of the rock-masses and their relations to the overlying Tertiary basalts *in situ.*

On the Limestone Creek (Pl. XXIX.), at the head of the Murray River, are bands of blue limestone and white marble, forming the Limestone Creek beds, whose stratigraphical relations to certain adjoining porphyries of a fragmental character have been well worked out, and the age of the latter determined, by the admirable and interesting petrographical researches of Mr. A. W. Howitt, as Devonian. From the position of the limestone beds, &c., and their relation to the porphyries their probable age was suggested as Upper Silurian. It fell to the lot of the author to confirm these views by the discovery of undoubted Upper Silurian fossils at Stony Creek, a small tributary of Limestone Creek. During a preliminary examination of these marble beds some years since the sectional notes were obtained which may be found in my paper, "Notes on a Geological sketch-section through the Australian Alps," read before the Royal Society of South Australia on February 5, 1884.

The Limestone Creek caves are, although of no great extent, yet sufficiently large to be of interest. I have already described the salient features of these caverns elsewhere,* so that I need

* On Caves perforating Marble Deposits, Limestone Creek. Trans. R. Soc. Victoria, 1883.

not enter upon a description of their character, except to state that the general direction of the caves conforms to the existing drainage system of the Limestone Creek, and is nearly parallel with the strike of the beds of limestone and marble in which they occur. One of the caves, which I have named Sheean's Cave, has quite a number of large chambers and an abundance of stalactitic growths. The roof of the entrance, and for some distance inward, consists of a mass of white marble beautifully scalloped by the action of running water. The general internal features of the cave is similar to that of most caves elsewhere, ramifying chambers, with, in some cases, narrow entrances, pillows of stalagmite, and charming recesses glittering with calcite crystals and innumerable pendant stalactites, forming an exquisite drapery over the ceilings.

The source basin of the Mitta Mitta and the upper valley of the Tambo River, are occupied by a great mass of Metamorphic rocks, formed by the folding and crushing of the Silurian sediments, and the invasion of the crushed and altered sediments by masses of intrusive granites and porphyries with their accompanying dykes. In those localities where the sediments have been most dislocated and compressed the metamorphism is most intense. Broadly considered, we may define three well-marked zones or stages of metamorphism. The first represented by the argillites are least altered. Members of the series usually indurated by increasing silification, and in many cases the conversion of the argillaceous material into a chloritic mineral. The second includes the hornfels rocks, forming contact schists, in which micaceous minerals are more abundant than in the argillites, and also present more siliceous ingredients than the latter. The third group embraces the regionally metamorphosed schists, the beds of mica-schist and gneiss typically developed in the Livingstone Creek Valley, near Omeo, and at Ensay.

Many of the gneissic schists are so granitiform that it is only by an examination of the beds *in situ* that their character as metamorphosed sediments can be determined. In many places the gradation from mica-schist to gneiss and metamorphic granite can be traced. The genesis of the metamorphic rocks of the Australian Alps is being so ably worked out by my friend Mr. A. W. Howitt, F.G.S., that it would be a work of supererogation for me to attempt a description of the lithological characters of the metamorphic rocks and their associated igneous masses. Having examined the areas described by Mr. Howitt and in many localities with that gentleman, I can with pleasure testify to the erudition and research shewn in his published writings on the "Granites and Diorites of Swift's Creek." The metamorphic and plutonic rocks of Omeo, and the sedimentary metamorphic and igneous rocks of Ensay, where Mr. Howitt has formulated a theory concerning the origin of the metamorphic schists, which

I believe is destined to play a most important part in the elucidation of a very difficult question, and add considerably to the sum total of our knowledge of the various changes which were wrought in the Silurian sedimentary rocks during the Devonian period.

There can be no doubt as stated by Mr. Howitt, that at Eusay the first igneous rocks that were forced into the sediments as veins and masses were varieties of aplites. Following these the rocks which are now the holo-crystalline quartz mica diorites; while the whole complex of rocks, metamorphosed sediments, veins, and masses of aplite and quartz diorite, have been crossed by dykes of quartz porphrite, still later by dykes of diabase, and finally in Tertiary times by a few dykes of basalt.

At Omeo, the granite masses, taken as a whole, are stated to represent an intrusion of plutonic rocks of several consecutive ages of the same period of plutonic invasion. At Day's Hill, of which I give sketch,* there is a mass of eruptive rock, younger than the main mass of granites, and Mr. Howitt remarks,† that as the granites and granite dykes penetrated the schists and metamorphosed them, so did the quartz-bearing and quartz-less porphyries of the Frenchman's (Day's) Hill, penetrate in masses and in dykes, both the granites and the schists, and react on them.

In summarising the general results of his work on the sedimentary, metamorphic, and igneous rocks of Ensay (p. 59), Mr. Howitt remarks that—"two kinds of metamorphism may be distinguished—dynamic metamorphism, or the effects produced by heat, resulting from vast movements within the earth's crust upon the sediments and the mineralised waters included in them—and contact metamorphism, or the effects produced on the sediments by masses of intrusive igneous rocks."

The movements which tilted, folded, and crushed the sediments at the close of the Silurian period over an enormous region of the Australian Alps metamorphosed them into argillites, and where the movements were greatest into mica-schist and gneiss.

Following these results of dynamical metamorphism, the more or less altered sediments were invaded by molten masses which reacted on certain areas producing contact schists.

At Omeo it is remarked‡ that—"The regional schists were probably phyllites and fine grained mica-schists, and by the further action of the invading granites have been converted for some distance from the contact into mica-schist, tourmaline-schist, and forms of gneiss." Some additional remarks on the schists of the Livingstone Creek valley are to be found in the author's "Report on a Geological Traverse of the Mitta." §

* A Geological Sketch Section Australian Alps. Trans. R. Soc., S. Australia.

† Notes on certain Metamorphic Rocks at Omeo. Trans. R Soc. Victoria, 1887.

‡ A. W. Howitt. Notes on certain Metamorphic and Plutonic Rocks at Omeo. Trans. R. Soc. Victoria.

§ Reports, Mining Registrars, Victoria, 1887. Appendix by J. Stirling.

DEVONIAN.

There is a well marked stratigraphical break between the underlying Silurian beds and the lowest members of the Devonian series. The sedimentary rocks of the latter occupy basins in the former, and are found in isolated areas.

The lowest Devonian rocks are certain quartz porphyries, fragmental porphyries, and felsitic rocks—the products of volcanic activities which marked the close of the Silurian Period. These rocks occupy a large part of the western watershed of the Snowy River. At several points, notably the Cobberas Mountains, Wombargo Mountains, &c., are very distinct remnants of this period of igneous action—round these centres are grouped beds of consolidated ash and tufa, while resting in hollows in these igneous masses are beds of conglomerate, shale, and crystalline limestone containing fossils of distinctively Middle Devonian age. Such Middle Devonian areas now form mere pockets in the general land surface, and have suffered extensive denudation. The principal Middle Devonian areas are Bindi in the Tambo Valley ; Buchan in the Snowy River watershed ; Cowambat and Native Dog on the flanks of Mount Cobberas, at the head of Cowambat Creek and Native Dog Creek respectively, and at Tabberrabera and Cobbannah Creek, in the Mitchell River valley.

The lithological and palæontological characteristics of the Middle Devonian areas are as follows :—

At Bindi, on the east side of the Tambo, beds of blue crystalline limestone rest on subordinate beds of conglomerate. The limestone beds are inclined at an angle of from forty to sixty to the west, and contain the following fossils—*Phragmoceras subtrigonum, Spirifera lævicosta, Chonetes australis, Favosites Goldfusi, Spirigera reticularis, Stromatopora concentrica, Cystiphyllum, Pterinea,* with fragments of *Asterolepis**

On the west are beds of shale, felspathic sandstone, and in the Main Dividing Range masses of conglomerate, and red sandstone, as at Mount Tambo. The Mount Tambo beds have been classed as Upper Devonian by Mr. Howitt, although I am not yet satisfied that they are really superior to the Bindi Limestones, and may after all form part of the Middle Devonian series.

The Buchan beds are situated between the Buchan and Merrindal Rivers, and occupy a hollow in the porphyries. In lithological character they are similar to those of Bindi, but darker in colour, in fact nearly black, and are very much contorted. These beds are between four hundred and five hundred feet thick, and only form part of the group. The lower members consist of coarsely aggregated felsitic breccias—the coarseness of the materials decreasing, but with alternations of texture, in ascending, and in

*Stirling, Notes on the Bindi Limestones. Progress Report, Geol. Survey Victoria, No. 3, p. 188.

places, as at Butcher's Creek, pass into or alternate with subordinate conglomerates, in which angular or rounded fragments of sedimentary rocks are of common occurrence. The whole of the Buchan beds have been ably described by Mr. Howitt.

The rocks at Cowombat are nearly vertical, yellowish and blue, thin shales, with bands of calcareous shale and limestone, resting on the porphyries and altered Silurian rocks. The corals and Brachipods found here are considered as younger than those of the Bindi or Buchan beds, but still of Middle Devonian age.

At the Native Dog Creek the beds consist of dark shales with calcareous nodules and blue compact limestone.

At Talboocabbera, junction of the Mitchell and Wentworth Rivers, especially on Swamp Creek, there are limestone beds and shales, containing *Spirifera, Atrypa,* and other fossils similar to Bindi. South-west from Talboocabbera are masses of slates, hard shales, sandstones, and quartzites extending beyond Cobbamale to Maximilian Creek, a tributary of the Avon River. The whole of the rocks have been tilted, folded, compressed and metamorphosed.

UPPER DEVONIAN.

Between the Middle Devonian beds and the succeeding shales intercalated with the sandstones and conglomerates of Iguana Creek (a tributary of the Mitchell River south from Cobbamale Creek), in which fossil plant impressions have heen discovered of an Upper Devonian facies, there is considerable unconformability. At Iguana Creek, the fossils include—*Cordaites australis, Archæopteris Howitti*, and *Sphenopteris iguanensis.* A splendid section shewing the sequence of the beds of conglomerate, sandstones, felsites, shales, vesicular basalt, mudstones, quartz grits, etc., of the Upper Devonian series at Snowy Bluff is given in Mr. Howitt's, "Notes on the Devonian Rocks of North Gippsland."*

The stratigraphical unconformability between the Lower and Upper Devonian groups would, I think, indicate an emergence of the land, and extensive and long continued denudation, probably littoral and sub-aerial, of the Middle Devonian beds subsequent to their plication, prior to the submergence of the surface and the deposition of the Upper Devonian series. There are not wanting evidences of such submergence to a depth of not less than 5,000 feet lower than it is now. Intrusive to the Devonian rocks are masses of quartz porphyry forming characteristic outlines where the sediments have been denuded.

The absence of Mezozoic, or of Carbonaceous rocks, in the Australian Alps, would I think, imply a continuous land surface since Devonian times over that area.

Between the Devonian and Miocene, there is a complete hiatus in the Australian Alps.

* Progress Report, Geol. Survey Victoria, No. 3.

TERTIARY.

MIOCENE.

The oldest members of the Tertiary series occurring in the Australian Alps, are certain beds of auriferous gravels, clay, sands, fine gravels, ferruginous or siliceous conglomerates, and lignites containing leaves of Miocene age. The leaves are found in a yellowish-brown laminar clay, and have been identified and named by Professor McCoy as *Lastrea dargoensis*, *Tæniopteris tenuissime-striata*, *Cinnamomum polymorphoides*, and *Salisburia Murrayi*. These Miocene river gravels are overlain by sheets of basalt, as on the Dargo and Bogong High Plains.* The present river valleys have been eroded along the margins, and in some places across the lava flows to a depth of, in some places, over one thousand feet, as on the Dargo at Mayford. Fine escarpments shewing columnar basalts are seen along the edge of several of these plateaux. The lava would appear to have welled up through fissures, as no localities have yet been found where volcanic vents occur. From the examination of the Dargo High Plains area, the basaltic sheet is not less than seven hundred to eight hundred feet thick in places. The localities where such basaltic sheets occur, are Bogong High Plains, 6,000 feet; Dargo High Plains, 5,000 feet; Gibbo Table-land, 3,000 feet;† Nuninyong Table-land 4,000 feet;‡ Gelantipy Tableland, 4,000 feet.

PLIOCENE.

The Pliocene fluvatile deposits are represented by terrace deposits in the mountain valleys, and deep leads at the lower levels—generally made up of heavy boulder and gravel deposits, clays, and sands, mostly auriferous.

These deposits have evidently suffered extensive erosion, and the removal of some of the huge boulders to long distances is strongly suggestive of glacier translocation.

The localities where such terraceous deposits occur are as follows:—In the Ovens Valley, above Bright; Mitta Valley, near Omeo, and on the Big River; Kiewa River, at Mountain Creek; Hume River, above Groggin; Tambo River, near Little River Junction; Snowy River, above Turnback; Mitchell River, on the hills east of Dargo Flats; along the upper courses of the Wongungarra and Wonnangatta. With the exception of an abundance of silicified wood, apparently of a species of *Eucalyptus*, in the terraceous deposits, I am not aware that any fossils have been found.

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* R. A. F. Murray, Progress Report, Geol. Survey, Victoria. No. 5, pp. 96-101.

† *Vide* Geological Traverse of the Mitta, by J. Stirling. Reports Mining Registrars, Victoria, December, 1887.

‡ Physiography of the Tambo Valley, by J. Stirling. Trans. Geol. Soc., Australasia, 1888.

That the warmth-loving plants of the Miocene and early Pliocene periods were supplanted in Post-Miocene times by the present semi-arctic flora of the Australian Alps, is evident enough; while the wide-spread dispersion of the boulder deposits, the rounded contours of the crystalline rocks, and the undulatory outlines of the foot-hills in many of the valleys, all bespeak agencies distinct from ordinary fluvatile action; and, in the author's opinion, point very distinctly to glacier action. Briefly the evidences may be summed up as follows :—

Erratics in the Mitta Mitta and the Kiewa Valleys, huge blocks weighing many tons;* smoothed surfaces on the Cobberas Mountains and Mount Bogong;† morainics at the base of the latter on the Mountain Creek Valley;‡ eroded lake basins, Dry Hill, Hermomugee Swamp; Omeo lake basin; morainic lake, Mount Wellington;§ smoothed and scratched surfaces on Mount Kosciusko.‖ The interest appertaining to this question is no doubt great, and although the fact of glacier action can, I think, be satisfactorily established in the Australian Alps, yet further evidence is desirable as to the synchronism of the glacier period in Australia, with that of the glacial epoch in the Northern Hemisphere. That the glacier action was wide-spread over South-east Australia I have no doubt, and without entering into a discussion as to the causes of such glacier action, it seems to me difficult to resist the conviction that, considering the uniformity of natural operations all over the globe during past time, Australia was not exempt from the refrigeration which in the Northern Hemisphere culminated in a glacial epoch. The geological evidences are, I think, accumulating in favour of the view that glacier action has played a very important part during Mesozoic and Palæozoic time in the distribution of boulder deposits and the abrasion of rock surfaces. Mr. Dunn, F.G.S., has recently found some well-marked striated boulders in the Older Tertiary conglomerates in the Beechworth district, which may be seen at the Melbourne Centennial Exhibition, while the author has found similarly striated boulders in the Upper Silurian conglomerates of the Gibbo River.

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* Sterling, Notes on the Evidences of Glacier Action in the Australian Alps. Trans. R. Soc. Victoria.

† Sterling, Some Further Evidences of Glacier Action in the Australian Alps. Proc. Linn. Soc. N. S. Wales.

‡ Von Lendenfeld and Sterling, Ascent of Mount Bogong. Reports, Mining Registrars Victoria, March, 1887.

§ A. W. Howitt, in Australasian.

‖ Von Lendeneld, The Glacial Epoch in Australia. Proc. Linn. Soc. N. S. Wales.

Friday, August 31.

The Vice-President, Mr. G. S. Griffiths, F.R.G.S., F.G.S., of Melbourne, in the Chair.

The following paper was read :—

1.—RIVERS OF NEW SOUTH WALES.

By H. G. McKinney, M.E., M. Inst. C.E., Engineer for Water Conservation, N. S. Wales, late Engineer to the Royal Commission on Conservation of Water, and formerly of the Irrigation Dept., Upper India.

The quantity of water carried by a river, and the regularity, or otherwise, of its flow depend on a variety of causes and conditions. Among these, the extent, elevation, and rate of slope of the catchment area, the rainfall and climate, the nature of the formations through or over which the stream flows, and the quantity and description of the surrounding vegetation, all play an important part. It is evident that with such complexity of influences at work the quantity of water discharged by one river may be entirely different to that discharged by another of equal catchment area, and with an equal rainfall. Hence formulæ for the calculation of river dischages, based on extent of catchment area and quantity of rainfall, are not only useless but misleading. Whilst the discharge of a river throughout the entire length of channel is increased by direct rainfall, and generally by surface flow and underground percolation, it undergoes diminution throughout the entire course owing to evaporation, to absorption by vegetation, and frequently to percolation.

If the course of a river be followed up, it will be observed that the stream gradually diminishes till it becomes a mountain rivulet, and it will be found on further examination that the position of the source of the rivulet varies not only in different years but in different seasons in the same year. These changes are generally due to natural causes, and particularly to the varying conditions of the rainfall ; but sometimes they are materially influenced by human agency. Some interesting experiments and observations on this subject were described in a paper read before the Royal Society of New South Wales, on 6th June last by Mr. W. E. Abbott. In the instance related by Mr. Abbott, the effect of ring-barking the trees in a district timbered with *Eucalyptus* was to cause a permanent flow of water in several creeks which formerly had run only after heavy rains. In other words the positions of the sources of these creeks were permanently altered —or rather, altered for such time as their catchment areas remain in the condition to which they were brought by the ring-barking. When the origin of a river is a spring, it is to be remembered that the spring is the apparent and not the real source ; for springs are merely the result of underground percolation, and represent the outflow of subterranean rivulets whose sources are at higher levels. The conclusion which these facts involve, namely that the position of the source of a river is constantly changing, may appear obvious ; yet it is seldom realized, and scarcely ever taken into account.

The same causes which operate in producing constant changes in the source of a river, have an important effect in rendering the destination of its waters also uncertain. When the course of a river, after leaving the higher and more effective portion of its drainage area, lies through a great extent of comparatively level country in which the rainfall is light, the discharge of the river diminishes as the distance from the mountainous portion of the catchment area increases. The question as to whether any portion of the waters will reach the ocean, or, if not, where they will cease to flow, is determined by the rates of evaporation, percolation, and absorption.

In addition to the recurring changes produced by the causes already referred to, the conditions of every river are being steadily altered by the action of its own current. If the course of a rivulet be followed down, it is observed that in addition to carrying silt in suspension, the stream constantly rolls forward the sand and other detritus in its bed, thereby wearing down rocks and boulders, precisely as the sandblast cuts into and carves the surface of glass or of polished granite. The rivulet thus by its erosive action and moving force carries on incessantly the manufacture and transport of material to raise the level of its bed and banks in the lower lands, or to contribute to the formation of a delta. But the erosion done by the direct action of the rivulet is generally trifling compared to that done by the innumerable rills which are formed during periods of rainfall. These acting on the softened soil contribute large quantities of silt, which the increased velocity of the swollen rivulet enables it to carry.

In addition to the constant erosion of the river bed and the general denudation of the catchment area during rains, erosion of the river banks is caused by bends and other obstructions which divert the current. In such cases, however, the transport of silt is, as a rule, non-continuous ; the products of erosion at the concave bends being deposited at the convex bends.

In connection with the subject of river action, it is important to note that the capability of a current to roll forward the loose material in its bed is proportional to the sixth power of the velocity. Hence when the velocity of a stream is doubled its transporting power is increased sixty-four times. It is necessary to state that the general applicability of this principle is disputed by some authorities; but, on the other hand, its correctness in theory is established, and its practical accuracy, in relation to some cases at least, has been verified by careful experiments.

These considerations all tend to show that while the position of the source of a river is ever varying, and the destination of its waters is uncertain, so also the condition of the channel is one of perpetual change. As the products of erosion in the higher parts of the catchment area accumulate in the valleys and on the low-lying lands, the course of the river lies in an ever-increasing extent through deposits of its own creation. In the portions of a river channel situated among hills, no great change of position can be looked for; the effects of erosion being confined chiefly to the bed of the channel. But in the alluvial deposits the case is very different. Here a trifling obstruction is sufficient to divert the current against one or other of the banks; and the bank so acted on is eroded, whilst at the same time the resistance which it offers has the effect of directing the force of the current against the opposite bank at a point further down. It is evident that after a bend has begun to form in this manner, the natural tendency is to increase the abruptness of the bend till at last the neck is cut through and an island is formed at one side of the river, and bounded by a horse-shoe-shaped lagoon. This process of erosion of the bank results in constant changes of the course of a river through alluvial deposits; but much more important changes sometimes occur through the alteration of the relative levels of the river and the land adjoining, caused by the deposit of silt. When a river channel passes through alluvial deposits where the rate of fall is slight and the velocity materially diminished, the silt carried in suspension is deposited and the bed of the river raised. The natural effect of this is to cause overflows in times of flood; and just as the silt is deposited in the channel on account of the diminished velocity when the river is low, so silt is deposited on, and near the river bank on account of the check which the velocity of the overflowing waters receive through their sudden spreading out over comparatively level lands. This silt takes approximately the form of a wedge with its thick end resting on the river bank. It is apparent that the effect of this process is to raise the bed and banks of the river above the adjacent land. When this stage is reached an important change in the course of the river is only a question of time. Erosion of either bank would lead to a complete change of channel, as the river after breaking through would seek the lowest ground and follow it.

I have endeavoured in the foregoing to describe in general terms the leading characteristics of rivers, the influences which affect their discharge, and the processes by which their conditions are altered. Before proceeding to apply to the rivers of New South Wales the principles enunciated, it will not be out of place to mention some prominent illustrations of these principles which are furnished by rivers of other countries.

One of the most striking instances of river erosion which I have seen is that furnished by the River Jhelum in Kashmir. Among the many interesting sights which meet the eye of the visitor to Kashmir, are the evidences that it was once a picturesque mountain lake about eighty-four miles in length by from twenty to twenty-five in breadth. The horizontal terraces which are to be seen stretching along the sides of the hills and jutting out from the spurs are the evident marks of different heights at which stood the surface of the lake. These terraces alone furnish sufficient testimony to the changes which have taken place in this respect; but the evidence borne by the condition of the river at the place where it leaves the Vale is no less conclusive. There the Jhelum has cut out for itself a narrow channel through a rocky defile, and the same process which brought the Vale to its present state is still at work, the boulders which have fallen from the steep hill sides being the tools which nature is using to lower the channel still more and thereby drain the water from the comparatively small remnant of the ancient lake. For a student of nature desirous of obtaining a comprehensive view of the results of river action, few places could be found more interesting and probably none more picturesque than a hill called the Takht i Suliman, situated near the centre of the Vale ot Kashmir. Although this hill is more or less steep and rocky, the labour of ascending about a thousand feet to the ancient temple which crowns its summit is well repaid by the prospect afforded. It requires little effort of the imagination to realize the natural history of the Vale since the time when the waters with which it was covered, washed the slopes of the hills at the level of the highest terrace, and when the numerous torrents and streams around it, which now flow into the Jhelum, discharged their silt-laden waters into the Lake. How great deposits of silt accumulated in the Lake whilst its waters were being drained off by degrees is easily understood. Looking towards the lower end of the Vale we see broad sheets of shallow water, which, as already described, are in process of being drained off. Following up the course of the Jhelum it is observed that at Srinagar, the capital of Kashmir, the progress of natural drainage is further advanced; but even here lakes of considerable extent are to be seen, while the River Jhelum constitutes the main thoroughfare of the city, and the other main streets are represented by canals. Above Srinagar the drainage is practically complete, and the Jhelum presents the ordinary appearance of a river flowing through alluvial deposits; the only difference being that the curves and bends are unusually abrupt, as may be understood from the generally admitted fact that their almost fantastic lines suggested the well-known Kashmir shawl pattern, to which they bear a distinct resemblance.

Among instances of river action on a stupendous scale there are two which deserve special notice, one a scene of action, the other illustrating results. The first of these is the Colorado River in America, and the second the Indo-Gangetic Valley in Upper India. In the former case it is estimated by leading American authorities that the area of maximum denudation is from 13,000 to 15,000 square miles, and that the average depth of the strata removed was about 10,000 feet. The wonderful results of river action are here placed in a startling light on examination of a typical section of the Grand Cañon. This consists first of a chasm from five to six miles in width and two thousand feet deep, beneath which is a second chasm three thousand feet deep and from three thousand to four thousand feet in width from crest to crest. The rocky sides of the lower chasm, which constitutes the present river channel, are almost vertical; while those of the upper chasm which are also steep and rocky have been so sculptured by erosion and atmospheric action as to give them the appearance of immense towers and battlements. Whether it is regarded as an instance of the wonderful results of river action and denudation combined, or taken as a specimen of the grandest description of mountain architecture, the scene presented by the Grand Cañon of the Colorado is probably without a parallel.

The transition from the Cañons of the Colorado to the Indo-Gangetic Valley affords a contrast as complete as could well be imagined. It is a change from one of Nature's grandest quarries, where the excavation and transport of material is being carried on with varying but unceasing energy, to a scene of monotony and sameness, where nothing is more striking than the complete absence of the picturesque, and where the traveller can go many hundreds of miles without crossing even a hillock or seeing a pebble. Yet the combined alluvial deposits of the Indus, the Ganges, and the Brahmaputra, which cover an area of 300,000 square miles, constitute a monument of the results of river action not less remarkable than that presented by the Cañons of the Colorado. With the information at present available, no idea can be formed of the depth of the alluvial deposits which constitute the plains of Upper India. Three deep bores were put down some years ago in these deposits, one at Calcutta—that is near the mouths of the Ganges—the second at Umballa, which is at no great distance from the ill-defined dividing line between the present drainage area of the Ganges and that of the Indus, and the third in the valley of the Indus, and about four hundred miles from the river's mouth. The depth reached in the first of these bores was four hundred and eighty-one feet, that in the second seven hundred and one feet, and that in the third four hundred and sixty-four feet; but in none of them was any indication found that the bottom of the alluvium was near. Under the title of "A River of Ruined Capitals," the manner in which the Hooghly alters its course while the delta at its mouth is being extended seaward, has been graphically described by one of the most brilliant of recent Anglo-Indian writers. The title is a suggestive one and recalls to mind that ruins of ancient cities are among the most substantial evidences of the important changes which are due to the alteration of the sources of several of the rivers of Upper India.

Some conception of the time required to accumulate such deposits as those of the Indo-Gangetic Valley may be obtained by examination of the rates at which deltas advance seaward. It is known that in the period of three hundred years ending 1869, the delta of the Tiber advanced a distance of five thousand five hundred and twenty feet, or at an average rate of about eighteen and a-half feet per annum. The deposits at the Sulina mouth of the Danube and at the South Pass of the Mississippi, are advancing seaward at a rate of from sixty to one hundred feet annually, and it is noteworthy that at the unimproved mouths of these rivers, the rate of advance is more than three times as great.

While these considerations give some clue to the length of time which may have been taken in the formation of deltas, it is to be remembered that the rate at which a delta advances is necessarily irregular, depending as it does on the varying conditions of a river. An important element in the formation of deltas and one which is generally overlooked, is the destruction of microscopic life at the place where the fresh and salt waters meet. A well-known authority, Mr. Baldwin Latham, M. Inst. C.E., states that in the case of rivers flowing into tideless seas, as in the instance of the Nile, the formation of the delta is due even more to this cause than to the solid matter brought down.

In applying to the rivers of New South Wales, the principles already discussed, we find that in relation to their silt-carrying capabilities, these rivers may conveniently be divided into two classes. The first comprises those whose transporting power is sufficient in an average series of years to maintain the sectional areas of their channels undiminished and to carry a great proportion of their silt to the ocean, or to the river or lake, into which they flow. The second class includes those rivers whose section beyond a certain point diminishes as the distance from the source increases, and whose silt is deposited chiefly along the lines of their courses. All the coastal rivers may fairly be ranked in the first class, while all the western rivers with the exception of the Murray, must be ranked in the second.

It is clear that the natural tendency of a river of the first class is to alter gradually to one of the second; for as denudation progresses and the catchment area wears down, the rate of fall of the river diminishes and the alluvial deposits increase in extent till at last the diminished moving force of the currents is unequal to the task of carrying the silt. Then commences a period during which the channel becomes choked up, at and near the place where the velocity receives its first important check—that is, as a rule, at and near the beginning of the delta. During this period the river during floods spreads over the delta, or flows through it in a series of small channels; but generally either it forms again at the end of the delta, or the channels into which had divided become deeper and better defined. Among the western rivers of New South Wales, instances of almost every stage of this process are to be found. The Darling and the Murrumbidgee maintain well defined channels down to their confluence with the Murray, but on examination of these channels I find that as they approach the Murray their sectional areas diminish. Thus the sectional area of the Darling at Bourke is considerably greater than that of the same river a thousand miles lower down near Wentworth, and the channel of the Murrumbidgee diminishes in section from Wagga to Hay, from Hay to Balranald, and from Balranald to the junction with theMurray. (Pl. XXXI.).

The nature of the relief which these rivers obtain in times of flood affords ample evidence that in the conflicts between the force of the currents and the resistance of the alluvium, the advantage remains with the latter. High floods occur only at long intervals; and those intervals allow the silt to consolidate and vegetation to spring up. When a flood comes it finds the channel contracted and the resistence to erosion considerable. Hence we find in the case of the Darling that the current through inability to erode its own channel to a sufficient carrying capacity, finds outlets through which the flood water flows into lakes and other natural depressions, as well as filling lagoons and creeks, and, in some instances, overflowing extensive areas of land. In this way during floods, Lakes Poopelloe and Woychugga, near Wilcannia, are filled, as are also the series of lakes and depressions on the east side of the Darling along the courses of the Upper and Lower Tallywalkas; while, in addition, temporary storage on an immense scale is provided by the lakes on the west side of the river near Menindie. The Cato and Tarrion Creeks represent important overflows from the Darling, or Barwon as it is there termed; but in these instances the overflow is due chiefly, if not entirely, to the rocky bar across the river at Brewarrina.

Just as the channel of the Darling proves inadequate to the discharge of the flood water, so in the case of the Murrumbidgee. After the latter river passes Wagga Wagga, its valley widens and the extent of the alluvial deposit increases; while the river spreads in times of flood in a corresponding degree, and fills numerons lagoons and ana branches. Beyond Narrandera, the source of the Murrumbidgee no longer represents the bottom of a valley but lies through immense plains which fall away from the river towards the south as well as towards the west. Hence, when a flood takes place and the ordinary channel proves insufficient to carry it off, overflows occur in a southerly and south-westerly direction. These overflows are numerous, and some of them come into operation at a comparatively low level of the river; while others have never been known to act except in 1870. Of the effluents which carry a portion of the flood waters of the Murrumbidgee to the Billabong Creek, the most valuable is the Yanko Creek, which is a most important natural distributary by itself, and the value of which is greatly enhanced by the subdivision of its waters at the Colombo Creek head. Although, under present conditions, Lake Urana receives a share of the waters of the Murrumbidgee only in exceptionally high floods, and even then only by overflow from the Colombo Creek, it is by far the most important of the lakes which that river can supply. The other lakes which depend wholly or chiefly on the flood waters of the Murrumbidgee are all situated below the junction of that river with the Lachlan. The most important of these are Lakes Tala and Yanga on the east side of the river, and Lakes Paika, Macommon, Ptarpunga, Tori, Merimlee, and Waldaira on the west side.

In the case of the Macquarie River, not only does the channel entirely disappear at the Macquarie Marshes, but it may safely be inferred that the process of silting up is in progress from the Marshes up to near Narromine. In proof of this, I found that the sectional area of the river at Dubbo is much greater than at Warren, and that the diminishing channel between these places is altogether unequal to the task of discharging the flood water. As the Murrumbidgee ceases to flow in a valley near Narrandera, so the Macquarie ceases to flow in a valley after it passes the neighbourhood of Narromine. Hence we find that during floods there is a series of overflows from near Narromine down to the place where the channel disappears, a considerable portion of the water reaching the Bogan River through the Beleringar, Gunningbar, and Duck Creeks.

The Lachlan affords another instance of what may be termed the old age of a river. Its case is almost an exact parallel to that of the Macquarie; the channel being a gradually diminishing one, while the surplus flood waters which are not carried off by effluent creeks are lost in the reed beds at the junction with the Murrumbidgee; only a small portion of the highest floods reaching the latter river. Lake Carjelligo, or Cudgellico, as it is frequently called, occupies the same position in regard to the Lachlan, as the lakes on the lower part of the Murrumbidgee do to that river; that is, it receives a supply of water when the river is in flood and allows a large portion of it to escape as the river falls. The most important effluent from the Lachlan is the Willandra

Billabong, a most valuable natural distributary channel which in 1870 carried the waters of the Lachlan to within about thirty miles of the Darling.

Other prominent cases of rivers passing through similar stages are furnished by the Namoi and Gwydir, whose condition corresponds with that of the Darling, the Narran, which occasionally flows into the lake of the same name, the Bogan, Castlereagh, Bokhara, Culgoa, and Warrego, which reach the Darling only during floods, and the Paroo which is known to have flowed into the Darling only once since the settlement of that part of the colony—namely, in January, 1885.

The characteristics which distinguish our western rivers, with the exception of the Murray, being the natural outcome of the physical and climatic conditions existing throughout the country west of the Dividing Range, are also found illustrated on a smaller scale by numberless creeks. It will be sufficient here to mention three instances which have frequently come under my observation. The first is Puletop, or Burke's Creek, which rises in the range constituting the watershed between the Murrumbidgee River and the Billabong Creek, and which after flowing about fifty miles, disappears entirely at the edge of the Bullenbong Plain. Burke's Creek when in flood attains the proportions of a river. Before it reaches that part of its course where its channel fails to carry the flood waters, its width is from eighty to one hundred and twenty feet and its depth from twenty to twenty-five feet. When in flood this creek carries a large quantity of silt which is used partly in raising its bed and banks, and partly in raising the level of the Bullenbong Plain. The waters of the creek after spreading over this plain, which is remarkably uniform, and about seven miles in length by five in breadth, collect again in a creek of greatly diminished section, and flow into the Bullenbong Creek.

The other two creeks to which I wish to refer are Brookong Creek and Boree Creek, both of which look unimportant either on a map or on the ground, though much interest attaches to them on account of the part they have played in the formation of the great fertile Brookong Plain. Both of these creeks have their sources in the ridges which run like long projecting roots from the Galore—the Brookong Creek in the ridges which run southward, and the Boree Creek in those extending to the north-west. In both cases the courses of the creeks across the plain have been obliterated. The process by which the plain was raised to its present level, and the creek beds silted up is still in progress. The tendency of the ends of the creeks to recede still further towards the ridges is apparent to any observer, and though the lowering of the average sources of the creeks cannot be observed it can no less correctly be inferred. As in cases of other creeks and rivers under similar conditions, both Boree and Brookong

Creeks re-form at the opposite side of Brookong Plain, the former at the place where it flows into Lake Cullivel, and the latter at the point where it joins Urana Creek.

As already pointed out, the coastal rivers of New South Wales differ in an important degree from those of the interior, in their silt-carrying capabilities. A brief examination of the nature of the catchment areas on the opposite sides of the Dividing Range is sufficient to afford an explanation of this fact. Between the coast line and the summit of the Dividing Range is inclosed an area of 50,000 square miles. As the length along the coast from the border of Victoria to that of Queensland is nearly seven hundred miles, the mean distance from the coast to the summit of the Dividing Range is little over seventy-one miles. On the other hand, the distance measured along the centre of the valley of the Murrumbidgee from the source of its head waters to its confluence with the Murray, is three hundred and ninety miles; and the corresponding distance in the case of the Lachlan three hundred and eighty-twomiles; while the distance from the source of the Macquarie to the point were that river is lost in the Marshes is about two hundred and forty-two miles, and to the Darling three hundred miles. Measured in the same way, that is taking the general direction of the river while avoiding its windings, the extreme length of the course of the Hunter is about one hundred and forty miles, and the corresponding lengths for the Clarence and Hawkesbury, each about one hundred and thirty miles. These figures place in a clear light the high rates of fall on the coast river basins as compared with those on the western basins. That the average rate of fall of the former is absolutely, as well as relatively great, is apparent when we consider that the height of the Dividing Range varies generally from 2,300 to 5,000 feet; so that a straight line drawn from the summit to the coast would have, on an average, a slope of about fifty feet per mile. In reality almost the whole of the descent is accomplished in a comparatively short length of the river. The natural consequence of this, is that when the foot of the mountains is reached and the velocity of the rivers is suddenly checked, a remarkable rise of the surface level occurs during floods and frequently results in the inundation of the alluvial lands. Whilst this great rise of the surface level at the points where the rivers emerge from the hills generally represents the heaping up of the waters consequent on the sudden dimunition of the rate of fall, it is often due in an important degree to the narrowness of the channels where these points are reached. In the instance of the Clarence at Copmanhurst, the great erosive power of the current at that place has resulted in the formation of a deep and narrow channel; so that when floods occur, their discharge is obstructed both by the diminution of the rate of fall and by the comparatively small section of the channel. Owing to these causes the rise of the

Clarence at Copmanhurst in a high flood is seventy-seven feet, while nine miles further down it is sixty-two feet, and at Moleville, twenty miles from Copmanhurst, only thirty-four feet. The range of surface level of the Nepean at its junction with the Warragamba is about seventy feet; while ten miles further down the river, near Penrith, it is only forty-two feet. Similar conditions exist on nearly all the other coastal rivers.

When we consider the effect of such changes of slope of the river surface, the causes of the extent and destructiveness of floods on the coastal rivers are easily understood. Taking the case of the Clarence, we find that in a high flood the average slope of the surface from Copmanhurst to Moleville exceeds that when the river is low by about two feet two inches per mile, so that at such times the surface fall between these places cannot be less than about two and a-half feet per mile. With such a river as the Clarence this fall gives a high rate of velocity which is only checked by degrees by the tidal waters. When the river is low, or even during moderate floods, the resistance of the tidal waters is sufficient to cause the deposit of all, or nearly all the silt before the Heads are reached; but in the highest floods the velocity is sufficient to retain considerable scouring power in the current even at the river's mouth.

The Clarence is here specially referred to; but a similar description, with only slight variations, would apply to all the coastal rivers. Their fall is in all cases at first rapid till they reach the alluvial deposits with which, in a large measure, they have filled their estuaries. The rivers are tidal; and the upper ends of the alluvial deposits represent approximately the limits reached by the tides, With few exceptions every river has a sandy bar at its mouth—representing the result of the conflict between the tidal and upland waters. To these characteristics of the coastal rivers is to be added that deltas in the ordinary acceptation of the term are not found on the coast of New South Wales. Enormous quantities of silt are carried out to sea during floods, but it is evident that the ocean currents are sufficiently strong to prevent its deposition near the coast.

Classification of our rivers according to their silt-carrying capabilities naturally suggests inquiry as to whether we have any information on which can be based an approximate estimate of the quantity of silt carried. This is a subject which has been dealt with by careful experiments in several important instances; but so far as I am aware its investigation has not yet been entered on in these colonies. It will, however, give some conception of the magnitude of the work being done by our rivers if we apply to them the results obtained elsewhere under somewhat analagous circumstances.

With a catchment area of 6,455 square miles, a mean rainfall of thirty-four and two-third inches and a length of two hundred and forty-five miles, the Tiber bears a fairly close analogy to some of our coastal rivers, and may, in the absence of a better instance for comparison, be taken to illustrate the probable amount of work done by the Murrumbidgee at Wagga in transporting silt. It has been ascertained that the quantity of silt carried by the Tiber is $\frac{1}{1138}$ by weight of the water discharged. If we assume that the corresponding proportion in the case of the Murrumbidgee is $\frac{1}{1200}$, and that the mean discharge for the year is 2,000 cubic feet per second, we find that the quantity of silt carried past Wagga on an average every twenty-four hours is 4,018 tons. This in a year would amount to about one million cubic yards, or slightly less than a depth of $\frac{1}{12,000}$ of a foot over the catchment area. In other words, on this hypothesis the catchment area of the Murrumbidgee above Wagga is wearing down at the rate of a foot in twelve thousand years. The proportion of silt assumed is intermediate to the proportions ascertained in the cases of the Ganges and the Mississippi, that of the former being $\frac{1}{510}$ and that of the latter $\frac{1}{1,500}$. In all probability the rate of denudation on the catchment area of the Murrumbidgee is considerably in excess of that here obtained for we know that on the basin of the Rhone the loss by denudation is at the rate of a foot in one thousand five hundred and twenty-eight years; in that of the Upper Ganges, a foot in eight hundred and twenty-three years; and in that of the Po, a foot in seven hundred and twenty-nine years.

It is necessary to mention here that while the process of denudation which has resulted in the formation of great alluvial deposits along and near the courses of our rivers is still in progress, there is much reason to believe that at some former periods, the rate at which this action took place was greatly in excess of what it is under present conditions. In connection with this it has long been well-known to geologists that the conditions of climate in the Northern Hemisphere have differed widely in different geological periods, and that at a comparatively recent period the British Islands, and nearly the whole of continental Europe, had a climate such as is not now found south of Lapland. The explanation of this fact which receives most general acceptance is that which was first propounded by Dr. J. Croll, and brought into prominent notice in his great work "Climate and Time in their Geological Relations." It would be out of place here to do more than mention that in the work referred to, Dr. Croll has shown that the remarkable changes of climate which different parts of the earth have undergone at different periods, can be accounted for by the changes which are known to have taken place in the eccentricity of the earth's orbit, and by the deflection of ocean currents; the second of these causes being in a very large degree a consequence of the first. That ocean currents have an important influence on climate has long been known; but this influence was placed in startling relief when Dr. Croll showed that "but for the gulf stream and other currents, London would have a mean annual temperature forty degrees lower than at present."

To Mr. C. S. Wilkinson, Government Geologist of New South Wales, is due the credit of first applying to the case of Australia, the principles which have been accepted in explanation of the changes of climate in the Northern Hemisphere. The results of his investigations which were given in his Address as President of the Linnean Society of New South Wales in January, 1885, are most interesting and instructive in their bearing on the formation of the great alluvial deposits of this colony, and on the present stage of development of our rivers. It is unnecessary here to follow Mr. Wilkinson in his description of the causes of the high rate of rainfall during a past epoch in the western plains of New South Wales, where the rainfall is now light and uncertain. That the conditions of rainfall and of vegetation, particularly in the western parts of this colony were entirely different to those now existing is proved by one circumstance alone—namely, the existence there of gigantic animals, such as the *Diprotodon*, which could not live under present climatic conditions. Mr. Wilkinson calls special attention to the significant fact that the largest find of fossil remains of large extinct animals in the western part of New South Wales—namely, that at Cuddie Springs, fifteen miles south of the Darling, near Brewarrina, was in a boggy spring on the open plains and about ten miles distant from the nearest watercourre. It has been said that we live in a zoologically impoverished age in which the largest and most striking forms of animal life have dwindled, or become extinct. That this remark applies accurately to New South Wales, is placed in a remarkably clear light in Mr. Wilkinson's Address to which I have referred. Whilst there are questions which only the geologist can investigate, their practical bearing on the development of our rivers must not be lost sight of. The researches of the historian are not more necessary to the statesman, than are those of the geologist to the engineer who deals with rivers and water supply.

As I have already pointed out, the position of the source of a river is constantly varying. It is an evident consequence of this that the effective catchment area is also indefinite. In steep and impervious ground a very slight fall of rain is sufficient to cause a flow of surface water; but as the slope of the catchment area diminishes, and the ground becomes more permeable or more densely covered with vegetation, a heavier rainfall is required before any surface flow takes place. Hence as a general rule the nominal drainage areas of rivers require to be divided into effective and non-effective areas; and it must be borne in mind that the ratio which the first of these divisions bears to the second is constantly changing. Thus in the case of the Darling, while the total catchment area is about 232,000 square miles, the portion of this which can be classed as effective in ordinary seasons does not exceed 54,600 square miles; and it is doubtful whether in a dry season the effective catchment can be estimated at more than a third of the latter area. It is clear from these considerations that only a small portion of the rainfall ever reaches the western rivers; and in addition to this fact it has to be remembered that the water flowing in these rivers is subject to constant diminution. This is due firstly to evaporation, secondly to absorption by vegetation in the channel or on its banks, and thirdly to percolation. In connection with the first of these sources of loss it is necessary to remark that evaporation takes place not only from the water surface, but from so much of the margin on each side as is kept moist by capillary attraction. The latter point is of much greater importance than might at first sight be expected; for Mr. H. C. Russell, Government Astronomer of New South Wales, has ascertained by experiment that the rate of evaporation from soil destitute of vegetation is from two to three and a-half times greater than from water, and the rate from a grassy surface from one and a-half to two and a-half times greater than from water.

In a Report on the Macquarie River, which I presented to the Royal Commission on the Conservation of Water, in May, 1885, I pointed out as the result of actual experiments that when the discharge of that river at Dubbo was one hundred and fourteen and a-half cubic feet per second, that at Warren was only fifty-two cubic feet per second, and that when the discharge at the former place fell to twenty cubic feet per second, the current ceased at about eighteen miles above Warren. I also showed that of the total loss of water between these places, sixteen and a-half per cent. in the former case and thirty-eight per cent. in the latter might be due to evaporation, while by absorption the trees on the river bank could account for twelve and a-half cubic feet per second. The opinion which I formed regarding percolation in that part of the Macquarie was that, at least when that river is low, very little loss is due to that cause. It is, in fact, unlikely that any considerable proportion of the waters of our western rivers is lost by percolation, excepting in the higher parts of their courses, for the natural tendency of a river flowing through alluvium is to tamp up all interstices in its channel. There are, doubtless, cases in which loss of water from river channels is sustained by percolation through alluvium. For instance, in that portion of the Murray between Mulwala and Echuca, I found distinct evidences of percolation in a north-westerly direction—that is into New South Wales. Judging from the physical conditions of the district, I suggested that probably it would be found that in the part of the Murray between Echuca and the junction with the Murrumbidgee there is a westward percolation—that is into Victoria—and the river gaugings which have since been made tend to confirm this opinion.

When we consider the great extent of the districts which contribute either nothing or very little to the supply of our western rivers and the great distances which these rivers flow without receiving any tributaries, but with diminishing influences constantly at work, there seems little left to answer in regard to the question, "What becomes of our rainfall?" If there be any who still entertain doubts on this subject, these doubts will probably remain till the Government Astronomer determines experimentally in the western district the rate of evaporation from shallow clay pans and from earth kept saturated by capillary attraction. Meanwhile I may recall a fact in connection with this which came under my notice when I was engaged in compiling technical information for the Water Commission. If the two lakes, which combined are known as the Narran Water, were filled, the extent of the surface is so great that an average flow of one hundred and ninety cubic feet per second would be required throughout the year merely to balance the loss by evaporation—that is assuming the latter at six feet per annum. Possibly this rate may be too high; but even if it were reduced by half, evaporation, and absorption by vegetation would account for the disappearance of the entire supply carried into the lake.

During periods of drought when the ground becomes parched, the beds of clay pans as well as hard and clayey ground in general, become cracked and fissured; and when rain falls, considerable quantities of water flow into the cracks so formed. There is, however, every reason to believe that by far the greater portion of the water which thus disappears is absorbed by the soil within a few feet of the surface, and that its effect is merely to restore to the soil its normal proportion of moisture. In confirmation of this it is found that after the downward flow continues for some time, the clay or other soil expands, and closes the cracks; so that the ground becomes to all appearance as impervious as before.

The scanty rainfall, the high rate of evaporation, and the uncertainty of the supplies of water in the rivers and creeks throughout a very large proportion of the country west of the Dividing Range, combine to give special value to underground streams. It has already been suggested that, as a rule, underground supplies depend on percolation at the higher parts of the drainage areas, and the reasons for this are not far to seek. In the first place, the rainfall on the high lands is greater than on the plains; in the second place, the debris washed down from the hills, and deposited near them is composed of boulders, pebbles, and heavy particles generally, which readily permit underground percolation; and, in the third place, owing to the denudation of the rocks of which the hills are mainly composed, free access for water is frequently given at the edge of the outcrop.

Although the conditions of occurrence of underground supplies of water have long been known, an extraordinary amount of popular misunderstanding still exists on this subject. As an instance I may mention that I have been gravely informed by intelligent as well as successful men of business, that certain persons merely by inspecting a plot of land in our western plains, can tell whether water is to be found there by deep boring. Mr. C. S. Wilkinson has done much to dispel such mistaken ideas and thrown light on the subject; but it is not yet sufficiently well known that in regard to the probability of finding underground supplies of water, the only true diviner is the geologist, and that the divining rod of common sense is geological information and experience.

In considering the object of underground supplies of water, it may be remarked at the outset that, as a general rule, all such large supplies of fresh water are streams and not merely reservoirs. On the other hand, if the water be salt the probability is that it is stagnant or nearly so. These are points which are frequently overlooked, although on reflection their correctness is evident. Another matter which is generally lost sight of is the fact that the flow of water underground takes place under conditions which are subject to common hydraulic laws. To illustrate this, take the case of a twelve-inch pipe, five miles in length, and with a fall of two hundred feet. We know that if for such a pipe we substitute as many pipes of two inches in diameter as would give the same internal sectional area the water would flow with considerably less velocity than in the twelve inch pipe, and the discharge would be less in a corresponding degree. If, still preserving the same sectional area of waterway, we substitute one inch pipes, the velocity and discharge are still further diminished. To take an extreme case, suppose that instead of the original twelve inch pipe, we take one of such diameter that when filled with sand, the interstices in the sand would be equal to the sectional area of the twelve inch pipe. We know that even with a fall of two hundred feet in five miles the velocity in this case would be small; but still if a vertical piece were added at the lower end of the pipe the water would rise in it to a height of two hundred feet, minus the height due to the resistance. Now if the height and length be each multiplied by ten and the sand be considered as covered with clay and soil, instead of being inclosed in a pipe, the case bears no little resemblance to that of the Liverpool Plains in which, as described by Mr. T. K. Abbott in a paper read before the Royal Society of New South Wales in 1880, an abundant and wide-spread supply of water is obtained from wells. There can be no doubt that the source of this supply is to be found on and near the Dividing Range.

When we examine on a map the basin of the Darling and its tributaries and follow the watershed line from the source of the Talbragar to the source of the Warrego, we find that there is a great continuous amphitheatre of hills ranging generally from 2,000 to 5,000 feet in height, and that the rainfall on these hills varies from twenty-two to thirty-five inches. Comparing a statement of heights above sea level, which was most kindly supplied to me by Mr. H. C. Stanley, Chief-Engineer for Railways, Queensland, with the information given by Mr. H. C. Russell in his rainfall returns, I find that throughout the 23,650 square miles of hills and tableland in the Queensland portion of the Darling basin, the rainfall occasionally rises in several places to over forty inches and seldom falls below twenty inches. There is some point here in the question, "What becomes of the rainfall?" While there is no doubt that here also, evaporation and plant life account for a very large portion of it, it is beyond question that an important share percolates underground. I have already pointed out in reference to this question that the underground flow is subject simply to the ordinary rules of hydraulics. Hence, with the same class of material, the resistance to the flow will increase with the distance from the source of supply. We find, therefore, that near the foothills the supply in springs and wells is much greater than at a distance. In fact the supply near the hills is in some cases apparently inexhaustible; while at a great distance down the valley—for instance in the Bourke district—the springs tapped, though most valuable, are mere driblets when compared to those near the foot of the Dividing Range. Also, as the distance from the source increases, and the flow becomes weaker, it is natural to find that the quality of the water is frequently deteriorated from its long contact with soil more or less impregnated with salts.

A feature of this question which forms a popular stumbling block is the unfailing nature of some springs and the apparent uniformity of their supply. There is really nothing surprising in this regularity when we come to consider its causes. Different kinds of earths absorb in their interstices different proportions of water; the proportion in the case of sand being as much as one-third of its bulk. In the instance of the Botany watershed whose net area is 5,262 acres, the depth of sand varies from thirty-four feet to one hundred and nine feet, Taking the mean of these depths—that is seventy-one and a-half feet—as the average, and deducting five and a-half feet from this on account of occasional strata of inferior holding capacity, we have still a storage capacity equal to a reservoir 5,262 acres in extent and twenty-two feet deep. The area here mentioned is that given in one part of Mr. Clark's Report on the Water Supply of Sydney; but at another place in the same report he gives the Botany catchment as 5.8 square miles, or 3,712 acres. Assuming only the latter area as representing the storage, we find that with the depth stated above, the storage capacity of the Botany basin is over twenty-two thousand millions of gallons, or more than three times the available storage capacity of the Prospect Reservoir, Taking as the total catchment the larger area mentioned by Mr. Clarke, namely, 5,262 acres, we find that more than three inches of rain actually stored from that extent of surface would be sufficient to give a uniform supply of one million gallons per day for a year. So long as the total demands of Sydney did not exceed the quantity contributed to the sands by the rainfall, the supply at Botany appeared inexhaustible. The case is similar in regard to our underground supplies in the western districts. Just as the Botany storage afforded a uniform supply, within certain limits, to Sydney, or as Lough Neagh in Ireland acts in equalising the flow in the River Bann, or, on an immense scale, as the great lakes of North America give a comparatively uniform flow in the River St. Lawrence, so the deposits of drift under our table-lands and under our alluvial plains, act in affording a steady supply in the underground streams.

In India irrigation from wells has been carried on from time immemorial, and throughout the Bengal Presidency wells are now to be seen in use for this purpose in thousands. I have no doubt that there are many places in New South Wales where wells could be so used to great advantage; but, with the exception of those in Chinamen's gardens, I have seen only two wells used for irrigation in this colony, although my opportunities for observation have been numerous and widespread. In the districts of the Murrumbidgee, the Macquarie, and the Namoi, I believe there are places where the underground supplies can be utilised in this manner; but I think it improbable that either the quantity or quality of the water obtained from wells or borings at a distance of more than a hundred miles from the hills will warrant expenditure for irrigation.

Deep underground supplies of water frequently flow in narrow channels; but they are more frequently met with in widespread deposits of drift. A prominent instance of the latter class of cases is that furnished by the Punjab, and the North West Provinces in India There, over very extensive areas, so regular is the slope of the underground streams as well as the surface of the ground, that the landholders can almost always estimate to within a very few feet, the depth at which a good supply of water can be obtained. But there are also cases both in India and New South Wales where water can be obtained at a moderate depth in river channels which have become filled up within a comparatively recent period.

I have already described the manner in which a river flowing through alluvial soil raises its bed and banks by degrees till at last, after breaking through one of its banks, it seeks the lowest land, and flows there. When that takes place in a district where there is drifting sand, the old river channel becomes choked up, and not only so, but on account of the obstruction to the wind caused by the trees and other vegetation on the river banks, the sand accumulates to some height above the surrounding plains; so that the old course of the river is indicated by a sandy ridge. In such cases the old river channel carries a small proportion of the original discharge and this is sensibly augmented by the rainfall on the ridge; for it is found that in heavy rain over eighty per cent. of the rainfall percolates into clean sand. Instances of this description are more common in India than in New South Wales; but there are good instances to be met with here, particularly in the district of the Castlereagh River.

It might at first sight be supposed that a fair approximate estimate could be formed of the proportion of the rainfall which passes to underground streams, but in reality this is a very complicated question. I have ascertained that in 1884, which was an exceptionally dry year, the quantity of water which flowed past Wagga Wagga was less than one-tenth of the rainfall on the catchment area of the Murrumbidgee above that place. But on examination of Mr. Russell's "Rainfall Return," I find that during the year the rain must have fallen chiefly in light showers; so that evaporation and the requirements of vegetation would account for nearly the whole quantity.

By giving due consideration to the principles described we dispel many apparent anomalies in connection with our rivers. For instance, at first sight it seems incredible that the Clarence, with a catchment area of only eight thousand four hundred square miles should in a high flood discharge more water than the Murray below Wentworth, when both that river and the Darling are in flood; yet such is a fact. The reason is that in the case of the Clarence, several causes combine to make the catchment area highly effective, while the conditions of the western rivers are exactly the reverse of this. The Clarence has a rapid fall and a short course, a compact catchment area, and a rainfall about fifty per cent. in excess of that on the more favoured parts of the Darling basin. The result of these conditions is that a large proportion of the rainfall on the Clarence basin runs off with a high velocity; or that while the duration of a flood on the Darling is reckoned by months, that of a flood on the Clarence is measured by hours, or at most by days.

I have endeavoured in the foregoing to give a fairly accurate general conception of the nature of the rivers, which flow on opposite sides of the Dividing Range. The rivers under these heads, namely, those which flow to the ocean on the east coast of New South Wales, and those which flow into the Murray and the Darling, include all of any importance, except the Snowy River. At the extreme south of the country of Beresford, a range of mountains leaves the Dividing Range, and extends in a north-westerly direction till it meets the south boundary of the county of Buccleuch. Thence it turns south till it crosses the border of Victoria; the part of the range running southwards being termed the Snowy Mountains, and including the highest peaks in Australia. The Dividing Range and the two parts of the watershed line described, form three sides of a quadrilateral, of which the fourth is the boundary line of Victoria. This figure represents the New South Wales portion of the drainage area of the Snowy River, which, though one of the finest rivers in this colony is the least known on account of being the most inaccessible.

In the brief description which I have given of our rivers, I have purposely avoided going into the details of any particular project for their utilization, though endeavouring to afford such information as should lead to a sound opinion as to the best uses to which they can be put. I have pointed out that the currents of our coastal rivers are in the main sufficiently strong to keep the channels free from silt, that the scouring out of the channels either is assisted or can be assisted by tidal action, and that the range of the tides generally extends to about the upper boundary of the rich deposits of alluvium. All these conditions are favourable to navigation, and show that the coastal rivers are highly adapted for this purpose. On the other hand the floods in these rivers rise suddenly and to great heights, the alluvial flats are in many places divided into islands and intersected by creeks, and in nearly all cases these flats are wanting in uniformity. These conditions are adverse to irrigation works of a large or comprehensive description; while, owing to the comparatively high rate of rainfall, the necessity for irrigation is felt only in a moderate degree.

In the country west of the Dividing Range, the conditions, as described, are entirely different. The courses of the rivers are long, tortuous and constantly changing, silt is accumulating in many places and altering the bed levels; and though the duration of floods is much greater than on the coastal rivers, the length of the rivers is so great, that steamers can seldom go on a long journey on them without the risk of being grounded and laid up for months. These conditions all tell against the suitability of the western rivers for navigation. But on the other hand, there is scarcely one of these rivers which cannot be conserved, and its waters utilised with great benefit to the country. The scanty rainfall in the western districts, the richness of the alluvial plains through which the rivers flow, the uniformity of these plains, and the fact that the land frequently slopes away from the rivers, are all conditions highly favourable to a system of conservation and distribution of the waters. Where a system of navigation can be carried out in conjunction with irrigation, by all means let us have both. But if one of these methods of utilising the western rivers has to be sacrificed, there can be no doubt that that one should be navigation. In a report on the subject of Irrigation in Riverina, which I presented to the Royal Commission on the Conservation of Water, I pointed out that on a moderate estimate, the net selling value of the available supply of water in the Murrumbidgee and Murray is £312,000 per annum. This estimate is based on the rate at which water was then supplied in the Goulburn Valley in Victoria; but if the rates be taken according to what a very large number of landowners state they would be willing to pay, the selling value of the available supply in these two rivers alone is £540,000 per annum. Among others of our western rivers which can easily be utilised are the Darling, the Lachlan, the Macquarie, and the Gwyder. In fact our western rivers generally are remarkably adapted for distribution and utilisation; and, though their waters would irrigate only a small proportion of the total area of the western plains, still that small proportion would have an enormous effect in mitigating the losses caused by droughts. It is well known that the losses which the western pastoralists and land holders generally suffer in one period of drought, would far exceed the cost of a complete system of water conservation for the whole colony. But for those who suffer such losses there is special application in the remark of the American writer, that to-day's dinner subtends a greater visual angle than yesterday's revolution. It is satisfactory, however, to know that the number of those who appreciate the importance of water conservation and irrigation, is increasing rapidly in this colony, which is not surprising when the examples of California and of the neighbouring colony of Victoria are considered. It does not require the gift of prophecy to forsee, that on the adoption of extensive and well-considered projects for water conservation and irrigation, depend in a very large measure the future progress and prosperity of this colony.

STATEMENT OF DRAINAGE AREAS.

General Description.	Detail.	Area in Sq. Miles. Hilly.	Plain.	Total Areas.	Sums of Areas.	Corresponding Mean Rainfall in Inches in Hilly District.	Plain Country.	Total Area.
Coast Basins	Richmond	......	......	2,660	......	......	......	31·88
" "	Clarence	......	......	8,340	......	......	......	36·13
" "	Macleay	......	......	4,200	......	......	......	31·20
" "	Hunter	......	......	8,300	......	......	......	27·42
" "	Hawkesbury	......	......	8,400	......	......	......	34·26
" "	Shoalhaven	......	......	2,840	......	......	......	39·55
" "	Minor Coast Basins...	......	......	15,360	......	......	......	41·69
	Total Area of Coast Basins.				50,100			35·31
Darling Basin in New South Wales.	Source to Walgett	10,430	9,290	19,720	......	28·17	18·12	23·44
	Subsidiary basin of the Peel and Namoi ..	4,440	11,800	16,240	......	22·37	19·20	20·07
	Darling from Namoi to Macquarie		390	390	......	......	15·56	15·56
" "	Castlereagh	2,860	3,890	6,750	......	19·10	17·43	18·43
" "	Macquarie	9,830	5,610	15,440	......	23·17	15·67	20·44
" "	Big Warrambool		3,110	3,110	......	......	15·83	15·83
" "	Bogan...	3,390	10,170	13,560	......	18·23	14·51	15·44
" "	Darling from Macquarie to Bourke		7,720	7,720	......	......	16·76	16·76
	Total to Bourke exclusive of area in Queensland.				82,930			19·54
" "	Bourke to junction with the Murray		29,510	29,510			9·60	9·60
" "	Paroo		15,730	15,730	45,240		10·77	10·77
	Grand total of Darling in New South Wales.				128,170			16·17
Murray in New South Wales.	Lachlan to junction with Murrumbidgee ..	7,200	6,260	13,460	......	20·33	13·41	17·11
	Murrumbidgee to junction with Lachlan ...	11,860	3,610	15,470	......	21·54	14·53	19·30
" "	" from Lachlan to Murray ...	......	310	310				
" "	† Billabong & Edward to junction with Murray	1,330	15,250	16,580	......	21·35	14·56	15·10
" "	Murray to junction with Edward	2,380	290	2,670	......	26·17	15·84	24·88
" "	" from Edward to Murrumbidgee... ...	......	50	50				
" "	" " Murrumbidgee to Darling	......	2,990	2,990	......	......	11·42	11·42
" "	" " Darling to S.A. frontier	......	140	140	......	......	11·14	11·14
	Total of Murray in New South Wales				51,670			17·35
	Total Area of Western River System.				179,840			16·51
Areas unconnected with Great Western River or with N.S.W. Coast.	Snowy River...	......	......	3,360	......	......	......	34·41
	* Mirool and other creeks	......	......	14,380	......	19·64	16·33	16·92
	Lake George	......	......	490	......	25.82	......	25·82
	* Manara	......	......	33,970	......	......	......	12·83
	* Yantara	......	......	22,050	......	......	......	8·56
" "	* Tara...	......	......	6,040	......	......	9·21	9·21
	Total of Miscellaneous Drainage Areas.	......	......	......	80,290	......	......	13·10
	Coast Basins as Above.	......	......	......	50,100	......	......	35·31
	Basin of the Great Western River System.	......	......	......	179,840	......	......	16·51
	Area of New South Wales as thus Calculated.				310,230			18·66
	Approximate Division of the Darling Basin in Queensland.							
Darling Basin in Queensland.	Mooni and other tributaries which flow into Darling above Walgett	7,000	8,000	15,000	......	34·17	23·97	28·73
" "	Balonne, &c....	10,000	40,400	50,400	......	27·73	21·93	23·08
" "	Warrego	6,000	18,850	25,850	......	......	21·50	Returns insufficient to give even an approx. mean for whole area.
" "	Paroo	650	12,750	13,400	......	......	13·11	
	Total area of Darling Basin in Queensland.	23,650	80,000	103,650				
	Summary of Divisions of the Darling Basin.							
Darling Basin.	In Queensland affluets above Walgett	7,000	8,000	15,000	34,720	34·17	23·97	28·73
" "	In N. S. W. affluets above Walgett	10,430	9,290	19,720		28·17	18·12	23·44
" "	In Queensland affluets from Walgett to Bourke	10,000	40,400	50,400		27·73	21·93	23·08
" "	In N. S. W. affluets from Walgett to Bourke ...	20,520	42,690	63,210		21·61	16·74	18·32
	Total area above Bourke.	47,950	100,380		148,330	26·15	19·53	21.67
" "	In Queensland affluets below Bourke	6,650	31,600	38,250	......	......	18·11	
" "	In New South Wales basin below Bourke ..		45,240	45,240	......	......	10·01	10·01
	Grand total of the Darling Basin.	54,600	177,220	231,820				

NOTES.

a. The Drainage Areas are necessarily given as close approximations, their sum is however almost identical with the mean of the last two calculations of the area of the Colony made by the Survey Department.

b. The statement of mean rainfall in the various drainage areas is based on the rainfall records prepared by the Government Astronomer.

c. Each of these tracts of country comprises a group of ill-defined drainage areas. The first three tracts contribute more or less to the rivers in extraordinary floods and only then.

† *d.* This area is an independent basin only in its upper portion. In its lower portion it has no well-defined boundaries, but receives flood water from the Murray River and the Murrumbidgee.

SATURDAY, SEPTEMBER 1.

The Vice-President, Mr. G S. Griffiths, F.R.G.S., F.G.S., of Melbourne, in the Chair.

The following papers were read:—

1.—SOME SUPPOSED FURTHER TRACES OF LEICHHARDT.

By JAMES PANTON.

THE fate of Leichhardt still remains a mystery, and although in this paper I will endeavour to show you that there is reason to believe a few further links of evidence have recently been obtained, I fear that there is little probability at this remote period of ever unravelling the whole truth of the disaster which must have befallen his band of explorers.

Some years ago, on reading Gregory's description of the remains of a camp and burnt hut discovered by him on the Elsey Creek, on his overland exploration from the Victoria River to the Eastern Colonies in 1856, I was impressed with these unaccountable traces of Europeans at a spot so far remote from any tracks of known explorers, and nearly four hundred miles from the seaboard.

He says, in his Journal under date 13th July:—"Several trees cut with iron axes were noticed near the camp. There was also the remains of a hut and the ashes of a large fire, indicating that there had been a party encamped there for several weeks. Several trees from six to eight inches in diameter had been cut down with iron axes in fair condition, and the hut built by cutting notches in standing trees, and resting a large pole therein for a ridge; this hut had been burnt apparently by the subsequent bush fires, and also some pieces of the thickest timber remained unconsumed. Search was made for marked trees, but none were found nor where there any fragments of iron, leather, or other material of the equipment of an exploring party, or of any bones of animals other than those common to Australia. Had an exploring party been destroyed here, there would most likely have been some indications; and it may therefore he inferred that the party had proceeded on its journey. It could not have been a camp of Leichhardt in 1845, as it is one hundred miles south-west of his route to Port Essington, and it was only six or seven years old, judging by the growth of the trees. Having subsequently seen some of Leichhardt's camps on the Burdekin, Mackenzie, and Barcoo Rivers a great similarity was observed in the mode of building the hut, and its relative position in regard to wood and water supply, and the position in regard to the general features of the country was exactly where a party going westward would first receive a check from the waterless table-land between the Roper and Victoria Rivers, and would camp and reconnoitre ahead before attempting to cross to the north-west coast. This creek is named 'Elsey' on the map."

Again, on 31st July he remarks—"Near this spring were several huts constructed in the rudest manner by heaping branches together." And on 6th August—"These water vessels were formed by hollowing out a block of wood in the shape of a canoe and had a capacity of three gallons, and it was evident that they possess tools of iron as also of stone." Further on 13th August—"Some fishing spears showed marks of iron tools."

The Elsey Creek is one of the southern tributaries of the Roper River, forming what is known as the Warlock Ponds on the Overland Telegraph Line. The position of the old camp, from what I can determine from a conversation with Mr. Gregory, is about fifteen miles south from the present cattle station, and on the east bank of the creek. About two and half years ago a letter appeared in the *Australasian*, from an overlander from Queensland to Port Darwin by the gulf stock track, stating that the writer had met with an old native woman on the McArthur River, who told him that she had seen two very old white men with the tribes far up the river to the south-west, that one of these men had used crutches, the use of which she imitated and that only one of these men was then alive.

After this, when proceeding on his journey near Limmen River, he was joined by two stockmen who had come from the newly formed stations on the head waters of the McArthur and Limmen, and who informed him that on their route they had seen an old grey-headed man, who looked like a white man, who was coming towards them calling out, "white fellow, white fellow;" when he was joined by a large party of natives who hustled him away, and they saw no more of him.

I had already heard from overland drovers that there was a rumour of whites being with the natives of the McArthur; and when I read this traveller's letter I felt that this statement of the native woman was most valuable evidence of Europeans having been with the natives. Her demonstration of the use of the crutches must have been acquired from actual observation, the few overland drovers that had passed by the Gulf Route would not have required them as they never leave the saddle, and natives never use them. The locality where these white men were reported to have been seen, is only some two hundred and fifty miles distant from the hut found on the Elsey, and is near to where Gregory found evidences of iron tools and huts constructed of branches. I therefore concluded that these men might be some of poor Leichhardt's party; and at a meeting of our Geographical Society, I urged the advisability of at once sending out a search party to rescue the survivors; but I regret to say, that upon discussion, it was not thought advisable to do so; our worthy President, Baron von Mueller being of opinion that the rumour had probably originated through some man in the employment of the Overland Telegraph Company having gone off to live with the natives, and that, as Mr. Lindsay was then supposed to be engaged in a zig-zag exploration of that portion of the Northern Territory, would be likely to hear something of this white man, should he be with the natives. Unfortunately, as I now learn, from a perusal of Mr. Lindsay's manuscript of that trip, he never extended his exploration to that locality, but from letters I have received from him recently, he appears to be upon the eve of obtaining still further information of a portion of Leichhardt's party, which I shall refer to further on. My theory was that Leichhardt from his last camp on the Barcoo, keeping on his course due west, would have passed through easy travelling country until he encountered the arid sand ridges explored by Winnecke to the west of Mulligan River, that finding that tract of country impenetrable with his equipment, he had fallen back on the Mulligan and followed the watercourses up north until he came to the Pitcherry Creek system, which would encourage him to continue on his former west course; that having reached as near the head waters of that creek as he could do with safety, he had halted and sent on a small reconnoitering party of horsemen to examine the country ahead, that this party had not succeeded, and that Leichhardt had then found it necessary to work up further north so as to avail himself of the inland waters from the coast ranges within the tropics. In this way he would reach Buchanan's Creek, follow it up, to be baulked again in making westward, would push still further north, reaching Creswell Creek with the same result, and then being driven further north and north west, he would for the first time meet with powerful savage tribes, and would probably encounter a check ending in disaster. That finding his calculations upset as to reaching the west coast within the time he expected, and having sustained loss in horses and live stock, he had despatched a small party for Port Essington in hopes of a chance vessel calling, or of leaving a *cache* with an account of the Expedition and his future plans. That this party had for its own safety and easy travelling kept to the open country, and passing the head of the Strangways River had come upon the Elsey when in high flood, and that they then had built the hut found by Gregory, to shelter themselves from the tropical rains and await until the country should become passable; and that it was most probable these unfortunates were murdered on their way from that point to Port Essington, as they would have to pass through country occupied by warlike and bloodthirsty tribes. Gregory found the hut in 1856, and judged that the trees had been cut six or seven years, so that we may fix the probable date of the Elsey camp as the rainy season, January 1849—which would be nearly thirteen months from the date of Leichhardt's start. No relief coming to the main party, and their stores exhausted, they would be at the mercy of the blacks and may have secured their friendship and protection. The use of iron tools as described by Gregory would thus be accounted for, and I may here remark that it is now well known that the natives in that northern portion of Australia do not construct huts. The small stone erections described by Gregory as huts, met with on the Victoria River, are used by the natives as traps, in which the hunter concealing himself, flutters a pigeon overhead, which lures the hawks to descend, and get knocked over when pouncing on the prey.

Next, I come to what I consider traces of the reconnoitring party sent on westward from the Pitcherry Creek waters.

The interesting paper contributed by Mr. Worsnop to the South Australian Branch of the Australian Royal Geographical Society, in 1887, entitled "Pre-historic Native Art," contained a number of illustrations of native drawings. I had studied this subject for many years and am familiar with native art from Cambridge Gulf to Cape Howe; but amongst Mr. Worsnop's illustrations I found what I recognised as a singular departure from any native drawings I had ever met with, and which I attributed to uneducated Europeans—one was a "rock hieroglyphic" found by Arthur John Giles, in 1873, near the junction of Sullivan's Creek and Finke River, consisting of seven vertical straight lines, some distance apart, and having an orb at the bottom of each line, but not touching. A wave-like double line crossed the vertical lines about midway, in the spaces between these vertical lines on both sides of the wave lines were two treble half-circle lines, and above and below these half-circles, were arrows formed with two barbs as used by surveyors; for the first three spaces these half-circles and arrows were represented, the arrows pointing in different directions and the half-circles changed in position; in the fourth the half-circles were only on one side of the wave line, but the arrows were on both, in the remaining spaces the arrows only were shown. To me this appeared to be the work of a European unable to write, endeavouring to make a record of so many months spent with natives on a creek. The orb denotes the moon, the spaces the months, the wave line a creek, the double half-circles camps, and the arrows indicate the direction of the hunting parties in search of food. As the season advances the fixed camps are discontinued, but the direction of the arrows still show the hunting parties going to and from the creek.

This theory, in the absence of further evidence, would appear rather too conjectural; but the next drawing which attracted my attention was one representing four red hearts, pierced by arrows or harpoons, found in caves by Winnecke in his explorations in 1869.

He describes them as follows:—

"The group of native drawings which I have roughly shown herewith are found in several large caves near Mount Skinner and Ledan's Hills in Latitude 20° 30′ south and Longitude 134° 30′ east."

Figure No. 1 apparently represents a heart pierced in the centre by a spear. The outline of the object representing the heart has been delineated with red ochre, whilst the spear has been drawn with a burnt stick or piece of coal. I have only seen this particular sketch in one instance, where four distinct drawings of the same object, exactly below and equidistant from each other, have been made in anything but a crude manner, the outline having been carefully and very distinctly traced on the rocks, showing a degree of perfection scarcely to be anticipated from these wild inhabitants. The breadth of the heart is about five inches and its length about six inches. The length of the spear portion is about three feet.

Here, in all four representations, we have the typical and not the true form of heart. The first, third and fourth have each the red heart pierced with a single barb harpoon, and the second has the heart pierced with an arrow or double-barbed harpoon.

Can anyone doubt this being the work of a European? Is it not true nautical art all the world over? A device to be found tatooed on the arm of nearly every sailor afloat.

As a further specimen of native art Mr. Worsnop says: "J. McDouall Stuart, in his Journal, under date February 23, 1861, at Marchant Springs, on the Finke River, says: "The natives had made a drawing on the bark of two trees—two figures in the shape of hearts, intended I suppose to represent shields, as there was a bar down the centre, on either side of which were marks like *broad arrows*. On the outside were also a number of arrows and other small marks. I had a copy of them taken. This was the first attempt at representation by the natives of Australia which I had ever seen."

Under date March 15th on the Hugh River, James' Range, he observed one of the gum-trees having marks similar to those he saw on the Finke—broad arrows and a wavy line round the tree.

On May 15th, at Hawke Creek, Ashburton Range, Stuart found stuck up in a tree what appeared to be a piece of wood about two and a-half feet long, sharp at both ends, broad at the bottom, and shaped like a canoe, of this he says: "It is the finest piece of workmanship I have ever seen executed by the natives. It was about twelve inches deep and ten inches wide, tapering off at the ends. Small lines were cut along both sides of it. It had been cut out of a solid piece of wood, with some sharp instrument. It is exactly the form of a canoe."

Here we have a *perfect model of a dug out canoe* in the interior of Australia, where such canoes are unknown. Does not this look like the work of a sailor?

Mr. Worsnop also mentions that Gosse in 1873, found amongst some cave drawings at Ayer's Rock, devices of two hearts joined together, but of this no illustration is given.

Stuart also mentions that he was astonished to find the natives near Newcastle Waters give Masonic signs. Is it not probable that they were given instruction by some poor European captive, the kindest return he could give for their attention, and trusting that some day it might be of service to his benefactors.

Mr. Lindsey in writing some months ago from the Ruby Mines, which are situated about one hundred miles to the east of where these traces were found and about Latitude 23°, mentioned that he had met with an old native who recollected, when a little boy, having seen a party of white fellows passing from east to west, at a point south from where he was then camped, and in reply to a letter which I addressed to him asking for futher information on this subject, he replied under date 16th July last:—

"I was very sorry at not being able to follow up that story of the blackfellow about the party of long ago, but without saying anything to us he went away and I did not see him again. The line of route was just south of Glen Annie, on the Ruby map, say in Latitude 23° 30′, and Longitude 135°. If I drop across the native when I am there next I will take a run down. Of course I cannot afford to devote much time to searching for tracks of poor Leichhardt. If I were single and had no one depending on me, I certainly would devote two years of my life in the endeavour to wrest from the silent bush the long kept secret. Do you not think that it is a disgrace to the colonies that such a man's fate should be left undetermined?"

Now that I have had the pleasure of reading Mr. Lindsey's report of his exploration and journey from the Finke River to Lake Nash, and thence north to the lower McArthur River, I think it is probable that the reconnoitring party may have crossed further to the south than the Pitcherry Creek, but I still think that they may have met with disaster about the McDonald Range, and that the survivors were the artists who executed the several devices which I have noted.

2.—ANTARCTIC EXPLORATION—THE DUTY OF AUSTRALIA.

By G. S. Griffiths, F.R.G.S., F.G.S., of Melbourne, Vice-President of the Section.

It is now over two years since the subject of Antarctic Exploration was first mooted by Baron von Mueller in his Presidential Address to the Geographical Society, and during the intervening period the subject has been kept more or less before the public—first of Australia, and latterly of Europe.

Although the efforts thus made have not yet borne the desired fruit, still the Antarctic Committee has been enabled to collect a mass of information which is of great value, bearing as it does upon the practical questions of equipment, personnel, the programme of work and the cost with respect to the objects to be served by such an expedition, which are numerous and important. They may be summed up briefly as follows:—A flying survey of the coast lines lying within the Antarctic Circle, the discovery of new waterways leading towards the South Pole, and of harbours suitable for wintering in, and observations in the following departments of science: meteorology, the sea depths, temperature and currents, terrestrial magnetism, the natural history and the geology of the region; lastly, the commercial value of the whaling grounds and the seal rookeries of these high latitudes. We have yet to learn whether the antarctic land is continental, or a congeries of islands smothered under a continental glacier, as Greenland now appears to be.

Croll has calculated that the periphery of this ice-sheet must be thrust outwards by the pressure of the ice-piled-up mountains high in the interior of the region by the snow-fall of ages, and that its rate of progress seaward may be a quarter of a mile per annum.

The structure of the volcanoes must be peculiar, as their cones may well be largely built up of falls of ash alternately with falls of snow. The known non-conductivity of volcanic ash is such, that elsewhere lava has been seen to spread over ice which has been covered with six inches of snow without melting the latter.

The viscous nature of ice under pressure would prevent this process proceeding beyond certain limits; but, nevertheless, the conditions are such that must give rise to interesting structural peculiarities. The cliffs and other sections should be searched for dykes in the hopes that masses of specular iron and nickel—similar to those found at Ovifak—might be discovered. The occurrence of such ultra-basic lavas as contain these metals at the South Pole would be suggestive, and the question must be worked out whenever the opportunity presents itself. It is desirable that a series of pendulum observations should be taken at points round the pole, within the Arctic Circle, the pendulum making more vibrations than it does at the equator by two hundred and forty per day, the increase in number being the result of the superior oblateness of the North Polar Region. We now desire to learn whether the same flattening of the sphere is characteristic of the South Polar Region, so as to know as nearly as possible the exact form of that part of our globe. Knowing, as we do, that the Arctic has enjoyed a warm equable climate during several distant epochs we ought to search for evidences bearing upon the past climate of our own pole.

The discovery in high northern latitudes of Palæozoic coal, of large suites of fossiliferous Jurassic rocks, and of extensive beds containing the remains of evergreen and deciduous trees, and flowering plants—all these latter probably of Eocene age—all these facts whet our apetite for such evidences from the rocks as may be gleamed from the south.

The faunas and floras of the lands and seas of the Southern Hemisphere, as worked out by Wallace and Hutton, point to the former existence of an extensive land.

We are told that forty-four per cent. of the New Zealand flora is of Antarctic origin. New Zealand and South America—so widely apart—have in common, three flowering plants, two fresh water fishes, five sea-weeds, three marine crustaceans, one marine mollusc, and one marine fish, and similar links unite these regions with the Crozets, Tristan d'Acuhna, Kerguelen Island, and the Marion group, and these with South Africa.

There must have been large earth surfaces to develop the progenitors of these now scattered forms. Where was that fatherland, and what else strange did it contain? These questions are ones which Antarctic fossils may help us to get at.

At present all we can say for certain is, that such lands there have been, and the disappearance of these regions beneath the sea must have modified the climate of this hemisphere profoundly.

This leads us to the subject of the meteorology of the region which deserves investigation. We believe that the conditions must be peculiar and extreme. All round the Antarctic Circle we have a low mean barometor, a moist atmosphere, and a perpetual grand cyclonic air movement from east to west. The co-operation of these three conditions permanently and in an extreme degree of development, without the circle, must surely produce within its vortex an exceptional meteorological state which ought to be studied, for its great scale and its location so near to Australia must enable it to dominate our Australian climate.

That the south polar winters must be milder than the polar seems to be likely. Many estimated that the difference between them was in favour of the Antarctic, in the same degree that the English winter is milder and better than the Canadian.

Another important branch of science which requires attention is that which deals with the earth's magnetism in its three elements of variation, dip, and intensity, and with their daily, yearly, and secular variations.

The exact position of the magnetic pole will be again determined if possible, as also the foci of magnetic intensity.

Connected with this subject is that of the phenomenon of Auroras, the nature of which has been investigated recently by Dr. Sophus Tromholt and others with some degree of success. Tromholt tells us that the Aurora Borealis, with its crown of many lights, encircles the North Pole obliquely, that it has its lower edge suspended above the earth's surface at a height of from fifty to one hundred miles; and that it changes its latitude of maximum intensity four times every year. The far-reaching, though subtle nature of the influence which characterises this phenomenon is shown by the fact that two years since when an Aurora was observed at Hobart, the telegraph apparatus was galvanised into such a state of activity that the wires were rendered simultaneously useless for their normal work all the way from Hobart to Hong Kong.

Tromholt and others believe that weather changes and auroral movements are in some way related. If this is so, and the eleven year period of auroral activity be correlated with our Australian cycles of drought and abundance, the Aurora will, in Australia, have acquired a new interest. We ought therefore to ascertain whether the Aurora of the Southern Hemisphere has its period as that of the North has been shown to have, and this can be done only by observations in high southern latitudes. In this periodicity of the Southern Auroras, we have the last problem to which I would call your attention. If its determination would give us a key to the periodic changes in the Australian seasons, which would enable us to forecast, even partially, their mutations for, say but a season in advance, it would give us in conducting those great interests of the country which depend for their success upon the annual rainfall, an advantage which would be worth many times over all the cost of the expeditions necessary to establish it.

In conclusion, I would submit that the exploration of these regions is a task which, by our geographical position and our wealth, is thrown on Australia as a duty which we cannot evade if we have any adequate conception of our great position in the southern seas, and any healthy ambition which transcends producing the best of wool, or the finest of wine, or raising coal, gold, or silver.

If ever an Australian statesman had a chance of immortalizing his name it is now. Where is the politician with a mind sufficiently educated, and with views sufficiently broad to grasp the situation, and to crown his brows with immortal laurels by taking a step which will secure to this colony universal attention, and the approbation of the entire civilised globe?

If we do not move in this matter speedily, Germany will forestall us to our mortification and disgrace.

In conclusion, I deem it my duty to say that we would deem it to be a risky proceeding and one which the Antarctic Exploration Committee would deprecate, to despatch an expedition of less than two ships to this region. If our German friends do go, we hope that they will send two vessels. If they send but one, we ought to find her a consort.

3.—AN EPITOME OF OUR KNOWLEDGE OF AUSTRALASIA.

By Sir Edward Strickland, K.C.B., F.R.G.S., Hon. Treasurer of the Association.

SECTION F.

ECONOMIC AND SOCIAL SCIENCE, AND STATISTICS.

President of the Section: Mr. H. H. Hayter, C.M.G., Government Statist, Melbourne.

WEDNESDAY, AUGUST 29.

The President delivered the following address:—

ON OFFICIAL STATISTICS.

It is the privilege of the official statistician, to furnish others with facts on which to base their reasonings, rather than to reason upon those facts himself; to supply, as it were, the raw material, which the political economist and the social scientist might turn into the manufactured article; to help to lay the foundation on which the historian and the politician might raise their edifices.

And here it is fitting I should pay a tribute to the memory of the late Dr. Hearn, Dean of the Faculty of Law at the Melbourne University, whose profound learning, strong common sense, sound judgment, and intimate acquaintance with the higher objects aimed at by this Section, would, if he had lived, at once have pointed to him as the most proper person to be its president, and the one best calculated to guide its deliberations to a useful and practical result.

Official Statistics being that branch of the subjects assigned for the consideration of this Section, with which I am most conversant, I shall confine this address mainly to them, and in view of their admitted importance when based upon correct data, compiled honestly, and used intelligently, I shall endeavour to point out a few of the defects, which my long experience has led me to observe in those published in some of the Australian colonies, not excepting my own, as well as in some other countries. Many of these defects can be easily rectified, and no doubt will be so when attention is drawn to their existence, but some which are dependant upon circumstances over which the statistician has no control, he will have difficulty in combating successfully; by dint, however, of determination and persistence, much may be done; and although, so far as my own colony is concerned, I have not been able to subdue all difficulties, I have conquered many, and others will no doubt disappear if the efforts for their removal are continued.

I trust it will not be thought for a moment that any observations I may make are offered in a captious or fault finding spirit, or with a wish to dictate to others who may be quite as well versed in the subject as myself. I know my own work is far from perfect, and I am always thankful for any hints which may show me the way to make it more nearly so, and glad to adopt suggestions for its improvement so far as they commend themselves to my judgment. I shall make my remarks as general as possible, and shall refrain from naming any of the colonies except where absolutely necessary, and then never to their disparagement. My only wish is that what I say may have the effect of promoting uniformity between the statistical records of the various colonies, of causing them to chronicle more completely and faithfully the events which are passing from day to day, and to describe with greater accuracy the progress and condition of the land in which we live.

Of all the duties the official statistician is called upon to undertake, the census is the most important and the most arduous. The census is the foundation and starting point of all statistics, the basis of legislation, and the groundwork of the calculations of actuaries, financiers, merchants, and many others; therefore, every pains should he taken to make it a success. All preparations should be designed, thought out, and perfected beforehand, and all precautions should be taken that no weak point exists in any of the arrangements. A good census is an inestimable advantage to a community, whilst an incorrect one is much worse than none at all.

As population is always on the move, it is essential to accuracy that the census should refer to one particular day, and the operation ought to be performed, except in scattered country districts, in three days, one day being devoted to depositing the schedules and two days to collecting them. In country districts more time must be taken, but except under very exceptional circumstances no more than five days should be allowed for the work. Much too long a time is sometimes taken over a census, which arises from the districts being made too large, and too few collectors being appointed. This makes it certain that some of the population will be missed, to remedy which enumerators are apt to make guesses and estimates, some of them being based on imperfect data and some on no data at all, and an incomplete and inaccurate census is the result.

I may here observe that although the Australian colonies are far from perfect in this respect, every one of them is much in advance of the United States, where one month is nominally allowed for the taking of the census, but much more time is often taken in the operation. The reason of this is said to be that the appointment of the census collectors is a political job, and it is considered essential that each collector should be long enough at work to enable him to earn a good round sum; and thus the accuracy of the census is sacrificed to the exigencies of politicians. The United States census of 1870 was an admitted failure in consequence of this, the returns giving several millions short of the actual population; and although the census of 1880 was less defective, or at any rate did not err in the same direction, it is questionable if the population was not largely over stated in its returns; though not perhaps to the same extent as the population of 1870 was understated in the returns of that year.

The census of ancient Rome was taken once in a lustrum, or every five years. We in all but two of the colonies are behind the ancients in this respect as we take ours only once in ten years. It is my opinion that in countries like these, with rapidly increasing populations, not more than five years ought to intervene between two censuses. It will be remembered that at the census of 1881 the population estimates which had been previously formed in all the colonies were wide of the truth, the error in the three eastern colonies alone amounting to as much as 112,000. And if the error was so great in the mere numbers of the population what chance could there be of our possessing a correct idea of the birth places, religions, ages, occupations, conjugal condition, or education of the population? An attempt is certainly being made now in two of the colonies to avoid such a discrepancy in future by making an allowance to correct certain supposed errors in the returns of immigration and emigration; but we who make the estimates know we are working in the dark and we have much need of a census to enlighten us.

Another reason for taking a census often is that the experience gained by those engaged in the work is to a great extent lost in so long a period as ten years. Every one, after superintending the operations of a census, feels how much more effectively he could do so if had to begin again. But after the expiration of ten years, the lapse of time and attention to the details of quite different duties, have probably caused him to forget much of what he had learned, and even if this should not be the case, the staff he had organised and trained with care to a full knowledge of their work is scattered, and he has to begin again the harassing task with a new set of men. There is no doubt in my mind that if the census were taken at shorter intervals, a better result would be obtained.

I am not in favour of burdening the census collectors with work outside the usual legitimate inquiries, connected with the enumeration of the population, namely, the numbers of the people, their sexes, ages, birthplaces, religions, occupations, conjugal condition, education, sanitary state and domiciliation; as experience has shown me that giving the collectors extra work does not tend to the success of the census. As an exception, however, I would still embody in the householder's schedule, a provision for enumerating the live stock of the colony, as that can be correctly done only when a census is taken, and every census shows how defective the intermediate estimates of live stock have generally been; but statistics of agriculture, school attendance, manufactures, mining, &c., can be secured as well or better by other means, and there is no good reason why the collectors should be called upon to collect them. However tempting it may be when a census is taken to endeavour to obtain information not immediately connected with the work on hand, it is certain that anything which tends to complicate the duties of the collectors, and especially to retard their labours, cannot fail to act prejudicially on the correctness of the particular enquiries they are specially appointed to secure. All the enquiries I have mentioned as connected with the population, should, however, in my opinion be made and insisted upon. One colony has hitherto obtained no information respecting the religions of the people, and two of the colonies have made no effort to obtain a statement of the amount of sickness and infirmity prevailing. As regards the propriety of asking a man what is his religious belief, there may be differences of opinion—although if a man has a religion, or even if he has none, there seems to be no good reason why he should be ashamed to own it—but the interesting and important enquiry respecting the sanitary condition of the people ought certainly to be made in all the colonies. I would suggest that, in future, not only the numbers, sexes, ages, and occupations of those laid up by sickness or accident should be ascertained; but that the enquiry should be extended to the numbers of the deaf and dumb, blind, lunatic, idiotic, epileptic, and leprous persons; the number of cripples, of humpbacked, club-footed, or otherwise deformed persons; of paralysed persons; of those who have lost a limb or an eye; of those who are partially blind or colour blind; of those who are deaf without being dumb; and of those who are imbecile without being strictly speaking idiots.

I now come to the compilation of the census. An approach to uniformity between the colonies was secured upon the last occasion, only one colony standing apart; with the result that her census returns—especially those relating to the occupations of the people—were rendered useless for comparison with those of the other colonies, or with the returns of the United Kingdom, upon the form of which the returns of those colonies which agreed to work in unison were based. There are, however, a few minor points in which some of the colonies which were in the main accordant, might in my opinion improve their work, and to these I shall now proceed to draw attention.

In three of the colonies, much care was properly taken to distinguish the natives of every independent country, large or small, living within their limits. When the census was taken, also the numbers born in every British colony, even to the smallest West India Island, the only remarkable exception being that natives of the respective Australasian colonies outside the boundaries of the three colonies referred to were not distinguished as to the colony of their birth, but were grouped all together in one total so that it has never been possible to ascertain with correctness the number of natives of the individual colonies of our own group resident in Australasia. As it is interesting to the inhabitants of each colony, to know the number of their fellow colonists by birth, living outside as well as within its borders, it is to be hoped that all the colonies will on future occasions exercise the same precision in regard to their neighbours as they have hitherto done in reference to natives of more distant countries.

Under the head of ages, several of the colonies have only given the numbers of the population living at and between the various quinquennial and decennial periods of age, but have made no attempt to show the numbers at *each year of age*, the latter being absolutely necessary for many actuarial computations connected with life assurance, for testimony assurance, also for estimating correctly the ages of the people between the censuses. Many interesting enquiries are also rendered impossible in consequence of this omission, such as the precise ages of centenarians and other old people, the exact age at which very young people marry, the state of education at every year of childhood, &c.

Whilst on the subject of education, I may mention that the age prescribed by law at which children are kept at school varies in the different colonies. In Victoria it is from ten to fifteen years; in New South Wales, from six to fourteen years; in Queensland, from six to twelve years: in South Australia and New Zealand from seven to thirteen years, and in Tasmania from seven to fourteen years. In view of the extent to which the mind of the community has been occupied with the subject of Public Instruction, it will perhaps be hardly believed that, from the way the census returns were compiled, it was possible in scarcely one of the seven colonies of the group to ascertain what proportion of children at the school age could read or write, or were uneducated. Such an omission on the part of the colonies, shows a striking want of appreciation on their part of the importance of rendering the information obtained at the census, applicable to the requirements of every day life.

In regard to the occupations of the people, it is most important that a uniform system of grouping should be adopted throughout the Australasian colonies, and that this system should as far as possible accord with that in use in the United Kingdom. At the census of 1881 this was secured in the case of all the colonies of the group except one, which preferred to adhere to a far less comprehensive system, which had been handed down from darker ages, but which had been abandoned by all the colonies, except the one referred to, as not professing that precision of detail which was necessary to render it suitable to the requirements of the present time, and conformable with the state of perfection to which statistics have attained in other countries. This is to be regretted, as the fact of one colony being non-accordant, has broken the uniformity between the statistical records of the various colonies which is so desirable, and has rendered summarised statements relating to the occupations pursued in the whole of Australia, or the whole of Australasia impossible. Had it been practicable to make correct comparisons between the relative strength of the different occupations and callings pursued in the colony referred to, and one of the others—her immediate neighbour—much light might have been thrown upon the question as to the relative merits of freetrade and protection, as well as many other moot points and important social problems. It is to be hoped that when the next simultaneous census is taken, there may be no difference of opinion between the colonies as to the propriety of adopting a uniform principle as to the compilation and arrangement of the facts embodied in their census schedules.

The system pursued by the six colonies which worked in uniformity provided for grouping the occupations of the people in classes, orders, suborders and distinct callings. Of the last-named there were 380, which were in at least one of the colonies, and should have been in all, again subdivided, so that as many as 1,600 occupations were shown. This further subdivision, however, was not attempted generally throughout the group. It is desirable it should be so in future, as, apart from the interest and utility of having a statement of the occupations of the people of the country published in almost the same words as they were returned in by the persons who pursued them, such a statement affords those who disagree with the mode of grouping adopted in the tables—respecting which there are many differences of opinion—an opportunity of retabulating them, according to any mode of classification they may consider more scientific and useful.

In one of the colonies, very interesting and curious particulars were obtained from the census schedules, relating to the ordinary occupations of the sick both in and out of hospitals, of the inmates of Benevolent Asylums, Lunatic Asylums, and prisons, and of those who at the time the census was taken were out of work; also, the occupations, if any, followed by the Chinese, the aborigines, the deaf and dumb, the blind, and the graduates of universities. As this information can be got out without much difficulty whilst the schedules are in hand, it seems desirable it should be obtained in all the colonies when next the census is taken.

It being important to find out the relative fatality attending various occupations, it is desirable from time to time to compare the number of deaths of persons of different callings with the number of those living pursing the same callings. This can only be done accurately when the results of a census have enabled the latter to be ascertained correctly, and in my opinion it ought to be done whenever a census is taken. Such a computation was made by me for the first time in Victoria, and, I believe, the only time in Australia after the census of 1881 ; the census year, and the year immediately preceding and immediately following it being taken as those in which the deaths occurred, which I used for comparison with the census numbers. The results which are exceedingly interesting, will be found in the Victorian Year Book for 1883-4, and in that work for the following year, in the latter of which the occupations of those who died of phthisis are also given. I may observe that some caution is necessary in accepting all the results, by reason of the fact that the occupations at the census, being returned by the persons actually following them, are likely to be more precisely defined than those returned by other persons after their death. Thus, according to my calculations, death appeared to press more hardly upon labourers (undefined), than upon followers of any other calling: but this no doubt largely resulted from the fact that the branch of labour followed by many of these, though defined at the census—as for example, store labourers, wharf labourers, road or railway labourers, farm or station labourers—was not stated after death. Upon the same principle, the mortality was apparently high of engineers, engine-drivers, and stokers (undefined), resulting no doubt from the fact that, at the census, many of these were returned in connexion with vessels, railways, or mechanical engineering. Clerks (undefined) also showed a high apparent death rate ; the reason doubtless being that many who died and were simply returned as clerks, at the census had been returned as law clerks, Government clerks, railway clerks, &c.

In more than one of the colonies, no attempt was made to distingnish the Chinese, and such of the aborigines as were enumerated, from the remainder of the population. These two peoples being so different from the other colonists in almost every respect, it needs little argument to show that they ought to be tabulated separately under every head of enquiry. It will readily be understood that a large number of Pagans (Chinese) or of persons set down as of no religion (aboriginals), lowers the proportion to the total population of each of the religions of persons of European birth or extraction, respecting whom it is especially intended that the census should give information. In like manner the returns of sex, age, and conjugal condition, are disturbed by the presence of a number of unmarried Chinese adult males; the returns of education by a number unable to read and write, as the Chinese are set down to be, unless they can do so in English; the returns of occupations by a numher of wandering aborigines of no occupation. At the same time, as particulars respecting the Chinese and aborigines, respectively, are important and interesting, they should be carefully taken out from the schedules and arranged in tables, so that the figures might be used either conjointly with, or apart from, those of the general population as might be required.

However carefully the census forms may be prepared, there must be under almost all the heads of enquiry certain indefinite groups, the component parts of which ought to be—but very seldom are—separately shown. Thus, under the head of Religions, there are groups styled other Presbyterians, other Methodists, other Protestants, other Religions; under that of Birthplaces there are—other Australasian Colonies, other British Countries, other Foreign Countries, other Countries; and under that of Occupations there are over sixty such groups, as, for instance, "Other's connected with Government, Defence, Religion, Law, Medicine, &c.;" and in one colony, the callings of 20,000 persons were merely classified as "Miscellaneous Occupations," no clue whatever being given as to what individual occupations were so placed. The absence of the necessity for accounting for the entries placed under these indefinite groupings, is no doubt very convenient to the tabulator, as, if his returns under the different heads of enquiry do not balance, he is able to make them apparently do so by adding some numbers to, or taking some numbers from these groups as occasion may require; but it should be placed out of his power to do this by requiring him to account strictly for every entry he makes in these groups. If this is not done, not only is the door opened to dishonesty for the purpose of hiding careless work, but all trace is lost of small but perhaps rising sects, of occupations in which perhaps only a few persons may now be employed, but which may be destined to be of great importance hereafter, and of particulars respecting the nationalities of which the population is composed, which might be of especial interest to the ethnologist of the future.

In the census returns, as well as in tables devoted to other branches of statistics, there are frequently to be found immediately above the total line, a line for items which have not been specified; and in working out proportions to show the value of the numbers in each line relatively to the total, it is a very common but erroneous practice to assign a proportion to this line, just as if the figures in it represented items of a similar character to those in the other lines in the table, instead of items of no value whatever except as contributing to make up the total, thereby giving less than its true value to each of the other items. Thus, if out of a total of 10,000 persons, there should be 5,000 Protestants, 3,000 Roman Catholics, 1,000 Pagans, and 1,000 of religion unspecified, it is common to make 10,000 the universal divisor, which of course gives 50 per cent of Protestants, 30 per cent. of Roman Catholics, 10 per cent. of Pagans, and 10 per cent. of unspecified religions. It is perfectly clear that the 1,000 unspecified should be omitted altogether from the calculation, and the universal division should be 9,000, which would give 55·6 per cent., instead of 50 per cent. of Protestants; 33·3 per cent., instead of 30 per cent. of Roman Catholics; and 11·1 per cent., instead of 10 per cent. of Pagans. Exactly the same result would of course be arrived at by distributing the 1,000 unspecified amongst the specified items, in proportion to their respective numbers, and using the unreduced total of 10,000 as the universal divisor.

Having, I believe, said enough about the census, I will advert to certain points in connection with other statistical matters in respect to which defects, or shortcomings, have come under my notice, or it has struck me as desirable that caution should be exercised.

The returns of the State revenue and expenditure are often given in so cumbrous a manner, that without more information than is to be found upon the face of the returns, it is impossible to find out what are the true receipts and disbursements of the country in any given year. In these cases, refunds, drawbacks, advances to be recouped, and recoups of such advances, are mixed up with the statements, and both sides of the account are swelled thereby, so that both revenue and expenditure appear to be much larger than they really are. On examining the financial returns of one of the colonies a short time since I found, without difficulty, that over £500,000 might well have been excluded from both revenue and expenditure, and there may possibly have been much more to which similar exception might have been taken, which I was not able to detect. From an accountant's point of view it appears to be considered not undesirable to multiply cross entries, but the statistician, whose object it is to give a clear account of the condition of things, eliminates them wherever possible. This applies not only to the revenue and expenditure of the country, but to those of municipalities, charitable institutions, friendly societies, and almost every other body which furnishes statements of its financial position, which statements are often burdened not only with cross entries innumerable, but with balances brought forward, contractor's deposits, and repayment of the same, bank overdrafts, borrowed moneys, &c., &c.

With reference to the Customs returns of imports, there can be no doubt that the values are considerably over-stated in some, if not all the colonies. This probably arises from the fact of the merchant's invoice being taken as that upon which the Customs valuation is based, whereas the invoice price—on the basis of which sales are effected here—is often entered much above the actual value. This was pointed out, so far as New South Wales was concerned, in a carefully written article published in the *Sydney Morning Herald* of the 22nd September, 1885, where it was clearly shown that the Customs value set upon the goods, was in many cases even higher than the retail price of the same goods. I have examined the Victorian returns, and find the over-valuations disclosed respecting the returns of the mother colony apply equally to them, except in the case of goods subject to *ad valorem* duties, the value of which, for obvious reasons, is not over-stated. I also found that the values of exports are over-stated, especially so far as the article wool is concerned, but that the total is not affected to the same extent as that of the imports. It is believed that this system of over-valuation extends to all the colonies, and that in consequence of this, the returns of imports and exports are made in each colony to appear larger than they really are.

In order to obtain a more perfect knowledge of what goods come into and leave each colony, as well as to facilitate comparisons between the imports and exports of one colony with those of another, it is expedient that the nature of the goods should be more accurately defined than they generally now are. The Customs returns frequently contain such entries as haberdashery, millinery, drapery, ironmongery, building materials, cotton, linen, silk or woollen manufactures, &c., under each of which, many articles are grouped in one colony which are named separately in another; and even in the same colony it is found that every change of tariff brings about a confusing variation of nomenclature, which makes comparisons difficult between the imports and exports of different years. There is, moreover, too great a tendency to enter the number of packages instead of the number, weight, or measurement of the articles, which often leaves the enquirer entirely in the dark as to what the quantities of the different descriptions of goods really are. This is an important matter, as an increase or diminution in value does not always mean a corresponding increase or diminution in quantity, particularly in the case of staple articles with considerable range of prices, such as wool, grain, &c.

It is to be regretted that the time honoured alphebatical arrangement of the goods imported and exported should still be adhered to, especially since a recommendation was made by a conference of heads of the statistical departments of the different colonies which met in Tasmania in 1875, that a more scientific system should be substituted therefor. This system provided for placing the various kinds of goods in groups corresponding with those adopted in classifying the census returns of occupations, means being thereby afforded of making calculations in respect to the number of persons working at the various trades in connexion with which articles are manufactured similar to those imported and exported. Another advantage of this grouping is, that similar articles being placed together, all articles of the same character are at once distinguished. For example, under the present system, hides are found under the letter "H," in one part of the returns; skins in another part under the letter "S;" pelts in another under the letter "P;" and leather in another under the letter "L." Under the classified system recommended by the conference, the four articles would appear near each other under the head "Animal Substances," where also would be placed other cognate matters such as bones, glue pieces, grease, hair, horns, hoofs, tallow, &c. Further, under the present alphabetical arrangement, perplexity is experienced in comparing the returns of articles in one colony with the same kinds of articles in another, owing to the difficulty of finding the required articles under the varying names they receive in the respective colonies. Thus, jams in one colony are found under the letter "J;" in another under the letter "F," as "fruits preserved;" in another under the letter "P" as preserves." Oysters in one colony are found under the letter "O;" in another under the letter "S" as "shellfish," and such instances might be multiplied. Of course under the system of classified arrangement a good alphabetical index of the names of the articles would be necessary, such as is given in the Victorian Year Book, near the beginning of Part Interchange; following which index, is a list of the articles of import and export classified according to the proposed system.

I may here remark that in his well known work "Greater Britain,"* Sir Charles W. Dilke humorously condemns the alphabetical system of arrangement in the following words:—"British Colonial Statistics" says Sir Charles Dilke, "are apt to be confusing. I have seen a list of imports, in which one class consisted of ale, aniseed, arsenic, assafœtida, and astronomical instruments; boots, bullion, and butter; capers, cards, and carroway seeds; gauze, gin, glue and gloves; maps and manure; philosophical instruments and pork; sandalwood, sarsaparilla, and smoked sausages. Alphabetical arrangement has charms for the official mind."

The import and export returns of all the colonies are, as is well known, largely swelled by the inclusion of articles which are simply re-exports of articles previously imported; and often sufficient care is not taken to distinguish these from articles of home produce. It must be evident that the mere adding together of the total imports or the total exports of all the colonies gives much too large a figure for the imports or exports of Australia taken as a whole, as in numerous instances the goods are passed from colony to colony, and so are imported and exported over and

* Second Edition. Vol. II., p. 125, London, Macmillan & Co , 1880.

over again; yet this is the way the statements relating to the whole of Australia are generally made up; and are afterwards quoted without qualification in the United Kingdom and other countries, which gives a misleading and exaggerated view of our external commerce. I am of opinion that Australia can well afford to stand or fall by her own merits, and that she does not require to swell any statistical results in order to make her appear to possess more importance than she really does.

Until recently a practice prevailed in some of the colonies of swelling their returns of shipping by counting the vessels afresh at every port they called at within the colony. More than one of the colonies referred to have, I know, changed their system, and now properly give the number and tonnage of vessels only at the first port of entry, and the latest port of clearance; but I cannot be sure that the practice of multiplying the shipping returns in the manner referred to, does not still exist in some of the colonies. If it does continue to exist, the sooner it is altered the better.

Very varied results are arrived at by those who attempt to ascertain the actual rate of interest we are paying for our borrowed moneys. To compute this correctly it is necessary—besides the nominal rate of interest at which the loan is floated, and the period it has to run—to take into account the expenses, including those of floating the loan and remitting the proceeds to the colony; then there is the allowance which has to be made for interest which may have accrued at the time of floating; and there is the difference between the amount received and the amount to be repaid, crediting the colony with interest over the whole period on that difference, if the loan was floated at a premium; or, on the other hand, debiting the colony with the annual sum which would have to be paid if a sinking fund were created to make good the deficiency, should the loan be floated at a discount. From some particulars respecting the latest New South Wales loan (floated in June of the present year) which have reached me, it appears that it has been raised at a lower rate of interest than any other Australian loan ever floated, the actual rate being only about £3 9s. 0d. per £100 borrowed; but it is far from generally known that the most successful New South Wales loan previously floated was a four per cent. loan—that of 1881—the actual interest on which, per £100 borrowed, was only £3 18s. 4d., as against £3 18s. 11d. for the three and a-half per cent. loan of 1884, £4 1s. 3d. for that of 1885, and £3 18s. 0d. for that of 1886. More successful than any of these four loans, was the Victorian four per cent. loan of 1886, the actual rate of interest, on which was no more than £3 15s. 5d. per £100, also that of January 1888, the actual rate of interest on which was only £3 12s. 9d. The latter of these, until the most recent New South Wales loan was floated, was undoubtedly the most successful loan ever raised in Australasia.

An account of the persons arriving by sea is, it is believed, kept with a fair degree of accuracy in all the colonies; but the proper officers seem to be unable, in any of the colonies, to secure an equally accurate return of the departures; the reason being that a large proportion of those who leave for the neighbouring colonies without taking their passages beforehand (which is a very common practice) escape their notice. The estimates of population are affected by this more than by any other cause, (except perhaps overland emigrants), and, if allowance be not made for it, they have always been found to largely overstate the truth. It will be remembered that, at the census of 1881, the estimates of population previously made in Victoria, New South Wales and Queensland were too high by 112,000, and I have ascertained that at a late census taken in Queensland during 1886, it was found that the population had in five years been over-estimated by 11,500, whilst at a census taken in New Zealand during the same year, it was found that the population had in a like period been over-estimated by 7,400. To counteract this tendency to over-estimate, an allowance is now made in two of the colonies, but this amounts to little more than a guess, and it would be more satisfactory if some means could be arrived at whereby an account of the departures could be kept with the same accuracy as that of the arrivals.

If the ports at which the passengers embark and disembark, were stated correctly, the returns of the departures might be adjusted with a sufficient decree of accuracy by means of returns of the arrivals in the other colonies, but since so much of the intercolonial passenger traffic is carried on by the large mail steamers which call at several Australian ports, and carry passengers besides to and from Europe, and the East, the passenger returns are so mixed up that I have found them entirely valueless for making corrections of this nature. There is much room for improvement in the immigration and emigration statistics of all the colonies, and I have more than once suggested to the Government of my own colony that an effort should be made to bring about a conference between the different officers charged with keeping the records of arrivals and departures with the view to their amelioration. I have also urged the desirability of an endeavour being made to procure returns—or at any rate reliable estimates—of persons crossing the borders from colony to colony; but this I have been told is altogether hopeless, and the state of matters in this regard it is to be regretted, appears likely to remain unsatisfactory.

The registration of deaths is fairly complete in all the colonies, but the registration of births is very far from being so in most of them, as each successive census has proved. This not only disarranges the estimates of population, but as the deaths of infants under one year of age are compared with the births for the purpose of determining the infantile mortality, it makes this appear larger than it really is. As an illustration, I may mention that observing the returns, year after year, showed the infantile death-rate to be much higher in one of the colonies than in any of the others, I drew attention to the fact in a paper which was read before the leading scientific society in that colony. This occasioned much excitement and some alarm, and my paper was followed by several others on the subject—contributed for the most part by medical men—in which various unconvincing theories were propounded to account for the evil, and the matter was also the occasion of editorial articles, as well of correspondence in the public journals. This occurred ten years ago, and it has only recently been discovered that the high infantile mortality supposed to exist had no being in reality, but that the erroneous supposition had arisen from the fact that the births were so imperfectly registered that the proportion of infants that died appeared much larger than it really was. More attention has since been paid to the registration of births in the colony referred to, and although it is not yet perfect, the infantile death rate derived from the recorded data has declined in a very sensible degree, and now differs but little from that of the other colonies. This is one of many instances which might be adduced to show how defective statistics may cause a wrong impression to be formed respecting a country, and may lead to its being condemned as a field for emigration, or may possibly injure it in other ways.

It is the practice in all countries in which marriages, births and deaths are registered, to find the proportion of each of these to the total population in order to compute what are termed the marriage, birth, and death rates; yet in making comparisons between different countries or between the same country and itself at different periods, results are arrived at which are often seriously misleading, for it must be evident that the rates will be largely affected by the component parts of the populations which are being dealt with. Thus, other things being equal, the marriage rate will be low in a country where the proportion of children, or of persons already married is great; the birth-rate will be low in a country where the proportion of women at the reproductive period of life is small; and the death rate will be low in a country where the bulk of the inhabitants are in the prime of life. I may remark that new countries, in regard to the component parts of their populations, being subject to rapid changes, and in quite a different condition from older countries, are those in which the marriage, birth, and death rates are the least reliable for purposes of comparison.

I have written much on this subject elsewhere, and have referred to it under the head of Vital Statistics in the last issue of my "Victorian Year Book," but it would take a whole paper, or perhaps more than one, to go into the subject fully. Suffice it to say that I believe I have made it clear that a marriage rate suitable for purposes of comparison, can only be obtained by finding the relation between the number of marriages and the number of single men at marriageable ages; a similarly suitable birth rate can only be obtained by finding the relation between the number of births and the number of married women at the child-bearing age; and a similarly suitable death rate can only be obtained by finding the relation between the number of deaths at different ages, and the number of persons living at the same ages. As the requisite data can only be got at or near a census taking period, conclusive results cannot be arrived at at any other time, and this is one reason out of many why the census should be taken oftener than it generally is.

It is much to be desired, that the causes of death should be returned by medical men with more precision than they often are. For example, in the case of women dying in childbed, it is very common to certify that the death occurred from debility, exhaustion, blood-poisoning, pyæmia, septicæmia, phlebitis, embolism, peritonitis, or hemorrhage; the fact that the circumstance entered was consequent upon child-bearing being kept entirely out of sight. Dropsy, which is rather a symptom of a complaint than a complaint itself, is often given as a cause of death, without any mention of the primary disease. Such ambiguous terms as atrophy, debility, old age, &c., are often set down, which should not be done when it has been possible to detect the true disease. Brain, chest, heart, liver, or stomach disease is frequently entered, when the nature of the complaint might just as well be given. The statistics of cancer and hydatids are no doubt affected by returns being made in this indefinite manner. Gunshot wound, poison or drowning is sometimes set down without reference to whether the death was accidental, homicidal, or suicidal. Such instances might be multiplied. The officer charged with examining the death registers should be instructed to refer back all doubtful cases for more complete information.

There are other points I should have liked to touch upon, did I not feel that I was already trespassing too much upon your patience. My Address is much longer than I intended it to be when I commenced to write it, but I have been led on from subject to subject, and I was at any rate anxious not to miss any subjects which might be really important.

Victoria first, and New South Wales afterwards, have wisely established departments, whose province it is to deal exclusively with statistics, thereby following the example of France, Germany, Italy, Holland, and especially Belgium. There are many reasons why statistical work can be better done by the Government than by private persons. Facts most important in statistical enquiries, can scarcely ever be got at by persons who have not access to State documents, and who do not possess the authority to collect information. But the State ought to supply machinery adequate to the purpose, and should not allow the preparation of statistics to be mixed up with other duties, such as for instance investigating the titles to, and regulating the dealings with real property. Where this is done, the chances are that the statistics will suffer, as the attention of the departmental head will almost certainly be diverted from an abstract, though most important subject, to one which deals with the pressing demands of every day life; and it is, moreover, only natural to suppose that the best of the subordinate officers will be called upon to attend to the latter, to the obvious disadvantage of the former.

It seems to me that in new countries it is even more important that statistics should be efficiently recorded than in older ones, as events move so fast in the former, that without a properly organized statistical system, correct accounts of progress are afterwards difficult to trace, or may perhaps be entirely lost. Mr. Giffin, the eminent English statistician has spoken of the doubling of the population of the United States in so short a period as twenty-five years, as "a fact unprecedented in history," and as "fairly bewildering as to its probable consequences." It is not perhaps generally realised that in spite of the enormous emigration to America from the countries of the old world to which it is in such close proximity, the population of Australasia is increasing still faster than that of the United States. Between the censuses of 1871 and 1881, the increase was forty-two per cent.; and a very simple calculation will show that an increase of forty-two per cent. in ten years, means an increase of rather over one hundred per cent. in twenty years; therefore if this rate of increase should be kept up—and there is reason to believe it is being more than kept up now—the population of Australasia will double in five years less time, than even the unprecedently short time in which the population of the United States has doubled. How essential is it therefore, that our statistical records should be accurate and complete.

To my brother statisticians I may perhaps be allowed to say—before all things record your facts honestly, and I would add—place them before the public in such a manner as to cause them to be convincing. It is not sufficient to assert that such and such is the case, unless you show how the conclusion has been arrived at. Mr. Goschen, the present Chancellor of the Imperial Exchequer, told the Statistical Society of London, of which he was the President, to "beware of totals"; and we know how seldom totals can be accepted as reliable without some explanation or some qualification. I would also say, that in drawing conclusions from your facts, do not start with preconceived notions, adducing only such facts as seem to support those notions, and ignoring others which seem to tell in an opposite direction, but look fairly at both sides of the question. Let your deductions follow your facts, not precede them. Love your work, and have your heart in it. If these few simple words of advice—which I offer in all humility and all deference—be taken and acted upon, we may rely upon it that Australasia will become, what to a certain extent she is already, a model of statistical states.

The following paper was read :—

1.—WHEAT, AS A NEW SOUTH WALES PRODUCT NATURE OF THE GRAIN, AND REASONS WHY IT IS FAILING AS A CROP, IN QUALITY AND QUANTITY.

By Angus Mackay, F.C.S., Instructor in Agriculture, Board Technological Education, New South Wales.

It is only the very necessity of the case which induces me to bring this matter before the Association, and with the hope that more than usual attention may follow to a matter of such importance as the main bread supply grain of the country.

A very brief reference to the nature of wheat may suffice for such an assemblage as this. Of the origin of the grain very little is known beyond the fact that it has been cultivated from the very earliest times of which we have records, and in climates very like that of Australia. There are different opinions held by experts in botany concerning the number of varieties of wheat. Some say there are seven, classed as :—1. *Hybernum*, or Lammas ; 2. *Æstivum*, spring or summer wheat ; 3. *Compositum*, or Egyptian ; 4. *Turgidum*, or Turgid ; 5. *Polonicum*, or Polish ; 6. *Spelta*, spelt wheat ; 7. *Monococcum*, or one-grained wheat. *Triticum* is the generic name of all the family, and is common to several of the grasses as well ; for, after all, our main food supply comes from grass. Some authorities cut out several of the foregoing as belonging to one or more of the others ; while there are others, and they have some show of reason on their side as well, who hold that all the family of wheat known up to this time, have sprung from one source. There is no need, whatever, for the object I have in view, to open discussion on these points.

Be the original sources seven or one only, is of secondary importance to the facts I have to bring forward concerning the deterioration of wheat in this country—deterioration in both quality and quantity.

To understand the situation clearly, it is necessary to examine into the character of wheat, in the practical and chemical sense; then to see in what manner the very existence of this grain is dependent upon the soil in which it is grown, and the methods of cultivation followed. I purpose dealing with each point briefly, only, and it will be my fault if the matter becomes wearisome.

It may be accepted as correct that, so far as climate is concerned, there are enormous areas of all the Australasian colonies situated in the very best position for wheat. I sometimes think that it has been a misfortune for this country, that we are so very favourably situated for many things—the production of wheat amongst them. The first efforts for wheat production in Australia were not fortunate. The classic slopes of Woolloomooloo, it is said, saw the first grain of edible *Triticum* sown in Australia. It was sorry poor seed, no doubt, for after a long voyage it arrived from the Cape of Good Hope, where weevils were as lively at that time as they are with us to-day. The season was dry too, the cultivation was slipshod likely enough, for we are told that the expert sent out specially to instruct the colonists in agriculture, was pensioned off, as an incapable, more fond of rum than steady work.

We need not wonder now that the first efforts at wheat growing were not successful. The land on which it was sown, we know, from its very nature was poor in wheat yielding qualities. Soil analyses, were not usual then, and it may be, unfortunately, before efforts had been made to get over the difficulty of soil poverty by manuring the ground, that historical stampede of cattle took place which led on to the discovery of that exceptionally fine stretch of country, the Cow Pastures, the districts of what are now Camden, Campbelltown, and others. There the soil, in its virgin state, was good enough to yield crops of wheat, so the grain was grown and crops reaped year after year; and the want of system was commenced which has gone on and on till the present wheat season of 1888. That is, the "Tickle the soil and it will laugh a harvest" process—some of the said harvests, all the time, making the ticklers weep while they gathered in about as much grain as the seed sown amounted to. The fact is that wheat is an exhausting crop. It extracts heavily certain materials from the soil, of which only very few places on earth have a big supply, and of which—it is well that the real state of the case should be known, and as widely as possible—there are but few localities with us that contain more than a moderate supply. Hence it is, that the locust like process commenced at the Cow Pastures has gone on, and that every season we see considerable stretches of country abandoned, so far as wheat farming is concerned, and new land brought under the process of exhaustion. Sometimes those who give it up as an occupation that does not pay, blame the seasons, the rainfall, westerly winds, blight, rust, &c., &c. Theirs is a case for commiseration, and cause for regret, that ever the notion got about in this or any other country, that because land is new, therefore it is rich; that men can farm it, by the simple process of "taking up the land," as the phrase is, breaking it up three or four inches deep, by a very doubtful kind of ploughing process sowing seed upon it, and waiting, patiently if possible, for a crop. Some get it on these terms for a few seasons; others fail at once. The few are those who from the outset do what they can to keep up the fertility of the land, and so increase their crops and better their prospects.

The results of the exhausting system are seen both in the quality and quantity of the grain. Millers are complaining of the former; the wheat-grower himself feels the pinch of the latter; and when, for his meagre crop, he finds that he cannot get the price being paid for the best lots sent to the mill, his case becomes grevious. As an instance of what is going on, a case could be mentioned where two shillings per bushel was all that could be got at a well managed flour mill, while three shillings were paid for lots up to the requirements of good class flour. The miller's test, in such case is the simple one of examining the grain, in view of its freedom from seeds of volunteer oats, barley, and others that should never be seen in wheat-fields, but which deteriorate the value in very many cases amongst us. Then he examines into the fulness or plumpness of the grain, and lastly he breaks up a portion with his teeth, and his mouth laboratory, tests for "strength," which is really the gluten, the pith and marrow of wheat. The test cannot be complete, even with a very perfect apparatus of the kind mentioned. But, it is wonderful, almost, how accurately, by long practice an unvitiated palate can get at the proportion of "strength" in wheat by this means. In the more perfect system of milling coming into use, the more certain chemical test is applied, and the proportions of gluten, and the quality of the wheat as a flour yielder are got at with absolute accuracy.

So far, I have spoken of the gluten mainly as an ingredient of wheat, and it is because the proportion of that substance has so much to do with its quality. The test for its presence in bulk is not difficult,* but before dealing with that, I would submit the following from Mr. J. J. Willis, who superintended the Lawes and

* In the "Elements of Australian Agriculture" (Mackay) a simple process for extracting gluten is given.

Gilbert tests at Rothamstead, England. The wheats tested were Australian :—

No.	General Character.	Weight Per Bushel.	Yield of Flour.	Dry Gluten in the Flour.
		Pounds.	Per Cent.	Per Cent.
1	Fine soft white Wheat	64	77.46	6.4
2	Superior soft red Wheat....	62¾	78.40	9.3
3	Average hard white Wheat	60	80.52	11.7
4	Average hard red Wheat ...	61¼	79.88	13.4

These figures show the immense range of difference in the gluten-yielding qualities of different wheats, and justify millers in what they state to growers, that they could afford to pay fully one shilling more for wheat that is up to their standard of excellence for making A1 flour.

Concerning the wheat reported on, Nos. 1 and 2, were small and somewhat pinched. Nos. 3 and 4 were fully developed and plump. Then the season of ripening is found to have much to do with the quality of the grain for strength. There is a series of tests from the same conclusive series, and the high averages are found to be from wheat which ripened in hot, dry weather ; and where, at the time of filling the ear, the plant had sufficient moisture, which up to that stage in wheat means a rain or irrigation supply equal to six inches at least, on the area of growth.

No.	Nitrogen.	Albuminoids.	Moist Gluten.	Dry Gluten.
1	1.93	12.08	39.46	12.98
2	1.71	10.68	7.32	2,80
3	1.54	9.63	24.89	10.30
4	1.62	10.15	28.13	10.37
5	1.46	9.10	25.14	9.92
6	1.76	11.03	31.20	11.67
Mean...	1.67	10.45	26.02	9.67

These figures are useful for the grower as well as the miller, they prove so clearly the advantages of sowing fully matured plump grain for seed ; it contains so much more nourishment for the young plant. Gluten is a mixture of the various aluminoids, which Leibig so aptly describes as the plastic element of nutrition. They are present in large proportion in the full matured wheat grown on new land in this country, but decrease in proportion to the deterioration of the grain, until, in not a few instances, it is found impossible to make the class of flour which meet the requirements of bakers, unless wheat can be got from new land, or from land that has been manured to mix with the poorer lots. There has not been an opportunity yet to test, amongst ourselves, more closely than the process followed by the millers regarding the precise effect of manuring upon the proportion and quality of the gluten, but we have the following from the Lawes and Gilbert tests :—

I.—Analyses of parcels of red wheat grown in the same year, without manure, and with manure :—

Constituents of the Grain.	Without Manure.	Compost Manure.	Farmyard Manure.
Moisture	14.2	14.3	14.2
Albuminoids	9.9	14.8	13.0
Oil and Fatty Matters	4.7	4.2	4.8
Woody-fibre..........................	2.3	2.4	3.3
Carbo - hydrates..................	66.6	61.6	62.3
Mineral matters (ash)	2.3	2 7	2.4
	100.0	100.0	100.0

The foregoing will, I believe, be found to come closely to the experience of Australian millers, who find that the weight per bushel of wheat is not, as a rule, a sufficient criterion for what is required for high-class flour—the gluten with its albuminoids. It is thus seen that manuring has the desired effect in improving the quality. That the quantity, in the case of the farmer, is improved by the same process of fertilising, is well known, and need not be discussed here.

This brings us to the all-important question: What are the ingredients necessary for a perfect wheat fertiliser? In order to meet that requirement effectually, it is first necessary to see how a wheat crop is made up, or rather what it takes from the land. And here, fortunately, we have Australian experience for comparison with the tests carried out at Rothamsted during twenty years.

FROM AN ACRE OF LAND—AUSTRALIAN.

(Weight of crop, 30 bushels; straw, 3,000lbs.)

—	Phosphoric Acid.	Nitrogen.	Lime.	Potash.	Soda.	Sulphuric Acid.	Magnesia.	Chlorine	Silica.
In lbs	25	46	11	28	5	3	8	1	100

II.—General characters of the wheat produce at Rothamsted, and quantities per acre, pounds—mean results for ten plots over each period :—

—	Grain.		Straw.		Total Produce.	
	10 years. 1852-61	10 years. 1862-71	10 years. 1852-61	10 years. 1862-71	10 years. 1852-61	10 years. 1862-71
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
Weight of grain per bushel.........	57.1	60.2	...	...	...	...
Produce, per acre...	1740.0	1833.0	3192.0	2878.0	4932.0	4711.0
Nitrogen..............	29.8	28.0	14.3	11.5	44.1	39.5
Ash (pure)............	28.9	28.9	148.7	134.6	177.6	163.5
Ingredients of ash—						
Lime..................	0.88	0.98	7.64	8.49	8.52	9.47
Magnesia..............	3.07	3.10	2.18	2.49	5.25	5.59
Potash	9.47	9.57	29.93	25.35	39.40	34.92
Soda....................	0.06	0.05	0.61	0.83	0.67	0.88
Phosphoric acid.....	14.68	14.38	4.69	4.28	19.37	18.66
Sulphuric acid	0.53	0.45	6 47	5.46	6.82	5.91
Chlorine..............	0.02	0.03	5.23	5.27	5.25	5.30
Silica	0.22	0.17	92.26	83.05	92.48	83.22

The greater richness of the Australian wheat in phosphates, makes it the more valuable as a bread corn, and is due, no doubt, to the more favourable conditions of temperature under which wheat is matured here. But it is the more exhausting on that account; and all the more so because our soils, while yielding their nitrates and phospates readily to grain crops and grasses, are but poorly supplied with them naturally—hence, as the analyses carried out by me in the Sydney Technical College, leave not a doubt—the reason, beyond all others, why much really excellent country in other respects, becomes impoverished for wheat production, and suffers materially in its capacity to support the richer indigenous grasses. The requirements of a fertiliser to meet the case, are as follows, compounded in parts :—

Superphosphate...	30	parts.
Sulph. ammonia	5	,,
Nitrate of potash	13	,,
Gypsum (Sulph. lime)	10	,,

This can be composted, to the extent of four or more times its own weight, with stable or cow-pen manure, or with ashes, or good loamy soil—the richer in organic matter the better, and applied with most satisfactory results upon wheat land. From four hundred to seven hundred pounds per acre would be ample, and the effect would be seen on three or more crops, of which wheat could be one. Amongst other advantages of such treatment as this, would be the strengthening of the roots and straw, which are stunted and do suffer badly for want of potash, especially during dry weather. The nitrogenous matters in our soils are quickly run down by grain crops, hence the slow growth for small returns on poor land, in comparison with the greater vigour of the crop, and its quality and bulk per acre, where the soil is good enough. The ammonia and nitrate compounds meet this requirement.

Touching the cultivation necessary to secure full crops of high-class wheat, much the same process as is followed with such excellent results in the British Islands, is necessary here. It is curious that, while the belief remained strong that our soils were so rich that they required no fertilising aid, the processes of cultivation necessary to get the best results from rich soil were applied mainly by those whose experience led them to doubt this great natural richness. They accordingly ploughed the land twice at least, harrowed it, and drilled in the seed, and when practicable rolled the crop or put a cultivator through it. Operations of the kind are really as necessary here as elsewhere. It pays to work the soil, and so expose it to the influences of sun, rain, and air, to secure the beneficial changes which nature is carrying on all the time. Poorer soils do not need so much working, for there is not the material in them to benefit by exposure to the weather, nor do they give the more vigorous growth of weeds, &c., nor the richer growth of grain as a consequence. The fact is, that it does not answer to farm land which is too thin or poor to send up a vigorous growth of something; nor does it pay to have anything other than wheat on wheat land. The better course is to so work the land as to get it to yield the largest possible crops of what is sown. This is especially true of wheat. The following tables from the Rothamsted tests afford further data concerning wheat and its milling properties; and for comparison purposes with milling experiences here. So far as I have been able to get at the results the averages of fine flour got here do not reach the figures submitted in connection with the Lawes and Gilbert tests.

III.—Produce of wheat per acre, weight per bushel, and proportion of fine flour obtained by milling four varieties of wheat grown under similar circumstances:—

Variety of Wheat.	Quantity grown per acre.	Weight per bushel.	Amount of fine flour.
	Bushels.	Pounds.	Per cent.
Downy white wheat	48	62	80.6
Dantzic, red..................	43½	63	79.8
Whittington, red	33	61	72.2
Talavera, red	52	61	78.5

IV.—Produce per acre, and chemical composition of the same varieties of wheat, grown without manure, and with a manurial supply, in the same field and in the same year :—

How Treated.	Dressed grain per acre.	Fine flour obtained on grinding.	Albuminoids in the flour.
	Bushels.	Per cent.	Per cent.
Without manure............	31½	66.7	9.4
With artificial manure..	48½	64.6	10.0
With artificial manure...	40	66.5	10.5

V.—Weight per bushel of different varieties of wheat, and the percentage of the various products obtained on milling :—

Variety of Wheat.	Weight per bushel.	Flour.	Mid-lings.	Fine Bran.	Coarse bran.	Total.
	Pounds.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Hunters, white......	62	74.40	10.50	10.50	2.10	97.50
Challenge, white ...	63½	73.40	12.10	11.10	2.70	99.30
Suffolk. white	61¼	68.33	12.88	12.22	3.00	96.43
Suffolk, white	64	74.83	11.00	9.91	2.00	97.74
Mean..............	62¾	72.74	11.62	10.93	2.45	97.77
Square head, red...	61	73.40	11.70	10 90	2.80	98 80
Golden drop, red ...	62	75.00	11.20	10.80	2 60	99.60
English, red	62½	74.92	12,07	10.64	1.50	99.13
Norfolk, Red.........	62	74.00	10.70	11.00	2.60	98.30
Mean	62	74.33	11.42	10.84	2.38	98.96

THURSDAY, AUGUST 30.

The following papers were read :—

1.—LABOUR CONDITIONS IN AUSTRALIA AND EUROPE.

By J. PLUMMER.

2.—CO-OPERATIVE POSSIBILITES IN AUSTRALIA.

By J. PLUMMER.

3.—SOME SOCIOLOGICAL PHASES OF STRIKES.

By T. B. Treatt.

Monday, September 3.

The following papers were read:—

1.—ON SOME MEANS OF GIVING "A MORE SYSTEMATIC DIRECTION TO SCIENTIFIC ENQUIRY."

By Felix Ratte, Ing. Arts et Manuf., Paris, of the Australian Museum, Sydney.

2.—ON SOME TENDENCIES OF MODERN SOCIETY.

By James Lambie, M.A.

SECTION G.—ANTHROPOLOGY.

President of the Section, Mr. Alan Carroll, M.A., M.D.

WEDNESDAY, AUGUST 29.

The President, Mr. Alan Carroll, M.A., M.D., in the Chair.

The following papers were read :—

1.—OUTLINES OF ANTHROPOLOGY.

By JOHN J. WILD, PH.D., F.R G.S., Melbourne.

ANTHROPOLOGY is one of the new sciences which owe their origin to the intense intellectual activity characteristic of the Ninteenth Century. The term is usually interpreted to mean, "The Science of Man," and to an outsider it may appear strange that man should be deemed for the first time a fit subject of scientific investigation, considering that he has been meditated upon, examined into, and experimented upon, from the remotest ages down to the present day. It is this generally entertained notion that we know all about him, or the contrary opinion, that we shall never be able to arrive at any definite and exhaustive insight into that mysterious compound of good and evil, which have been the chief obstacles to an unprejudiced and strictly scientific treatment of this important and universally interesting question.

If Anthropology claims to be admitted to the rank of a positive science, it is because it professes to have discovered a new method of investigation, by means of which it hopes to attain results of a sufficiently definite charcter to throw a new light upon the nature of the being which it has undertaken to analyse, and to explain. The field of inquiry occupied by the Anthropologist coincides to a large extent with the domains hitherto appropriated by the historian, the philologist, the antiquarian, and the ethnologist, by all of whom a vast store of material has been gathered and stored up in our libraries and museums. It is not intended to displace these predecessors of and co-operators in anthropological research. On the contrary, the principal object of Anthropological science is to concentrate, as it were, in a focus all the information collected up to this date by their separate labours, and to project these combined lights upon man in such a way as to make him stand out from his surroundings a clearly defined and strongly illumined figure, displaying all these characteristics by which man has always been known to himself, but of which until now he has had only a dim perception. In other words, the method pursued by previous inquirers has been mainly historical and descriptive, that of the Anthropologist professes to be strictly scientific and critical, and consists in a careful study of all those phenomena which are the outcome of man's activity and enable him to occupy a distinct place in creation.

Therefore, the leading purpose of Anthropological science, considered as a distinct branch of scientific research, is not confined to the elucidation of historic events, which is the business of the historian, nor to the study of the different languages spoken by man, which is the work claimed by the philologist, nor to an inquiry into the date and origin of the works of art, the remains of former periods of civilization, which is the purpose of the antiquarian ; but the Anthropologist uses all these materials in order to obtain an insight into the historic development of evolution of man considered as the chief actor in history, the maker of languages, and the creator of the works of art which have escaped the destroying hand of time. Hence the object of Anthropology may be more strictly defined as the critical examination of the intellectual and material progress of man from the earliest ages down to the present. As such, Anthropological science presents itself to us as the logical offspring of the new tendencies which in the course of the Nineteenth Century have invaded and revolutionized every branch of scientific inquiry. This change of front which has forced itself upon every student of science, manifests itself chiefly in the combination of the older sciences, formerly cultivated separately under a new name, and a grouping together of the resources furnished by each for the realisation of higher and wider aims. It would be wrong to conclude that this reformation has been accomplished at the expense of older sciences, and by the sacrifice of their independence. On the contrary, the fusion of the older sciences, which is one of the most remarkable events of our time, has been brought about, not by an invasion of the territory properly belonging to each, but by an exchange of their methods and instruments of research. Thus, the astronomer has borrowed from the physicist his spectroscope and photographic camera, and by means of these instruments he has created a new astronomy and has been enabled to show us new worlds and a new heaven. The naturalist has also gone to the physicist for his microscope, and to the chemist for his re-agents, and what was natural history before has become biology. By a similar process of co-operation, mineralogy has expanded into geology—geography which until lately was little more than topography, has put forth three important and flourishing branches : physical, commercial and historical geography. In all directions we notice the change from purely descriptive science to comparative, or critical science, from speculative to experimental philosophy. We are no longer content with collecting, classifying and labelling ; we not only want to know, but we also wish to understand, to be able to explain, demonstrate and convince. It is to comparative anatomy that we owe the first germ of the theory of evolution ; comparative philology has ripened into the science of languages, and the comparative study of the remains of antiquity has widened out into a history of the technical processes employed by the ancients, and given us an insight into the gradual rise of the fine arts from the rough carvings and paintings of the savage down to the admirable creations of the civilised workman.

In obedience to the tendency above described, we have set about collecting all the available evidence of man's past existence upon earth, for the purpose of producing a picture, as complete as possible, of man's progress from the earliest times up to the present day, and in this manner the science of Anthropology has been founded. Although one of the youngest of sciences, it numbers already numerous adherents in every part of the civilised world; societies for the pursuit of Anthropology have been established in England, the Continent of Europe, the United States, and the far East, nor has Australia been left without its band of distinguished contributors; and contemporary literature includes several periodicals exclusively devoted to the interests of Anthropological science. The limits of this short paper will not allow me to quote the extensive list of writers belonging to every nationality who have studied the remains of the civilized races of antiquity, or investigated the life and habits of the aboriginal tribes still to be found in the interior of the great continents and upon the islands of the Pacific Ocean. The numerous works published on the subject of Anthropology already constitute a vast treasure of information, and are readily accessible in the public libraries founded by the munificence of the Australian Governments and private citizens.

On a review of the work accomplished during the last twenty years, we find that the labours of the Anthropological student and explorer have been rewarded by a series of the most surprising discoveries, sufficient in themselves to completely change the views formerly entertained as regards the early history of mankind. The apparently impenetrable curtain, which, until lately separated us from the life of the pre-historic races, has been lifted up, and through the long vista of ages suddenly revealed to our astonished gaze, we behold our remote ancestors slowly toiling up towards the stage of civilisation made known to us in the first pages of history.

Abandoning for once the often doubtful testimony of books, the student of Anthropology has seized the spade and the pickaxe and in turning over the soil of Italy, Greece, Syria. and Egypt, he has obtained ample proof of the existence of races and nations which have left little or no trace in the pages of history. We are now better able to judge of the conditions under which man lived in the earliest period of his existence on earth, of the influence of race and climate which left their impress upon all he has done, of the various stages of his progress towards civilisation, and of the means he employed to raise himself above a state of degradation but little removed from the level of a purely animal existence. A better acquaintance with the aboriginal tribes still found in America, Africa, Asia, Australia, and the islands of the Pacific has thrown much light upon the difficulties with which mankind had to contend at the beginning, and also upon the moral and intellectual conditions which appertain to the earliest stages of the human race. Thus, the sea-built village still flourishing in New Guinea and the Malayan Archipelago, bear a striking resemblance to the pre-historic lacustrine villages, the remains of which have been discovered in the lakes of Northern Italy, Switzerland and Ireland. The age of stone has continued from the time of the cave-men down to the present inhabitants of New Guinea, the Admiralty Islands and other islands in the Pacific, who have only recently become acquainted with the use of iron.

Among the most remarkable triumphs of anthropological research are the discoveries made by Dr. Schliemann and his fellow-excavators upon the site of ancient Troy and subsequently at Mycenæ and Tiryns, the cylopean ruins of which overlook the Gulf of Argos, once alive with the sails of Agamemnon's host. The French and American Institutes established in Athens for the pursuit of antiquarian exploration are at the present moment engaged in their important labours, and the soil of Olympia and Delphi has yielded many valuable specimens of ancient Greek sculpture. The Museums of Rome and Naples continue to be enriched by the fragments of ancient art buried for centuries in the bed of the Tiber, or under the lava-streams which overwhelmed Herculanum and Pompeii. The researches carried on for years by the English Society for the Exploration of Palestine have placed the most precious materials at the disposal of the student of Biblical History. Egypt has had to give up the bodies of her Pharaos entombed for ages in the rocky caves of the Nile Valley, and the Museum of Egyptian Antiquities, founded near Cairo, merits the attention of the Australian traveller upon his pilgrimage to the home of his fathers. The Anthropologists of the United States threaten to outstrip their European rivals by the energy displayed in their investigation of the ancient monuments of North and Central America; not a moment too soon, for we hear now and then of the death of some old man or woman, the last of their tribe, and the last who had not forgotten their native tongue. Thanks to these labours, we are now beginning to obtain a glimpse of the process of immigration and transmigration by which the American continent has been populated.

A vast field of inquiry still lies open to the philological student who has set himself the task of deciphering the manuscripts and monumental writings of Babylonia, Egypt, Etruria, or Mexico. There are some critics who assert that the rules of interpretation applied until now are unsatisfactory, and will not readily bear the scrutiny of such as are accustomed to the strictly deductive and experimental methods, which in the physical and natural sciences have yielded such splendid results. But a new and more scientific spirit has already manifested itself in the prosecution of archæological and philological research. In view of the daily accumulating materials furnished to the historical inquirer it is time to set aside the prejudices and the rather lax methods of investigation of the old classical and philological schools. We are indebted to them for the collection and preservation of the most valuable documents indispensable to an understanding of the life of ancient days, but their attempts to connect the mythologies, the traditions and the arts of the various nations of antiquity seems to have left the materials at our command in a state of almost inextricable confusion. The shelves of our libraries are adorned with voluminous and often amply illustrated works descriptive of the monuments of antiquity, but there can be no doubt that a fresh and exhaustive examination of the latter by technical experts will lead to a more satisfactory explanation of their real significance and original purpose.

But Anthropology, while tracing the gradual progress of man towards a higher civilisation, may claim to subserve a still nobler purpose. In the face of all racial and national distinctions, which until now have divided and estranged from each other the scattered members of human society, it proclaims the essential unity of mankind. It supplies evidence that in speaking of the great human family we are not using a phrase which has no meaning. Anthropology asserts and proves that men are indeed brothers and fellow-workers in the great movement of civilisation. It shows that although the latter has been the outcome of a long struggle extending over thousands, and may be tens of thousands of years, we have evidence of a steady advance commencing with the first dawn of human life upon this globe, and that in spite of the numerous and terrible catastrophies which have overwhelmed one period of civilisation after another, the higher type of man, like the phœnix of the fable, has always sprung up again from its ashes in order to continue its course towards a still higher destiny.

In presenting these imperfect notes upon the auspicious occasion of the first meeting of the Australasian Association for the Advancement of Science, I chiefly intended to trace a general outline of the aims and scope of Anthropology, and to press the claims of this youngest of sciences upon the attention of all those who are disposed to encourge research within the limits of the Australasian colonies. The wonderful progress achieved by the latter during the century which has elapsed since the date of their foundation, must react favourably upon all intellectual pursuits, which, to a greater extent than any others, contribute to the glory of a nation and secure for it an honourable place in the annals of the future.

THE GENEALOGY OF THE SUN—A SAMOAN LEGEND.

By the Rev. G. Pratt, Sydney.

(Communicated by the Secretary of the Section.)

This Legend I obtained from Mr. S. Wilson, who lived among the natives, and, as a native, got it from them. That was about 1835. He also paraphrased some of the more difficult passages, and I have followed his suggestions.

The first part explains the Origin of the Sun. In those ancient times there was much intercourse between the inhabitants of heaven and earth ; probably before the time, when, according to their tradition, the skies were raised from lying low down near to the face of the earth, into their present position. The tale gives a perfect picture of Samoan life ; the courtship at first by proxy, with a present of food ; followed up by the coming of the lover himself, the quarrels of the lovers, and the angry departure of the offended lady ; the reconciliation and marriage through the influence of friends ; the dowry of fine mats, and property given in exchange by the husband's friends ; the desertion of the wife and subsequent reconciliation and re-union ; all these are events of daily occurrence, or were so up to a recent period.

The scope of the second part is not so clear as that of the first part. It seems merely to relate the miraculous powers of the Fly Hook given by the husband's friends, up to its final loss. These hooks are made out of pearl shell, cut in the shape of a small fish. To this was lashed, through small drilled holes, an unbarbed hook made from tortoise shell, and small feathers were added to imitate fins. The time and labour consumed in making these fly hooks, when men had no iron tools, must have been very great, and the value of the hooks was in proportion. There were many superstitious observances in all preparations for fishing, but especially with regard to the bonita. The person who attached the hook to the fly must first bathe his body, then put on the fisherman's apron of cloth, then seat himself on a mat, and thus solemnly set to work. Only by a strict observance of these particulars could success be looked for in the subsequent use of the hook.

The element of fable is noticeable : the rat watching the work observes that the hook is not fastened exactly according to rule, and he runs off to tell it to a fish found near the margin of the beach. That fish again tells a fish living further out to sea, and that one tells the most interested party, the bonita, only found outside the lagoon. The bird also flies up to heaven to give notice of the return of the woman. The tedious repetitions in the tale are also peculiar. Had a Samoan recited the tale of the woman who had seven husbands (Mark, 12,20), he would have given the name of each of the seven, and an account of each separate marriage and death.

The giving of the hook from one to another as they swam, and each in succession felt that he was drowning, was intended to show the power of the hook to bring calamity ; so that the womam, though naturally the weakest, yet having it given up to her the last, would be so near the land that she was able to get safely ashore.

The language of the Samoans was kept pure before their intercourse with other nations. Afterwards they seemed to be proud to adopt foreign words. The translation of the Bible, according to the testimony of the natives, fixed their language. There are therefore no archaisms in the language of the legend. One mark of age is the entire absence of chiefs' language or the language of respect. Such language as is used to chiefs in the Legend would not be tolerated in present times. To use any other than the language of respect would now be considered as an insult.

The parting command not to look back, and the serious consequences of disobedience, cannot fail to recall a similar command given by the angel to Lot, with the fatal consequences of disregard in the case of his wife.

This is a sacred composition, mostly recitative but partly sung. It is one of the most ancient legends, and was kept secret by the orators from every one except their successors.

THE GENEALOGY OF THE SUN.

PART I.

Pua and Singano* were man and wife.. †They had three children; the daughter was changed into the ‡ifiifi tree.. Tafa'i and Alise were her brothers.. Lauamatoto their attendant, desired to find a wife for Tafa'i.. Lauamatoto ascends into the skies.. There in crowds slept the handsome men of the skies.. The man had gone up with a large pig..§ He makes his appearance amongst them.. The woman seated under the ridge pole of the house, suspected his object. [She asked him].. From whence are you?? The man answered her, I came from below, from Tafa'i.. The woman was pleased with the suit of Tafa'i.. Then the woman asked, Where is Tafa'i? Lauamatoto answered her, Tafa'i is in Tutuila :—which was false..

*Names of odoriferous trees.

†The double punctuation throughout this translation indicates the end of a line of the Samoan text, and is intended to help the reader to compare the text with the translation, line by line. The words in square brackets are not to be found in the text.

‡An odoriferous tree.

§A courting present.

The woman asked.. Will he be a long time or will he come soon ?? The man answers thus ::—

> *To-morrow will the trade wind blow,,
> By this time of the day he will have come ;;
> Though seeming distant, still 'tis near ;;
> When he arrives, do you come..

The man descends to the earth,, for his chief to ascend.. He descends to Tafa'i and Alise and gives them his report.. He tells them the words of the woman.. Tafa'i bids him,, make a girdle of its leaves,, and then take it and dip it into the sea,, also dip the musty portions of meat.. The man then re-ascends with these two things.. Tafa'i comes from Tutuila, then the man ascends with his gifts to Sinataeoilangi, the daughter of† Tangaloalangi..‡ He places the things before her, and she rejects them with disdain, because they were musty and unpleasant.. Why, [said he], have you rejected the provisions of Tafa'i ?? They were musty from the voyage.. Then said the woman, Sina,, Go and bring up Tafa'i.. Joyfully the man went to the brothers.. Then the brothers prepared to ascend to the woman..§ As they went, they consulted together on the way.. The brothers were both handsome.. They presented their request to their god to give them ugly bodies, lest they should be killed.. ‖ Then the pair appeared in front of the house in which was Sina.. She disliked to look at their bodies which appeared so ugly.. She said,, Go to that end of the house, and sleep there on the cocoa-nut leaf mats, lest the sleeping mats be dirtied.. The pair then slept at night on the cocoa-nut mats.. When it was near morning, the morning birds whistled.. Then the brothers asked their god to restore to them their handsome bodies.. When it was broad daylight, Sina was pensive.. She sat with the ¶wife-seekers of the handsome men of the skies.. She saw the end of the house shining ; the young men arose to go on their return journey, it being morning.. The woman repents [of having rejected them], and rises up to follow them.. Then she calls to them, Tafa'i stop !! [They answer], Sina, come on.. In this way she followed them till they reached their own land.. They descended to the place where their parents dwelt.. Then Tafa'i pushed the woman down into a long chasm ; and the two went down to the sea beach to their own land.. Pua and Singano heard the woman crying from the bottom of the chasm ::—

> I have been pushed down into the long chasm ;;
> Cover me with the leaves of the māfoa..
> I have been pushed down the great chasm ;;
> Cover me with leaves of the mangele,,
> And with the wide leaves of the fangufangu..

* A Song.
† The great God of Polynesia.
‡ There is much repetition here.
§ Repetition in MS.
‖ Through jealousy.
¶ Soa, " Persons who acted as a go-between to a young man and woman."

This was what the pair, Pua and Singano, heard.. Then they had pity on the crying woman, and brought her up [out of the chasm].. They brought her up to dwell with them.. The woman Sinataeo-ilangi asked them .. Is there no salt water here ?? Pua and Singano answer,, The sea is there in front of the house.. [Sina asks], How is it that we do not prepare made dishes of food ?? [They answer].. It is because we have no one to fetch *salt water..] Sinataeoilangi said,, Give me the water bottles, and I will fetch salt water.. This was her scheme to meet with Tafa'i with whom she was still in love, and who dwelt by the sea.. The brothers looked up, and the woman appeared to them.. [They accosted her saying],, Woman come, let us drink together,, [She replied], Let me first get my salt water, then I will come.. She returns, and Tafa'i relents, having thought she was dead.. Tafa'i calls to her, and she resolves to retort on him the same as he had served her in the skies.. [He says], Sina stop !! [She answers], Tafa'i come on.. Again he cries, Sina stop !! Again she replies,, Tafa'i come on.. The woman reached the place inland where the parents of the brothers dwelt ; then she sprang up to the top of the house.. Tafa'i came and entered into the house.. The woman called down to him from the house top :—

Tafa'i come outside..
Let us bid farewell, and I will go..
This is my road..
I shall not return another day..

Tafa'i's heart was angry as he sat in the house, and he would not go out.. The woman then sprang up into a tall cocoanut and from thence went to the skies, and the Manuma went with her.. On the road she met her family, the whole tribe of Tangaloa, bringing her marriage portion.. Tangaloa-langi said to her,, Come daughter, let us return to the earth.. At first she refused,, but afterwards said, Let us go down,, for my love for my husband is not ended.. Tangaloa-langi agrees.. We will, he says, go down to Tafa'i.. The Manuma then went on ahead,, to report that the family of Tangaloa were coming with Sina's dowry.. His sister, changed to an ifiiti,, shook from her boughs a large supply of food with which to receive the family of Tangaloa.. Then the family of Tangaloa and the woman arrived.. So abundant were the provisions that they were thrown into the sea..

Tafa'i and the woman were married.. The family of Tangaloa waited till she was in the family way ;; and then he returned to his own country.. In due time the woman brought forth her son, the Sun (La).. When he was born, the heat of his body was like a whirlwind.. [When he was grown], the Sun planned a scheme ;; the Sun said,, What land is this ?? He was told, This is the country of Tafa'i.. He asked, Where is my mother's country ?? The answer

*This was used in the preparation of many made dishes.

was, Her country is in the skies.. He said, Very well, I don't wish to dwell in this country of Tafa'i;; let me visit the country of my mother in the skies.. The Sun prepared to go above.. He went to the western side of the heavens,, but it did not suit the desire of the Sun.. Then he went to the eastern side of the heavens, and it suited the desire of the Sun.. He then prepared to descend to the country of his father to tell him his desire to dwell up above in his mother's country.. He then went down to bid them farewell, [saying], "I am about to depart now, I shall pass over the heavens . If you have any children, let them sun their sleeping mats, and I will have compassion on them.. I am going to pass across the skies ; when I reach the west side of the heavens, in shades of evening then the cricket will chirp, he is my brother. At midnight Sina's palankeen will be lifted up and again the cricket will chirp ; and the Sun will ascend into the fasa tree."

Part II.

So it was, that Mangamangaifatua, a woman from Leipata, was there, *picking up the rubbish. The Sun arose, and his beams fell on the woman, and he went up and embraced the woman, and she became pregnant, and she bore a son called (Alo-alo-o-le-La) Sun-beam.. He married a Fijian woman, the daughter of the king of Fiji.. Then were brought two fine mats, the dowry of the wife of Sun-beam.. Then the man took a voyage to Fiji to bring the property to his father the Sun.. He arrived at Leipata where his mother was.. She told him to leave the property with her ; Sun-beam refused,, lest, said he, misfortune should overtake me through you,, I will take it up to my Father from whom I came. He then took it up before the Sun arose.. He delivered the property to †Matiu and Longalonga and Saasaa-mai-le-tala..‡ Sun-beam asked, where is my father the Sun ?? I am come in my distress.. [His sisters said], Go and break off a vine rope with which to catch the Sun.. The Sun asks, What god of Samoa has ensnared me ?? [Sun-beam answered], It is I, your son, the child of Mangamangaifatua ;; the dowry of my wife from Fiji is here with Matiu, and Longalonga, and Saasaa-mai-le-tala ; I am come in my difficulty to seek§ marriage property for my wife.. The Sun answered, Go to the women,|| and choose one of two articles which are in their keeping ; either the Hook of prosperity or the Hook of adversity ;; leave the Hook of prosperity and take the Hook of adversity ; because that is first adverse and then prosperous ; whereas the Hook of prosperity is first prosperous and then adverse.. Then came to him the women, Matiu and Longalonga, and Saasaa-mai-le-tala, and they said to him, Go you with the

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* The fallen bread fruit leaves, &c., women's daily task.
† Sisters of the Sun.
‡ There seems to be an omission here.
§ Property given by the husband to the wife's family.
|| His sisters.

Hook of adversity, and leave the Hook of prosperity; because it is bad.. The women then made this parting command, Place the property in the stern of the canoe; beware lest you look back until you stand on the beach of Fiji.. Then the man went on his journey, to part with his mother who was angry. He went on his voyage; but his mother had departed in anger to the island of Savaii.. She went, and it lightened from Avalua, while Aleipata was plainly visible.. She then paddled to the land at Sataelea.

Meanwhile her son went to Fiji with the property.. He transgressed against the parting command, for he looked back, and his hook fell into the sea.. Then he went on to Fiji, and reported, My hook has fallen into the sea; let some go down and look for my property.. They went and searched *diligently, but could not find it.. Then went down a fisherman who had fish traps, and he found the property in his trap.. The trap was full of fish. He took up the Hook of adversity, and there was only the hook part.. Then he enquired for a Fijian to repair the Hook.. The Fijian fisherman did not know how to do it.. Then some came to Samoa seeking fishermen.. When they had finished in the bay of Lāua, then Sun-beam went.. The brothers Utu and La'ulu, and Auloloto, and Aumamao and Aupaupau, and their sister Sina, these are the brothers who went to Fiji, and they repaired the Hook.. When they had ground the hook, Unu lashed it on while the Rat was looking on.. He went and reported to †Avaava, The Hook is wrongly lashed.. Avaava went and reported to ‡Tavatava, Tavatava the Hook is wrongly lashed.. Tavatava went and reported to §Bonita, Bonita the Hook is wrongly lashed. Unu then let down the Hook into the sea, but it was not taken by any fish.. Then the Hook was given to La'ulu, who lashed it.. The Rat looked on; the Hook was wrongly lashed.. The Rat went and reported to Avaava, Avaava, the Hook is wrongly lashed. Avaava went and reported to Tavatava, Tavatava the Hook is wrongly lashed; Tavatava went and reported to Bonita, Bonita the Hook is wrongly lashed.. La'ulu let down the Hook, but no fish was taken.. Then the Hook was given to Auloloto who lashed it. The Rat looked on and saw that the Hook was wrongly lashed.. The Rat went and reported to Avaava, Avaava the Hook is wrongly lashed.. Avaava went and reported to Tavatava,, Tavatava the Hook is wrongly lashed.. Tavatava went and reported to Bonita. Auloloto let down the Hook, but no fish took it.. Then the Hook was delivered to Aumamao, who lashed it.. The Rat looked; the Hook was wrongly lashed.. The Rat went and reported to Avaava, Avaava, the Hook is wrongly lashed.. Avaava went and reported to Tavatava, Tavatava the Hook is wrongly lashed.. Tavatava

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* Searched, searched. Like the Hebrew idiom for intensity.
† A fish found near the beach.
‡ A fish found further out than avaava.
§ A deep sea fish.

went and reported to Bonita.. Aumamao let down the Hook, but no fish took it.. Then the Hook was delivered to Aupaupau, and he lashed it.. [He then applied to] Sina,* she says I will lash the Hook.. Do you go and bathe, and dress in the fisherman's apron. . Take out from the house, all that is within.. Place a mat to sit on, and so lash on the Hook.. The Rat looked, and the Hook was fastened properly.. Then the Rat went and reported to Avaava, Avaava the Hook is properly fastened.. Avaava went and reported to Tavatava, Tavatava the Hook is properly fastened. Tavatava went and reported to Bonita, Bonita, the Hook is properly fastened.. Then the youth prepared his canoe, to go and let down the Hook.. The Hook was prosperous, and the canoes were filled to sinking with Bonita. Then the report went forth that the Hook was to be cut from the line : and that the brothers were to sail to Samoa with the Hook,, and to tell Fiji that the Hook was broken off [by fish].. Then Fiji pronounced a curse ! If it is true that the Hook was broken off [by a fish], you will reach Samoa in safety ; but if you broke off the Hook, then you will not reach Samoa.. The canoe came away, and it was swamped at sea.. The brothers swam.. Unu had the Hook ; they continued to swim, till dying he gave up the Hook.. La'ulu had the Hook, and they continued to swim till La'ulu was exhausted, when he gave up the Hook to Auloloto.. Auloloto had the Hook, and they continued to swim till Auloloto, drowning, gave up the Hook to Aumamao., Aumamao had the Hook, and they continued to swim until Aumamao, drowning, gave up the Hook to Aupaupau.. Aupaupau had the Hook, and they continued to swim till Aupaupau, drowning, gave the Hook to Sina, Sina here is the Hook.. Sina went ashore on the western side of Savaii.. She went up inland and married a man called I'umangamū.. She still kept the Hook.. She dwelt with this man till she became pregnant, and then he† deserted her.. She went away inland to a village standing by itself in the depth of the bush ;; she went and married Afia, and lived with him ;; she brought forth a son, and called him I'umangatunu..

The child grew up to mature age.. Then a courting party of the youth came to the house of the ladies in the family of I'umangamu.. I'umangamu rose up early to go out fishing, [and called out], Woman, wake up your suitors to go and fish with me.. The older ones refused, not feeling disposed.. Only the lad [I'umangatunu] offered to go with him., The youth went down to the sea, and took the seat in front of the steersman in the canoe.. The hooks at the stern were not taken by the fish, but the Bonita made strenuous efforts to get at the Hook of the youth, I'umangatunu.. Then I'umangamu said, Come here young man and steer our canoe.. The youth would not consent.. The canoe went ashore

* His sister.
† lit.—Threw her away.

unsuccessful.. The youth went up in land with the Hook to his mother, and said to her: Sina, I'umangamu asked me to go fishing with him.. Sina said, That is good ;; if I'umangamu again asks you,, wind up his fishing lines, and undo yours.. The courting party again came down, and again I'umangamu woke up the suitors,, and asked them to fish with him.. The elder ones were unwilling ;; but the youth went down and sat on the seat of the canoe in front of the steersman.. The man trailed his hooks, but the fish did not take them ;; but made efforts to get at the youth. Then said the man,, Do you come here and steer the canoe ; perhaps you may catch a Bonita.. Then the youth went to steer. He trailed his fly hook, the Hook of adversity.. The youth's hook was taken by the fish, and the canoes were ready to sink with fish. They dragged the canoes to the land.. It then occurred to the man to make up a burden of fish and take it to his family.. The family looked and saw him coming with the burden of fish.. Then Afia resolved concerning I'umangamu, and said to Sina, This is but right that as I'umangamu has brought back your son with a gift, that you should return with him.. Go, then, with your son, and don't forget Afia in his bush dwelling.. Then went the youth with his mother to I'umangamu, and his mother lived with him.. But I'umangatunu made a journey round *Salafai with the artificial Hook ; and he got loads of fish all round the island..

After that he came over to Upolu ;; beginning at the lee end of the Island, he passed along by the †Alofi side, meaning to travel round the island.. The youth reached the passage through the reef at Tofanā, when the Fly-Hook was broken off by the ‡Sapatu. Upon this, the ‡Malautea held a council in the passage through the reef at Tofana.. All the fishes of the sea then sought for the Hook.. Malautea was free from blame ; it was Saputa whohade taken it.. Let some visit the Saputa, who sleeps away by himself, and see whether the Hook is there.. They visited, and it was there ;; so they brought away the Hook,, and brought it to I'umangatunu.. There was a man from Tāpanga,, who gave a charge to I'umangatunu.. Wind up your hook lest it be broken off.. He went to Lemataleipata and wound up the Hook.. He reached the back of the island, Falealili, with the Hook.. He is about to break his promise.. He unloosed the Hook.. He reached the reef opening of Matapalapala. Two fishes there broke his line, the §Matopoto and the Tagia'a ;; the Hook was broken off by Tagia'a.. There still lies at Matapalapala,, the Hook of Adversity.

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* The name of respect for Savaii.
† Aana.
‡ The name of a fish.
§ Names of two fishes.

THE SAMOAN TEXT OF THE LEGEND

ENTITLED

THE GENEALOGY OF THE SUN.

Furnished by the Rev. G. Pratt.

O le Gafa o le La.

Part I.

O Pua ma Sigano le uluga alii, [Page 448, line 1
E toatolu le uso.
O le fafine na liu la'au o ifi,
Ma Tāfa'i ma Alise, ona tuagane ia.
O Lauamatoto le tamaloa. " " " 5
O lo'o fa'asasano ifo le fa'anofo a le fafine ia Tāfa'i.
O le a alu i luga le tamaloa o Lauamatoto;
Moe ulu, moe vae manaia o le lagi.
A o le tamaloa ua alu atu ma le mea tele, o le puaa.
Ona fotu mai lea o le tamaloa o Lauamatoto
O lo'o ua masalosalo i ai le fafine e nofo i le auau.
Ona fesili mai lea o le fafine,
E te sau maifea? " " " 10
A e tali le tamaloa,
Ou te sau mai lalo ia Tafa'i.
Ua fiafia mai le fafine i le soa a Tafa'i; e manao i ai le fafine.
Ona fai lea o le upu a le fafine, Oifea Tafa'i?
O le a tali atu e le tamaloa o Lauamatoto,
O Tafa'i o loo i Tutuila; ua faafiti ai.
O le a fai mai le fafine, [Page 449, line 1
E tuai mai ea, pe vave mai? " " " 1
Ua faapea atu a le tamaloa,

> Taeao e toelau mai;
> Pe na i se aso ua oo mai, " " " 5
> E mamao fua a e fetaitai.
> A oo mai, tou o mai.

O le a alu ifo le tamaloa,
E o ae ia le tamaloa.
Ua alu ifo ia Tafa'i ma Alise,
E fai i ai lana tala;
Ua logologo ifo upu a le fafine.
Ona fai atu lea o Tafa'i, " " " 10

E fatu le togotogo ; [Page 449, line 10
Ave, ina fufui i le sami ;
Ia, ina ave ma le tufa'aga a mea mafu, ina fufui ai.
Ua alu le tamaloa i luga ma mea e lua,
O le a tu'u i ai.
Ua sau Tafa'i mai Tutuila. [Page 449, line 12
Ona alu a'e lea o le tamaloa,
Ua avatu ana mea ia Sinataeoilagi, le afafine o Tagaloālagi.
Ona tu'u atu lea o mea,
Lafoai e le fafine.
Ua a'u isa ! ua lafoai mea ina ua mafu ma loua mai.
[Page 449, line 15
Funa, ua e lafoai e ā le oso o Tafa'i ?
O lē mafu mai vasa.
Ona fai mai lea o le fafine o Sina,
Se, alu ia, tou o a'e ma Tafa'i.
Ona fiafia lea o le tamaloa i le uso ua o'o i ai.
Ona sauni lea o le uso,
O le a o'o i luga i le fafine.
O le a o fo'i i ai le uso.
Ona o fo'i lea o le uso ;
Ua fai la la manatu i le ala,
O le nu'u e mananaia uma ,, ,, ,, 20
O le a fai i lo la aitu,
Ua fai i lo la aitu,
E tu'u i lo la tino leaga,
Ne'i la manunu'a.
Ona fotu mai lea o le nu'u i lumāfale, i le mea o i ai Sina.
Ua 'ino'ino le fafine i va'ai atu i lo la tino ua leaga mai.
Ua fai atu Sina,
Se'i ui a'e i le tala lela, lua te momoe ai i tapa'au, ne'i eleelea fala.
[Page 449, line 25
Ona momoe lea o le nu'u, ua po, i tapa'au.
Ona tausani lea o manuao, a lata i le ao.
Ona fai atu lea o le uso i lo la aitu,
E tu'u mai o la tino e mananaia.
Ua aogalemu le ao, ona sogasogā lea o le fafine o Sina.
Ua nofo le fafine i le nofo ma soa o manaia i luga, ,, ,, ,, 30
Ua vaai mai le fafine, ua maina le tala.
Tutu atu le nu'u, ua usu ina ua ao.
Ona salamo lea o le fafine, ua tula'i e tautali.
Ona valaau atu lea o le fafine.
Tafa'i tu mai
Sina e, sau.
Ua o'o atu i le nu'u, o fa'apea lava. ,, ,, ,, 35
Ona o ifo lea i le mea e i ai o la mātua ;
Ona tulei lea o Tafa'i le fafine i le vanu loa.
Ua o lava le nu'u i tai, i le matāfaga i lo la fanua.

Ona fa'alogo ifo lea o Pua ma Sigano,
Ua tagi a'e le fafine i lalo i le vanu loa [Page 449, line 40

Ua tulei a'u i le vanu loa;
Ufiufi i le lau mafoa,
Ua tulei a'u i le vanu tele;
Ufiufi i le lau magele,
Ma le fagufagu lau tetele.

O le fa'alogo ifo lea o le ulugāli'i o Pua ma Sigano; [Page 450, line 1
Ona alofa lea i le tagi a'e a le fafine, ona la ava'e ai lea.
Ona ava'e ai lea e fai la latou faia'ai.
Ona fai atu lea o le fafine o Sinataeoilagi,
E leai ea se sami?
Ona fai mai lea o Pua ma Sigano, [Page 450, line 5
Sami le lā le i tai.
A pefea lava ona le faia a tatou sua?
Ona leai se utu sami.
Ona fai atu lea o Sinataeoilagi,
Tu'u mai ni sami, so'u utu sami mai.
O lona manatu lea, o lona manamea ia Tafa'i o i tai. [Page 450, line 10
Va'ai a'e le uso, a fotu atu le fafine,
Funa, sau, tatou inu.
Se'i utu mai la'u sami, ou sau.
Ona alu a'e ai lea o le fafine,
Ua salamō Tafa'i, fā'i ua oti le fafine.
Ona vala'au atu lea o Tafa'i.
O le a fai le fetauia'iga i le mea na i luga i le lagi. [Page 450, line 15

Sina e, tu mai.
Tafa'i, sau,
Sina e, tu mai.
Tafa'i, sau.

Ua papa'i le fafine i uta i le mea na i ai mātua o le uso,
Ona oso lea o le fafine i luga i le fale;
A e sau Tafa'i ua ulufale i le fale.
Fai ifo lea o le fafine i luga o le fale, [Page 450, line 20

Tafa'i liliu mai i fafo,
Se'i ta mavae i le ou alu,
O lo'u lava lenei alu;
Ou te le toe sau i se aso ,, ,, ,, 25

Ua leaga le loto o Tafa'i i fale,
Ua le alu atu.
Ona oso lea o le fafine i le niu loa,
Ua alu i le lagi.
Ona oso atu lea o le manuma, na la o.
Ona fetaiai lea i le ala ma lona aiga i luga, sa Tagaloa uma lava

E au mai i ni ona mea avaga, [Page 450, line 30
Ona fai mai lea o Tagaloalagi, ,, ,, ,, 30
Funa e, sau ia, ina tatou fo'i.
E le mafai le fafine,
O mai tatou o i lalo.
E le'i uma lo'u loto i lau tane.
Ona gau ifo lea o Tagaloalagi,
O le a tatou foi ifo ia Tafa'i.
Ona muamua ifo lea o le manumā;
O le a tala mua, sa Tagaloa ua sau ma le saga o Sina. [Page 450, line 35
Ona lulu lea o le fafine, ua liu ififi.
Ua faupu'e taumafa tali a'e sa Tagaloa. ,, ,, ,, 37
Ona papa'i ifo lea sa Tagaloa ma le fafine,
Ua lafoa'i i le tai taumafa.
Ona fa'ato'a fai lea o le faiaiga a Tafa'i ma le fafine. [Page 450, line 40
Ona tatali lea o sa Tagaloa, se'i ia to i le tane;
Ona mavae lea o Tagaloa i luga i lona nu'u
Ua fanau le fafine ina ua nofo ia Tafa'i;
O lona atali'i le La.
Ua te'a le tama i le fafine, ua se asiosio le vevela o le tama.
Ona fai lea o le togafiti a le La,
Ona fai atu loa o le La, [Page 450, line 45
O le fea lenei nu'u? ,, ,, ,, 45
O le nu'u lenei o Tafa'i.
A o ifea le nu'u o lo'u tina?
O luga i le lagi. [Page 451, line 1
Io, ta te le fia nofo i le nu'u nei o Tafa'i.
So'u asi a'e le nu'u o lo'u tinā i luga i le lagi.
O le a alu i ai le La i luga.
Ona alu lea i le itu lagi i sisifo;
E le tau ai le loto o le La. ,, ,, ,, 5
Ona alu lea i le itu lagi i gaga'e.
Ua tau ai le loto o le La.
O le a fo'i ifo i le nu'u o lona tamā.
Ua fia nofo i luga i le nu'u o lona tinā.
Ona alu ifo lea e fai lana mavaega,
O a'u, o le a a'u alu nei, ou te sopo lagi, ,, ,, ,, 10
Ai sa latou fanau tama iti, fa'ala fala, a a'u alofa ifo.
A a'u alu e sopo lagi; a ua maua le itu lagi gagaifo, a malū afiafi, ua tagi alise, o lo'u uso lea.
A tulua po ma ao, sii le fata o Sina, a e toe tagi ai foi alise,
Oso a'e le La i le fasa. [Page 451, line 15

Part II.

O le mea lea na i ai le fafine nai ia Leipata,
Na tae otaota o Lemagamagaifatua;

Ua to ai le fafine i le ave o le La.
Ona oso a'e lea o le La;
Ona saua mai lea o le ave o le La o le tauupu o le fafine.
Ona fanau ai lea o Aloalo-o-le-La [Page 451, line 20
O le tamaloa lea na fai avā i Fiti.
Ua nofo ai le afafine o Tui Fiti.
Ona sau ai lea ma ie e lua,
O mea avaga o le avā a Aloalo-o-le-La.
Ona folau mai lea o le tamaloa i Fiti,
E au mai toga i lona tamā i le La;
Tunu'u mai i Leipata, o i ai lona tinā;
Ona fai atu lea o lona tinā, e tu'u toga ia te ia;
E le mafai Aloalo-o-le-La. „ „ „ 25
Pe tu'u ou te malaia ia te oe? „ „ „ 25
E ave i luga i lo'u tamā, ou te mai ai.
Ona ava'e'ai lea, a o le'i oso a'e le La.
Ua tu'u toga ia Matiu, ma Logaloga, ma Sa'as a'a-mai-le-tala.
Tu'u ai toga, a e fai atu a fafine,
Fai atu lea o Aloalo-o-le-La,
O ifea lo'u tamā o le La?
Ou te sau i lo'u tiga. [Page 451, line 30
Sau ina momotu le fue e pena ai le La, o le fasa ma le tauanave ma le fetau.
O ai le Vave o Samoa e na mailei a'u?
O lou atalii a'u, o ou o le tama a Lemagamaga ifatua;
O mea avaga a la'u avā mai Fiti; o la, e i la ma Matiu, ma Logaloga, ma Sa'asa'a-mai-le-tala.
Na a'u sau i lo'u tiga i se oloa e sama ai la'u avā. [Page 451, line 35
Tali mai lea e le La;
Alu i fafine la, fili oloa e lua o i ai, po o le 'au-a-manū, po o le 'au-o-mala.
Tu'u la ia o manū, alu pea ia ma le 'au-o-mala;
Auā mala mala manu. [Page 451, line 40
Peitai le 'au-a-manū, manū, manū, mala.
Ona alu ane lea i fafine e toalua, o Matiu, ma Logaloga, ma Sa'asa'a-mai-le-tala.
Ona fai mai lea o fafine,
Sau ia ina alu ma le 'au-o-mala,
A e tu'u le 'au-a-manū, e leaga. [Page 452, line 1
To ifo ai le mavaega a fafine,
Tu'u le oloa i le taumuli o le vaa, ne'i e tepa lava i tua ai, a sei tu lauoneone i Fiti.
Ona alu ifo lea o le tamaloa, a folau; a mavae ma lona tinā, ua ita. [Page 452, line 5
Ona alu lea o le folauga a le tamaloa,
A e tevá lona tinā i le motu i Savaii.
Ona alu ifo lea a uila mai i Avalua, taatia mai lava Lepata, e le'i lilo.

Ona alo ai lea i uta i Sataelea,
Ona alu ifo lea o le tamaloa ma le oloa, ua alu i Fiti,
Ua tu'umavaega, ua tepa i tua, ua pa'u ai lana oloa.
[Page 452, line 10
Ona alu ai lava lea, ua alu i Fiti, ua logologo i, ai, ua pa'u la'u oloa i tai, o ifo ni e sailia lau oloa.
Ua o ifo, saili saili, ua le maua.
Alu ifo le tamaloa tautai na fāi faga ;
Na maua le oloa i le faga [Page 452, line 15
Ua tumu le faga i taumafa i le i'a.
Ona av'ae ai lea o le 'au-a-mala,
Uu na o le 'au
Ua saili i ni tautai i Fiti e faia le oloa.
E le iloa e tautai o Fiti.
Ona sau lea o le sailiga a tautai i Samoa nei. [Page 452, line 19
" Ua atoa le faga i Laua," i le alu atu o Aloalo-o-le-La.
[Page 452, line 20
O le uso le la, o Utu, ma La'ulu, ma Aulotoloto, ma Aumamao, ma Aupa'upa'u, ma lo latou tua-fafine o Sina
O le uso lea ua uma atu i Fiti, na faia le oloa,
Uu uma ona olo o le pa.
Ua fau e Unu, a e matamata le Imoa.
Ua alu, ua logologo ia 'ava'ava, O le pa ua fau sala.
[Page 452, line 25
Alu 'ava'ava logologo ia tavatava,
Tavatava, le pa ua fau sala.
Alu tavatava logologo ia atu,
Atu, le pa ua fau sala,
Fufui le pa e Unu ; e le'i aina.
Ona tu'u ane lea o le pa, fau e La'ulu ;
Tepa a'e le imoa, ua fau sala le pa. ,, ,, ,, 30
Alu le imoa e logologo ia 'ava'ava,
'Ava'ava, le pa ua fau sala.
Alu a'va'ava, logologo ia tavatava,
Tavatava, le pa ua fau sala.
Alu tavatava logologo ia atu,
Atu, le pa ua fau sala,
Fufui le pa e La'ulu, e le'i aina ,, ,, ,, 35
Ona tu'u ane lea o le pa, fau e Aulotoloto ;
Tepa a'e le imoa, ua fau sala le pa.
Alu le imoa e logologo ia 'ava'ava,
'Ava'ava, le pa ua fau sala.
Alu 'ava'ava logologo ia tavatava,
Tavatava, le pa ua fau sala.
Alu tavatava logologo ia atu.
Fufui le pa e Aulotoloto, e le'i aina, ,, ,, ,, 40
Ona tu'u ane lea o le pa, fau e Aumamao ;
Tepa a'e le imoa ua fau sala le pa.

Alu le imoa e logologo ia ʻavaʻava,
ʻAvaʻava, le pa ua fau sala.
Alu ʻavaʻava, logologo ia tavatava,
Tavatava, le pa ua fau sala.
Alu tavatava, logologo ia atu. [Page 453, line 1
Fufui le pa e Aumamao, e leʻi aiua.
Ona tuʻu ane lea o le pa, fau e Aupaʻupaʻu.
Sina, ole a aʻu fausia le pa.
Io, ina alu, ina taele;
Lavalava ma lou ʻieʻie; „ „ „ 5
Tapena ma mea o i le fale, ia uma i fafo. „ „ „ 5
Avane le fala e nofo ai; fau ai le pa.
Vaai ifo le imoa, ua autonu le pa.
Ona alu lea o le imoa e logologo ia ʻavaʻava,
ʻAvaʻava, le pa ua autonu.
Alu ʻavaʻava, logologo ia tavatava,
Tavatava, le pa ua autonu. „ „ „ 10
Alu tavatava, logologo ia atu,
Atu, le pa ua autonu.
Ona sauni lea o le vaʻa a le tama;
A alu, e fufui i le pa.
Ona manuia lea o le pa,
Ua gogoto vaʻa i atu.
Alu atu le logologo,
O le a sasala le pa,
ʻAʻau i Samoa. „ „ „ 15
Faʻafiti aʻe i Fiti, ua motu.
Ona fai ai lea o le mavaega nai Fiti,
A o moni ona motu o le pa, tou sao i Samoa.
A outou momotu le pa, tou te le au i Samoa.
Ona sau lea o le vaʻa;
Ona toilalo lava lea o le vaʻa i le vasa.
Ua feausi le uso; „ „ „ 20
O ia Unu le pa; feausi, feausi, feausi, ua oti, a e tuʻu mai le pa.
O ia Laʻulu le pa; feausi, feausi, feausi, mole Laʻulu tuʻu mai le pa ia Auloloto.
O ia Auloloto le pa, feausi, feausi, feausi, mole Auloloto, tuʻu mai le pa ia Aumamao [Page 453, line 25
O ia Aumamoa le pa, feausi, feausi, feausi, mole Aumamao, tuʻu mai le pa ia Aupaʻupaʻu.
O ia Aupaʻupaʻu le pa, feausi, feausi, feausi, mole Aupaʻupaʻu, tuʻu mai le pa ia Sina;
Sina! o le pa.
Ona to ai lea o Sina i le itu gagaifo o Savaii.
Ona alu ai lea, nofo i le tamaloa o Iʻumagamū [Page 453, line 30
Ua nofo ai lava ma le pa.
Ona nofonofo lea o le fafine, ua to i le tamaloa.
Ona lafoaiina lea o le fafine,

A e te'a a'e i uta.
O le a'ai tuloto i uta,
Ona alu ai lea o le fafine;
Ua nofo ai Afia, au nofo ai le fafine
Ona fanau ai lea o le tama tane,
Ona igoa ai lea ia I'umagatunu. [Page 453, line 35
Ua tupu le tama, ua matua;
Ona alu ifo lea o aumoega a le tama,
I le fale o le aualuma, e i le fale o I'umagamū.
Ona laga mai lea o le alafaga I'umagamū:
Soufuna, fafagu ane o outou ta'a, matou te alo.
E le mafafai nu'u matutua, e mumusu; ,, ,, ,, 40
Na o le tama itiiti, ua ofo atu, tatou te alo.
Ona alu ifo lea o le tama,
Ua nofo i le iato taumuli.
Ua le aina pa i tua;
A ua vili mai lava atu i le pa a le tama a I'umagatunu.
[Page 453, line 45
Fai atu lea a le tamaloa a I'umagamū,
Sau le tama, e te foemulia lo tatou va'a.
E le mafai le tama.
Ona alu a'e lava lea o le alafaga atu, ua asa. [Page 454, line 1
Ua toe usu a'e le tama i uta i lona tinā ma le pa, au fai a'e,
Funa, Sina, na fai ane I'umagamu, matou te alo.
Ona fai ane lea o Sina,
Io, ua lelei.
Ona fai ane lea o Sina,
A toe fai ane le tamaloa ia I'umagamu, e alu ane, tou te alo;
[Page 454, line 5
Io pea ia le pa a le tamaloa, a e tala lau pa.
Ona alu ifo lea o le aumoega, ona toe fafagu mai lea o I'umagamū,
Ni ta'a teine latou te alo.
Ona mumusu fo'i lea o le nu'u matutua;
A e alu atu fo'i le tama ua nofo i le iato taumuli. [Page 454, line 10
A o tata'a lava pa a le tamaloa a I'umagatunu;
E le aina lava le pa,
A e sili mai i le mea e nofo ai le tama.
Ona fai atu lea o le tamaloa,
Sole, sau ia, se'i foemulia le va'a; na tonu se atu e tali ai lelā.
Ona alu ane lea o le tama e foemuli;
Ua tata'i lana pa, o le au-a-mala.
Ona aina lava lea o le pa a le tama,
Ua gogoto va'a.
Ona alu a'e ai lea, ua tata'i va'a i uta;
O lona alu a'e lava lea,
Ua fai ai le manatu a le tamaloa a I'umagamū
Ua teu le amoga atu e ave i lona aiga. [Page 454, line 15
Ua na va'ai ifo lea, ua fotu ma le amoga i'a.

Ona pule ifo lea o Afia i le tamaloa ia I'umagamū:
Funa e, ona tusaga ua sau ia I'umagamū, ua momoli mai i lau tama; sau ia, ina alu ia ma lau tama; ne'i galo mai Afia i lona vao. [Page 454, line 20
Ona o ifo ai lea o le tama ma lona tinā ia I'umagamū ua nofo ai foi le tinā.
A e fa'ata'amilo I'umagatunu ma le pa; ua so'o lava Salafai i tautu'u i uta atu.
Ona te'a mai lea a Upolu.
Fua mai i le Mulifanua; [Page 454, line 25
Ala mai i le itu alofi, o le a fa'ata'amilo ia Upolu.
Ona pa'ia lea e le tama o le ava i Tofanā.
Ona motusia lea o le pa i le sapatu.
Ona fai ai lea o le fono a malautea i le ava, i le ava i Tofanā. [Page 454, line 30
Ona su'e lea o le pa e i'a uma o le sami
Tauateatea lava Malautea, a ua ave e le sapatu.
Se'i asi atu sapatu moe ese, po o i ai le pa.
Ona asi foi lea o i ai.
Ona au mai lea o le pa. ,, ,, ,, 33
Ua au mai ia I'umagatunu le pa,
O i ai le tamaloa nai Tāpaga.
Ona alu foi lea o le tamaloa o I'umagatunu; ,, ,, ,, 35
Ua fai lana mavaega nai Tāpaga,
E'e ia le pa ne'i motusia.
Ona alu a'e lea i le Mataleipata,
Ua e'e ai le pa.
Ua ia maua ifo le itu tuafanua o Falealili i le pa.
O le a tu'umavaega foi.
Ua tala le pa.
Ona ia maua lea o le ava i tua, o Matapalapala, fa'afuala ma figota e lua, o le Matapoto ma le Tagia'a. [Page 454, line 40
Ona motusia lea o le pa.
Ua tagia'aina,
Ua motu ai le pa,
Lelā lava le i Matapalapala
Le au-a-mala.

3.—THE NUMERALS IN THE ETRUSCAN LANGUAGE.

By John Fraser, B.A., LL.D., Secretary of the Section.

The Etruscans are still the unsolved problem of Ethnology. Who they were; when, how, and whence they came into Italy; to what family of mankind they belonged, are questions to which no one has been able to give an answer such as to secure general assent. And yet the subject is of deep interest; for, in the confederacy of the Etruscan States, there existed a high civilisation a thousand years, it may be, before our era, certainly long before Rome was founded; the Romans themselves were indebted to the Etruscans for the models of their religious observances, social institutions, government, and laws; two of the Kings of Rome, the Tarquins, were of Etruscan origin; the story of 'Lars Porsena of Clusium' is one of the choicest legends in the early Roman annals; many of the high Etruscan families* passed into the Roman peerage after their country was conquered by the Romans; and, even in our own times, the discovery of the rock-hewn tombs of the Etruscan chiefs, so sumptuously furnished, and so magnificently adorned with vessels of gold, silver, and bronze, and so enriched with jewels—all this has given to the Etruscan name a romantic attractiveness which makes us eager to know who they were, and how they came to be a great and wealthy people at so early a period, when most of the rest of Europe must have been only in its first stages of civilisation. Many modern writers have tried to throw light on the Etruscan mystery; but it is no disparagement to their learned labours to say, that, although a few well ascertained portions of the truth are now known, yet the whole truth is nearly as far from our grasp as ever. Among the best of these writers are the late Dr. Donaldson, Lord Lindsay, Dr. Isaac Taylor, Mr. Ellis, Dr. W. Corssen, Dr. W. Deecke, and Professor Campbell of Montreal, besides several French and Italian *savants*. The majority of these claim the Etruscans for some one or other branch of the Aryan family, but a few make them Turanians. No one thinks that they were Shemites. To almost every ancient branch of the great Aryan family has been ascribed the honour of the parentage of the Etruscans; but it is obvious that only those nations can compete for that honour, which were located in Europe early enough to cast themselves, or a portion of themselves, into Northern Italy. The Greek and Roman chroniclers had a tale that the Etruscans came by sea from Lydia to Italy under the leadership of one of their chiefs, Tyrrhenus; but that is not history.

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* *cf.* "Maecenas, atavis edite regibus."

They must have descended into Italy from Central Europe through the passes of the Alps, and this is expressly stated by the historian, Dionysius of Halicarnassus, who had his information from the best Roman sources. Hence, one theory maintains that they were of German or Gothic origin; but it would be hard to prove that Germanic tribes were in these parts at so early a time. It is well known, however, that Kelts were in Europe, and in Northern Italy too, at the dawn of European history; if they were not its earliest occupants, at least they came next after the Iberians. To-day, therefore, I wish to show, by an examination of their numerals, that the Etruscans, so far as their language is concerned, *may* have belonged to the Keltic nation, and to the Insular* branch of it.

Philology is one of the helps to Ethnology. It is true that, by itself, it does not disclose the origin of the nations, but it tends to develope research in a right direction; it serves as a finger-post to point out the way which leads to a safe issue. It is in this sense that I now proceed to examine the Numerals of the Etruscans, as these are found in the mortuary inscriptions on the Etruscan tombs; and, in an inquiry of so great difficulty as is the origin of this interesting people, even a small contribution may be considered worth accepting.

I. Now, the numerals of a people do not change in principle; the forms of the words, as happens in the case of the pronouns, do change, but their inner mechanism remains always the same. Let us then look at the Etruscan numerals. In the most of the inscriptions these are expressed by Roman letters, as, *e.g.*, AVILS LXX LUPU, but in several of them the numbers are, fortunately, written in words in full. For example:—

		PAGE.
LUPU AVILS ESALS	Corssen,	556, 654
AVILS HUTHS MUVALCHLS LUPU ...	„	808, 662
AVILS HUTHS CELCHLS	„	661
AVILS HUTHS LUPU	„	661
AVILS MACHS MEALCHLS	„	660
AVILS MACHS SESPHALCHLS LUPU ...	„	689, 703
AVILS THUNS	„	554
AVILS THUNS SI MUVALCHLS LUPU...	„	552
AVILS XX TIURS SAS	„	701
LUPU AVILS MACHS ZATHRMS... ...	„	657, 660
AVILS CIS MUVALCHLS	„	800
AVILS CIS CEALCHLS	„	800
AVILS SI	„	676
AVILS SAS AMCE UPLES...	„	700, 812
ZILCHNCE AVIL SI	„	556

* I make three divisions of the Keltic languages:—(1) Insular Keltic (abbreviated into I.-K.), to include the language of Ireland, the Isle of Man, and the Highlands and Islands of Scotland; (2) Cymric (=C.), the language of Wales, Cornwall, and Brittany; and (3) Gallo-Keltic (=G.-K.), such remains as we have of the language of the Continental Kelts. Keltic, when used in a general sense, will be represented by the letter K.

In all these words I shall assume that the final *s* is inflexional, and will, therefore, leave it out of consideration.

II. Corssen, in his large and learned work (*ü. d. Sprache der Etrusker*), is of opinion that, in these inscriptions, the word AVILS must be a Roman proper name, Avilius, and LUPU must mean sculptor; but all the other Etruscologists are agreed that these are mortuary words, and that their meaning is "age" and "died," AVIL = "age," LUPU = "died." To these I add another mortuary word, ril, which by common consent means "year." Thus the inscription, AVILS LXX RIL LUPU, would mean "he died in the seventieth year of his age," or, "he died aged seventy years," for it is not certain whether AVILS is a noun or an adjective. If we remember that the lines given above are portions of the inscriptions on the tombs, and if we look at the words themselves and the way in which they are combined with LUPU and AVILS, we can scarcely doubt that they are numerals. I shall therefore try, in the following pages, to prove that they are indeed numbers, and that they are capable of explanation if we refer them to the Keltic language.

III. Among the oldest numerals to be found anywhere in the history of languages are those of the Hebrews, and there the digits (2 to 10) are substantives with an abstract meaning and use, like the Greek pentas, &c;* they are also used adverbially, like the Gr. dis and tris. Now, in the I.-K. branch of the Keltic languages, the abstract substantives have usually the termination ad or adh, which is the same as in the S. daçat, vimçat, and as in the Gr. pentas, pent*ad*-os, duas, du*ad*-os, &c.; the ordinal numbers are formed from the cardinal by adding to them the adjective termination -amh, pronounced av when aspirated, otherwise equivalent to -am, -im, -om; but the Irish dialect, to form the ordinal, joins on the -adh to the adjective termination -amh; *e.g.*, G. ochd, "eight," ochd-amh, "eighth," but Irish ochd-amh-adh, "eighth." Both of these modes exist in Greek and Latin, for to the G. in -amh correspond the Latin primus (=pri-im-us), sept-im-us, oct-āv-us (av = -amh), and the Gr. hebd-om-os, ogdoos (=ogd-oϜ-os); while to the Irish form correspond the Gr. trit-at-os, and hebd-om-at-os, which forms are found in Homer; similar are the Gr. numerals hebd-om-ēkonta (as if hebd-omā-konta, for hebd-omad-konta), ogdo-ē-konta, where the number itself is cardinal, but the inner part of it is ordinal. Nevertheless, the Ir. does not invariably use both forms at once; for, while ceathr-amh-adh is "fourth," yet cuige-adh is "fifth,"

* I shall use the following abbreviations :—Gr. = Greek, L. = Latin, S. = Sanskrit, Z. = Zend, Ger. = German, K. = Keltic, I.-K. = Insular Keltic, including Gadhelic, Irish or Erse, and Manx, G. = Gadhelic, Ir. = Irish, E. = English, Fr. = French, H. = Hebrew, Goth. = Gothic, Etr. = Etruscan, Sl. = Slavonic, Ar. = Arabic, Dr. = Dravidian, C. = Cymric.

and ceud-adh is "hundredth;" neither does the G. always use -amh; for, while ochd-amh is "eighth," yet cuige-adh is "fifth" Then again, these forms in -adh appear also in the Lat. and Gr. cardinals; for the L. quadrāginta is for quadr*ad*ginta, and the Gr. triākonta for tri*ad*konta; so likewise quinquāginta, &c., triākosioi, &c. Moreover, the I.-K., to express the numerals, makes use of other forms of abstract substantives (*vide* Zeuss, *Gram. Celt.*), such as oin-ar, neut. oin-de, "one," di-as, neut. de-de, "two" (*cf.* G. deise, "a pair)," &c.

From the investigation in this paragraph I gather the following Results :—

1. The syllable -ad (=adh) is used as the K. formative for cardinal numbers, and -am (=amh) for the ordinal.
2. The syllables -ad, -am, and, in combination, -amad, are used indiscriminately for the ordinals.
3. Some "tens," as Gr. hebdomēkonta, are expressed by -amad.

IV. Is there in the Etruscan inscriptions anything analogous to these modes of forming numerals? Yes; for, in my opinion, the word SESPHALCHL is equivalent to SEIS-AMH-AD-D-CH-AD, of which seisamhad is entirely an I.-K word now in use, meaning "sixth," and d-ch-ad (=the Etr. l-ch-l) is deichad, also a Gadhelic word, the number "ten" (Gr. dekad-), from the G. deich, "ten." Deichad becomes l-ch-l by the simple change of the dental d into the dental-liquid l, as in the L. delicare for dedicare, lingua for dingua—a change not at all surprising since the Etruscan Alphabet had not the medials b, g, d; and any one who has read Etruscan inscriptions will have observed how frequently the letter l occurs in the words there. This substitution of l for d in the number "ten" is found also in the German numerals ei-lf, zwö-lf, in the Lithuanian dwy-lika, try-lika, in the Goth. ain-lif, twa-lif, and in the Lapp lokke. Thus, the words seisamhad and deichad, each of them an abstract substantive, (*cf.* L. quadrāgintā, &c.), would easily become, according to the pronunciation in use among the Etruscans, Sesph-al-lech-al, and then Sesph-al-l-ch-l, and would mean "sixty," by Result 3 of the preceding paragraph. In the same manner I find MUVALCHL of the inscriptions to mean "twenty" (assuming for the present that ma or mu means "two"); for, if written in full in Keltic, it would be mu-amh-ad-deich-ad (-amh=-av, as in the L. oct-av-us), abbreviated into mu-av-al-l-ch-l, muv-al-l-ch-l; similarly I take MEALCHL and CEALCHL to be shortened forms for me-ad-deich-ad, and ce-ad-deich-ad. In the Etr. word MUVALCHL, I suppose muv to be an adjective form for ma-amh (=ma-av or mu-av), and on the analogy of the Gr.

h e b d o m ē k o n t a (adj. form + konta), MUVALCHL would mean some one of the tens, say, "twenty;" the Etruscan word MEALCHL,—the m e-a l (for m e-a d) not having an adj. form,—would then mean "twelve" (*cf.* Ger. z w ö-l f and z w a n-z i g.).*

This view of the formation and meaning of MUVALCHL is corroborated by what we find in the Dravidian numerals; in them e i m-b a d u, e i v-a t t u is 50, and e i n-n û r u is 500; and Dr. Caldwell tells us that the e i n or e i m is an adjective increment = a n or a m. It corresponds with the I.-K. adjective termination a m, as above. The Dravidian word for "five" is e i, e i-d u (see par. IX.); and so these two forms for "fifty" might be written e i-a m b-a d-u and e i-a m h-a d d-u (m h = v); they would thus present a striking parallel to the K. formations in -a m-a d.

This analogy of mechanism in the formation of the Etruscan and the Keltic numerals seems to confirm my view of their common origin, and will justify me in proceeding now to consider the Etruscan digits separately. Let us see how they arrange themselves.

V. In my opinion, the ESAL of the inscriptions means "first," and is the ordinal form of the number "one." In many languages, as Bopp has shown ("*Verg. Gram.*"), the number "one" is expressed by the pronoun of the third person. Now, that pronoun in G. is e s a (S. stem s a, "he"), from which I form regularly, by Result 2, a G. abstract substantive e s a-a d, Etr. ESAL (long ā), whence L. s ō l-u s (long ō), s ō l-e n n i s; and from the stem e s a, by dropping the e, the L. s i m-p l e x, s i n-g u l i, and the Gr. h a-p a x, h a-p l o o s (*cf.* S. s a-k r i t, "once").†

But, in the Aryan languages, the cardinal "one" comes from a root different from that of its ordinal (*cf.* S. ê k a, "one," but p r a t h a m a s, "first;" Gr. h e i s, h e n, "one," but p r ō t o s, "first," &c.); thus the Etr. word HUTH seems to me to be the G. u a t h, "solitary, alone, single," which, by the mere change of the dental d (= t or t h) into its dental-liquid n, gives the L. u n-u s, "one." The Etr. HUTH is thus to me "the number one" (*cf.* the Gr. m o n a s), and this G. word u a t h is formed in the usual way (see Result 1) from a root u or h u. It is true that the G. u a t h is at this hour obsolete; but, nevertheless, it still exists in its derived noun o t h a-i s g (o-t h a for o-a t h), "a

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* Corssen and others read SEMPHALCHL in the inscriptions, and not SESPHALCHL, the Etruscan alphabet characters for m and s being very much alike; but this difference of reading will not affect my argument, for the Irish even now sometimes omit the s in their word for "sixth."

† In this connection it is curious to note that, of eighteen Malayan, Papuan, and Micronesian words to mean "one," given by Wallace in his "Australasia," ten are either the simple word s a or a longer form of it; one of them is e s s a and another s a l i. I have no means of getting to know if this word s a is connected with a personal pronoun meaning "he." The Polynesian words for "one" are t a or k a with the suffix s i or k i; the k a is the same as the S. e k a, "one."

sheep 'one' year old," and, in the forms oth-ath, uath-ath, Zeuss found it in the old Irish MSS. which he examined (*vide* Zeuss, *Gram. Celt.*); uaig-neas also (for uaith-), "loneliness," is still a good G. word. The modern G. word for "one" is aon, pronounced ūn, in which, as I think, the a represents the root u or hu, and this root shows itself clearly in the Z. ha-keret, "once," and the o.h. Ger. ha-ihs, ha-ufs, and is itself a form of the S. sa, "he," êka, "one."

So far as I know, the root u or hu does not exist in the Keltic as a pronoun, but the Teutonic languages have it in the forms hua, hu, ho, E. "he," and the H. has hua (fem. hia) as the pronoun of the third person, of which suffix forms are o, "his," ho, "him;" with these correspond the demonstrative Greek ho, "the," hos, "this, he," hou, "of him," he, "him," and also the old pronoun his or is, hi or i, L. is, is-te, i-dem, G. i or si, "she," e or se, "he," and the L. reflex su-i, su-us, se. Other facts show the intimate connection between the third personal pronoun and the numeral "one;" for the S. êka is "one;" in H. it is echâdh, fem. āchāth, "one;" in old G., chiad, "one," now found in ceud-amh, "first," and in ceud-na, "the same, also" (*cf.* idem and item); but the S. êka, "one," also brings us to the L. hic, "this," sic, "so." Again, the Z. form aêva, "one," is the same word as the S. êva, "also, only," êvam, "so," and the G. amhain, "only," Gr. monos "alone," onos (for Ϝonos), the number "one" on dice, Sl. on, "that." The Sanskrit defective pronoun êna, ênam, "this," is the same as the Gr. heis (for hens), hen, "one," and the Ger. ein, einer. The old G. uath, "one, alone," I take to be the same word as the Gr. autos, "he;" for, in the Homeric expression autos per eōn, it is used in the sense of "alone;" and with autos correspond in form the G. ud, "that," L. id, S. tad.

I thus arrange the words quoted in this paragraph:—roots, (1) hu, ho, hua, hia; (2) esa; (3) êka; (4) aêva; (5) êna(m); —derived from (1) hu, &c., are *G.* u-ath; *Etr.* hu-th, *L.* u-n-us; *Gr.* ho, hos, his, is, hi, i; *L.* is, ea; su-i, su-us; *G.* i, si, e, se; derived from (2) esa are the *Etr.* esāl; *L.* sōl-us, sōl-ennis; sim-plex, sin-guli; *Gr.* ha-pax, ha-ploos; *Goth.* ha-ifs, ha-ufs; derived from (3) êka are *H.* ech-adh, ach-ath; *G.* chi-ad, ceud-amh, ceud-na; *L.* sic, hic; derived from (4) aêva are *S.* êva, êvam; *G.* a-mhain; *Gr.* mon-os, Ϝon-os; *Sl.* on; derived from (5) êna are *Gr.* heis, hen, *Ger.* ein, einer; derived from u-ath (a-uth) are *Gr.* aut-os; *G.* ud; *L.* id.

VI. In my opinion, the Etr. MACH means "two." The theme of this word is the S. dva, Gothic tva, "two." The most of the other Aryan languages have retained the dental d, but the

Etruscans, not having this letter, have rejected the d of dva and retained the next letter, the labial v, which is equivalent to bh, b, m; thus the root-word dva may become either (1) bha, or (2) ba, or (3) ma; and all these forms occur; for, (1) S. ubha, Gr. ampho, L. ambo mean "both;"* (2) in Gothic bai, and in German bei-de, mean "both;" in Hindustani ba-rah is "twelve"; and in L. also bis, bi-ni, bi-dens, bi-farius, &c., have the b only; in the dialects of the Australian aborigines, the word bula is almost universally used for "two," and I consider the bu there to be a surviving proof of their connection with the rest of mankind; (3) the form ma I recognise in the Gr. words mak-kor, mad-ibos, mak-ella (*vide* Hesychius), "a mattock with 'two' teeth;" and perhaps in the Gr. machē, "a fight, a battle," when it is compared with the L. bellum for duellum; three of these words have the k, ch, of the Etr. mach, and the other has d; for, while (by Result 1) ma-ad or ma-adh would be the usual form for the number "two," yet the I.-K. often changes dh into gh; besides this, the guttural remains in the Gr. dicha, "in two," and in the L. big-ni, which Festus says means "twin;" and I think that the H. she-ba (g), "seven," (see par. XI.) also contains this numeral. To account for the form ma instead of ba, we must remember that on Oriental lips the b and the m are sounded almost alike, and, as the Etruscan alphabet had no b, the nearest labial m was adopted.

I believe, moreover, that the original idea hidden in the syllable ma is that of repetition, as in the H. shenāim, fem. shetāim, "two," from the verb shânâh, "to bend, fold, change, repeat;" ma would thus give us the G. muth (for ma-adh), "a change," "an alteration," and the L. muto, "I change;" perhaps also the L. mov-eo, "I move," and the Gr. ameibo, "I change, exchange;" the L. vix, vicis, (for mhiks), from the same root, also has the guttural of the Etr. mach. The same idea of "change," "repetition," shows itself in the L. alter, "second," "the other of "two" (alterplex = duplex, says Festus), Fr. alterer, "to change," E. "alter," which are congeners to G. eile, "another," L. alius, and to the I.-K. aile, ala, "second" (*vide* Zeuss, *Gram. Celt.*, II.-3); and, lastly, the same idea is found in the I.-K. tanise, "second" (Zeuss, *ibid.*), which, in my view, is the Etr. THUNS, "second." Words of the same root-origin as THUNS are the modern G. tionnd-adh, "to turn, come back," and tiunn-al, "a match, likeness." Festus says that paribus equis = duobus equis; it is therefore possible that the pa in the L. word par, "equal, a

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* The word ubha, ampho, is probably equivalent to gam-dva, "all two," which, like the Fr. tous deux, would mean "both;" gam = S. sam, "all" = L. cum = L. om-nis. As in Etruscan, so in Sanskrit, the d of S. dva, dvi, is rejected and the v retained in the S. vim-çat, "twenty."

match," and in the E. pair, represents the root ba, meaning "two."

I thus arrange the words quoted in this paragraph :—roots—(1) dva, (2) d-bha, (3) ba, (4) ma ; derived from (1) dva are *L.* and *Gr.* duo, and all the other words with initial d ; derived from (2) bha are *S.* ubha; *Gr.* ampho; *L.* ambo; derived from (3) ba are Goth. bai; *Ger.* bei-de; *Hind.* ba-rah; *L.* bis, bi-ni for bigni, bi-dens, &c.; *Austr.* bu-la; *H.* (she)-bag; *L.* pa-r; *E.* pa-ir; derived from (4) ma are *Gr.* mak-kor, &c., mach-ē; *Etr.* mach; *G.* (ma-ath) muth; *L.* muto; *L.* vic-is; and perhaps, L. mov-eo; *Gr.* a-meib-o.

VII. The Etruscan word TIUR in the inscriptions is, in my opinion, the numeral "three;" at all events it very much resembles the Aryan tri; the G. abstract number for "three" is triur, which is sufficiently like tiur, especially as the Etruscans sometimes dropped the letter r after t, as in their word Cluthumus*tha* for Clutaimnes*tra*. Other I.-K. forms for "three" are tri, teoir, teora, of which the last two also are very like tiur.

VIII. The Aryan number for "four" is made up of "one" and "three" (*cf.* Bopp, *l.c.*). Thus, the S. chatur, "four," consists of cha, chat, from S. êka, "one" (H. āchāth, echâdh), and tur, for tri, "three;" the L. quat-tuor has its nearest analogue in the G. cei-thir, "four," = I.-K. chiad, "one," and I-K. teoir, "three." For these reasons I consider the Etruscan word zathrm, in these inscriptions, to be a contracted form of zalthram, an adjective form meaning "fourth" (by Result 2), the body of the word being ZAL for ESAL, "one" (*ut supra*), and thr, "three," with the adjective termination am added.

Under this head I may be allowed to introduce a reference to our own Australian aborigines and their numerals. Everywhere, from Sir John Lubbock down to the commonest scribbler in a daily newspaper, it is quoted as a proof of their degradation that they count no higher than one, two, three. Suppose that an examination of the numerals of the Aryans, the most civilised of all the families of mankind, should prove that they too count no higher than three, and for four say one-three, and for five say hand, and so on; while they are permitted, unchallenged, to say one-three, is it to be urged against our Australians as a proof of their savagedom that they say two-two, for four? If they are still to be talked of as among the very lowest of savage tribes, other proofs than their numerals should be given; for, in many of the most ancient religions, three was a sacred and perfect number, a *ne plus ultra*; and I believe that a careful inquiry

quiry into the numeral systems now in use, will show that these are founded on separate words for one, two, three, and no more, and that the words for four and the higher numbers are in fact, however much changed now, only combinations of these with one another, and with words for hand, and, &c.

IX. The number "five" presents some difficulty. In many languages it is the word for "hand," as Lepsius, Pictet, and others have indicated. In most of the Malayan, Papuan, and Polynesian dialects of Oceania, lima, "hand," is likewise the word for "five." Now, although I do not assert that there is any direct connection between the Keltic languages and the Oceanic except a common ancestral origin, yet lima, "five," is very like the I.-K. word lamh (lam), the "hand," = that which "takes," "the taker, holder," and this word I connect with the Gr. lambano, "I take," through the root gam. The Scotch word hadd, "to hold," is of the same origin as the E. "hand." Some writers connect the S. panchan, "five," with the S. pâni, "hand," and say that the pan is for pam, as in the Aeolic Gr. pempe, "five," and the Goth. fimf, "five," C. pump, and that the pa itself is ka, kam, as in the L. quin-que. I have no doubt that this root ka, or kam, is the same as the root gam found in many languages in the sense of to "take," and in I.-K. in the form of gabh (=gamh), from which I derive G. lamh, the "hand," as "the taker." The change of g into l is certainly uncommon; but the Gr. mogis and molis are the same word, and the Australian and Polynesian languages often change g into l; the proper name Lav-erna, "the goddess of robbers," finds no derivation in Latin, but it becomes significant when we trace the Lav to the Keltic root gabh, pronounced gav, "to take, to seize;" and, further, the Gr. word lē-is, "booty," for lē(v)i(d)s, is to me the same word as the G. ga-bh-aid, now contracted into gāid, "to steal." The change of g into l comes through the intervention of d; thus g = d = l. That the idea "hand" and the idea "seize" are closely allied is seen in the S word harana, the "hand," which, as an adjective, means "taking, seizing," and its S. root har-y is for hri, originally bhri, "to take." Again, the Gr. word cheir, the "hand," although Curtius gives a different derivation for it, seems to me to come from the same root gabh; for ga-bh-air, with the bh silent as is usual in such a position, closely approximates to cheir. Be that as it may, the Gr. pux, pug-me, the "fist," is the same word as the G.-Ir. kaog, koig, kuig, (p for k), "five," and this word kaog, as I think, ought to be assimilated to lamh, the "hand," by writing it ka-mh-ag or ka-bh-ag (bh, mh silent), so as to show its relation to the verb gabh, which gives also the L. cap-io, "to take, to seize." Kuig becomes L. quinque by giving to g the nasal sound, and this sound comes clearly out in the Fr. poing, the "fist." I think therefore that quinque, is a descriptive word; for, when we were boys at school and wished to communicate the time up or down the form, we extended the arm and then closed and opened the poing, each operation counting five minutes; and, in the same way, our Australian natives count, by extending the fingers of the hand. The L. cunct-us, "the whole," may be the same word as koig "five."

I have already said that the m is an essential letter in the Aryan numeral "five," as it is in kamh, pronounced kav; now the position of z in the Etruscan alphabet between the digamma and the aspirate h, and the fact that v, s, and z are spirants, show us that these letters are closely allied; hence I say that kav may become kaz, and, with the vowel weakened, the Etr. CEZ, CIS, CI, "five," just as the G. triamh becomes treas.

If additional proof be required in support of my view of the derivation of the numeral "five," I may cite the Dravidian languages of India, and the Scythic languages of Europe. The original root of "five" is, as I have said, gam, "to seize, lay hold of," from which nouns are formed to mean "hand," and hence "five." From this root the S. has çama, the "hand," where the ç represents an earlier k or g, the g of the root; and from the same root the H.-Ar. has châmĕsh, kams, "five;" the added s here is important and occurs in Sanskrit too; for, from another root-word, gam, "to say, to speak," the S. has çams, "to say," çamsa, "praise, speech." Now, this çams may be softened into ças, just as the S. yam becomes yams, and then yas; (*cf.* the root gam, "to leap," which gives the S. ças and çaç.) In the Dravidian languages, y often takes the place of the m of these root-words; for instance, the S. kâma, "desire," is from the same root as the Dr. kây, "to be hot, to burn," and from a root gam, "to lean towards," the Dr. has sây; hence our root gam, "to seize," gives the Dr. kei, the "hand," and, in the Telugu dialect, cheyi, which is a nearer approach to the root form. Other forms of this word for "hand," cognate to the Dravidian, are the Hungarian kêz (for kams, kas, as above), and the Permian ki; these forms bring us very near to the Etruscan cez, cis and ci, "hand, five;" through the intervention of ms.

The cardinal number "five," in some of the Dravidian dialects, is aydu, eidu, eindu. I take ay-du to be for kay-du, by dropping the initial k, as is commonly done, and this kay comes from our root gam. Dr. Caldwell himself says, that the ei may be for kei, "hand," and that the numeral adjective is ei or ê in all the dialects, in some ein or eim; an abstract noun from the root is eimei (eim=keim, from gam).

I thus arrange the words quoted in this paragraph :—roots—(1) gab (gabh), =(2) gam (gamh) = (3) kam (kamh) = (4) kav; derived from (1) gabh are *G.* (ga-bh-air) = *Gr.* cheir; derived from (2) gamh are *G.* lamh; *Poly.* lima; *L. proper n.* Lav-erna; *Gr.* (lēv-ids) lē-is; derived from (3) kam are *Gr.* pem-pe (p for k); *Goth.* fim-f; C. pum-p; *S.* pan-cha (pan for pam); *G.* (ka-m h-ag) kaog, koig, ku-ig; *Gr.* pug-me; *Fr.* poing; *L.* quinque (for kuig = kuing), cunctus; derived from (4) kav, kavs (=kamhs), are *Etr.* cez, cis, ci.

X. There is considerable uniformity in the Aryan words for "six;" *e.g.*, S. shash, old Sl. shesty, Goth. saihs, Gr. hex, L. sex, I.-K. se, sia; and to these I may add H. shēsh. I have never been able to satisfy myself as to the composition of this word; for that it is a compound word I do not doubt, as are also all the numerals beyond five. The k in sex, hex, I consider to be radical to all, and this guttural is softened into h in saihs. We should bear in mind that numerals, from their frequent use in daily life, must have been, in the early stages of language, subject to great mutilation; the numeral sex I therefore take to be a shortened form of an original word sakas, afterwards softened into sekes, seks; but in weak languages the guttural sounds are often dropped from words, as is so commonly seen in the Polynesian dialects; and thus sakas would give the S. shash, and its corresponding forms. The G.-Ir. sia seems to be for sai, and is thus allied to the Gothic saihs.

The supposed word sakas would then be compounded of sa and kas; the kas I form in the usual way from S. êka, "one," like the Gr. trias from the root tri; by Result 1, êka or ka would give kad, kat (*cf.* S. vim-çat), kath, and from kath there is an easy transition to kas; the presence of the formative th is not a mere assumption, for it exist in the I.-K. words siath-amh and siath-adh, "sixth;" sias, seas also probably once existed in that language, like G. treas, the number "three," but it may have disappeared because there is another word seas, which means to "maintain." The G. chiad, and the H. achath, "one," are a near approach to kath, and kas. The kas would thus mean the number "one." The initial syllable sa I cannot explain, unless it be for the S copulative particle cha, "and;" the whole word sakas would then mean "and one," that is, [the first hand, five] "and a unit" [more], a mode of reckoning "six," which does exist among primitive peoples. I do not know that the S. cha, "and," ever takes the form of sa, although it is certain that the Sanskrit palatals, ch and j, are represented in other languages by sibilants; its corresponding Hebrew prefix conjunction vē, vâ, "and," (vâv = "a hook, a binding or fastening)" is the same as the Gr. digamma, and that is the original of the character S a n, used in Gr. manuscripts to mean "six." The digamma and s are interchangeable, for the L. s u i represents the Gr. pronoun Ϝ o u. The S. c h a is the Gr. k a i, "and," and the L. q u e ; possibly also the Gr. t e (which may become s e), and the L. e t are from the same root; c h a with the a transposed becomes a c h, and that is the G. a g's, contracted into a's, and the L. a c.

The G. words for six are s è, s i a, s e s e r, and these appear, as I have already shown, in the Etrus. SES-PHS. The word S'AS is also found in the Etruscan inscriptions.

XI. The Aryan words for "seven" are also uniform ; viz., S. s a p t a n, Z. h a p t a n, Gr. h e p t a, L. s e p t e m, Ger s i e b e n, I.-K. s e a c h d ; the H. is s h e b ā, and, as this ends with the letter a y i n, I would write it s h e b ā (g). The first syllable in these, s a, s e, s h e, I take to be the same as in "six," and the b a g in s h e b a g is a near approach to the Etr. MACH, "two," from the root b a (see par. VI.). The root b a would give (by Result 1) b a - a d, and the whole word would be s a - b ā d, or by transposition s a b d a, which is the S. s a p t a-n ; the b a d could also become b a n (n being the liquid for d or d h), and this would account for the Ger. s i e b e n, E. s e v e n. The I.-K. s e a c h d appears to me to be a corruption of s e-Ϝ a c h-a d, and is thus allied also to the Etr. MACH, "two," through the digamma, which equals b or m aspirated. The Aryan words for "seven" therefore are equivalent to "and (s e) two" (b a).

In the Etr. inscriptions the numeral "seven" does not seem to occur at all.

XII. Nor does eight, unless MACH ZATHRM be taken to be the Etr. for "eighth." There are two ways of expressing the number "eight," either by 6 + 2 or 2 × 4. The latter mode is common enough in language ; the French say q u a t r e v i n g t and the Kelts c e i t h i r f i c h e a d, four 20s, for "eighty ;" the S. says t r i s a p t a n, three 7s, for "twenty one," and p a n c h a s a p t a n, five 7s, for "thirty five ;" even the Papûans, in some places, say t a u r a a n i, two 4s, for "eight." On this principle the Etr. MACH ZATHR, according to my previous analysis, would mean "eight," from MACH = 2 and ZATHR = 4.

The Aryan words for "eight" are S. a s h t a n, Z. a s t a n, Goth. a h t a n, Ger. a c h t, Gr. and Lat. o k t o, I.-K. o c h d. The S. a s h t a n, must be a softened form of an original word a c h t a, and that I consider a corruption of a supposed word d v a-c h a t, two 4s, changed into Ϝ a c h t a ; the S. d v a, "two," becomes b a, v a (see par. VI.), and c h a t is the first syllable of S. c h a t u r "four," L. q u a t u o r for q u a t t u o r (see par. VIII.).

XIII. The Latin writes u n d e v i g i n t i, "one-from-twenty" for "nineteen," and the S. says e k a - u n a v i m ç a, or merely una vimça (= "one-wanting twenty") for "nineteen;" it is therefore possible that "nine" may be expressed in languages by "ten-less-one," or something similar. Now the German neun, Gothic niun, I.-K. naon, naoidh, seem to me to consist of the negative na, ne, and the numeral "one;" and the Keltic n-aoidh reminds us of the word a-uth or u-ath, from which I have taken the Etr. HUTH, "one." The S. navan, L. novem, seem to be formed from the Z. aêva, "one," with the prefixed n to represent the negative, while the Gr. ennea is for en-n-eϜa, from the same root. The Roman numeral sign IX. (= one from ten) for "nine" seems also to favour this view.

The numeral "nine" does not appear in the words of the Etruscan inscriptions.

XIV. The Etr. numeral "ten" is found only in the compound words given in paragraph IV., and is in them represented by l-ch-l. The Aryan words for "ten" I take to be equivalent to "two-five," that is, "two hands," and the numeral sign X. is only two Vs, conjoined, the lower one being inverted. Some Oceanic languages say distinctly rua lima, "two hands," for "ten." In examining the words for "five," I have endeavoured to show that they may be traced to the root kam or kav, and this root, with da, de, "two," prefixed, would give L. decem, Gr. deka(v), and the S. daçan, as well as the Goth. taihun, E. ten. The I.-K. deichad, however, comes nearest to the Etr. l-ch-l.

XV. Having now examined all the digits, I have, in conclusion, only to refer to the two dice well known to Etruscologists, the dice of Toscanella, so called because they were found there about forty years ago. These dice have not pips marked on their sides to indicate the numbers, but have words instead, viz., mach, huth, ci, sa, zal, thu. Corssen reads these words as a continuous inscription, and maintains that they are votive. But why should words be written on dice, if not to express numbers? I find them all among the digits already examined; ZAL I take to be for ZALTHR, "four," a word too long for the side of the cube; for the same reason I take THU to be for THUR or TIUR (see par. VII.), and this would agree with the tur in the S. chatur and the Oscan pe-tur.

My work is finished. I have not discussed the opinions of others, for my aim is not controversial; I have given my own views, and these have come from my own independent investigations; let them go for what they are worth.

Thursday, August 30.

The President, Mr. Alan Carroll, M.A., M.D., in the Chair.

The President delivered an Address :—"On Movements of Races from Asia to America and Australia."

Friday, August 31.

The President, Mr. Alan Carroll, M.A., M.D., in the Chair.

The following papers were read :—

1.—MAORI ART.

By Augustus Hamilton, of Napier, New Zealand.

[*Abstract.*]

The author said that in New Zealand no branch of ethnographical enquiry exceeded in interest the investigation of the vast amount of skill, time, and labour which must have been expended by the Maori on the art of wood carving and similar decoration ; and that from a careful study and collation of these carvings, he thought it might be possible to locate that land of shade—the "Hawaiki" of the exodus—the land from which long years ago, the seven historical canoes of Maori story came, laden with a warlike race. But caution was needed in drawing any conclusions from supposed coincidences in a decorative pattern or design, for one characteristic form in wooden carved work, known generally as the Greek key pattern—simply a flowing arrangement of the line form—had been common to all nations even from the very dawn of civilisation. A document of the decorative kind, worthy to be examined, was the "Moko," or face-marking, of the Maori Rangatira. Viewed from our point of view a tattooed Maori chief may be called a savage, but that is an injustice to a noble and (until spoiled by contact and association with the outcasts of European society) an industrious race. Pride of lineage and position, amongst the Maories, covered the face and some parts of the body with an accurate and well executed combination of lines and symbols, partly conventional, partly totemic ; a heraldic blazon high in the scale of abstract art. In the large edition of Cook's "Voyages" there is a sketch, drawn from nature in 1764, of a style of tattooing which is noted by Cook as "rare," and yet occasional specimens of that same pattern are seen now, after the lapse of

one hundred years, among the natives on the same part of the East Coast. Thus it may be that this people, conservative by predilection, are conservative also by force of a religious or superstitious code of moral ethics, scarcely inferior in strictness and minutenees to Aryan caste. It is almost certain that every part of the design had a definite and constant meaning, and that some parts, notably those near the ear, had all the properties of a personal totem. Among the Rangatira class there was a general consensus of idea as to the necessity of a highly complicated face pattern; hence the amount of work lavished on the face. Among the Samoan the whole figure receives equal attention, but none of their patterns can be classed with any Maori pattern. In addition to the "Moko," the Maori chief's craving for ornament showed itself in the bright colours of the feathers which he used as a head-dress on gala occasions, and in the elaborate and gay patterns worked into his mat or cloak. In Maori pictorial weaving, instead of any serious attempt at accurate proportion, the general idea of representing an ancestor was somewhat after the style of a court card essentially decorative; when the subject was mythical the treatment was decorative and artistic; when derisive or defiant, the protruded tongue appeared. This protruded tongue also forms the "spear-head" (so called) on the end of the *taiahas* or staves always carried of old by Maori orators. Another very persistent and typical form of ornament was the figure-head of a first-class war canoe. The only approach to the form of these canoe carvings was to be found at Woodlark Island, near New Guinea.

Mr. Hamilton concluded by saying—"All the points I have mentioned will, I feel sure, when properly investigated, place Maori art, in a truly decorative sense, at the head of the Art of the South Pacific."

2.—THE LAST OF THE TASMANIANS.

By the Hon. J. W. Agnew, M.D., M.L.C., Hobart.

To readers of the earlier history of Tasmania it is well-known that after disturbed relations, attended with much bloodshed on both sides, had existed for sometime between the natives and the white settlers, all that remained of the former were induced to submit themselves to Government. They were afterwards removed to Flinder's Island, a dependency of Tasmania in Bass Strait, where, although kindly treated, death became so rife, that in the course of about ten years they were reduced to one third of their original number. The new mode of life in fact was unsuited to their habits, nostalgia even came to be a factor in the mortality and children ceased to be born. The survivors, forty-five in number, were subsequently removed to Oyster Cove, a locality on the mainland, about fifteen miles south of Hobart on the shore of D'Entrecasteaux's Channel. The change did not prove beneficial, and the abnormal mortality continued to the end. Though the numbers of the natives declined thus rapidly under artificial environments, it is most probable the same decrease would have taken place had they remained at large, subject as they would have been to constant molestation of all kinds by the whites.

To induce these children of the forest by persuasion alone to submit to Government, was a task which required both tact and courage. It was successfully accomplished by Mr. Robinson, who fortunately secured the entire confidence of the various tribes, and by his knowledge of their language, was able to convince them that their struggle against the whites was hopeless, pointing out at the same time the great benefits they would obtain by prompt submission to government. When engaged in this beneficial task in some of the southern districts, Mr. Robinson was much assisted by Truganini (Pl. XXXII.) who, as the daughter of a chief of a southern tribe—that of Bruny Island—was able to induce many of her friends to listen favourably to his proposals. For this action she subsequently gained much ill will from some of the natives who ubraided her for her conduct, and distressed her by prophesying she would live to be the last of her race. She continued however to be firmly attached to the whites, and on one special occasion was undoubtedly the means of preventing a cruel murder. During a raid by the natives she made her way to a solitary hut occupied by a lady and child with whom she was acquainted, and whom she guided to a hiding place in the bush, securing their eventual escape by returning to her friends and directing their attention to another quarter. All this was done with the knowledge that had her action been discovered her life would have been forfeited. She was married four times, without issue, her last husband being "King Billy," a character well known in Tasmania. On his death, at Hobart, proceedings were taken to secure his skeleton for the Museum, but this was frustrated by the abstraction of the head, under peculiar circumstances, from the person in charge of the body. The skull was subsequently forwarded, as that of a pure Tasmanian Aboriginal to the Museum of the Royal College of Surgeons, London, an unfortunate presentation, as it was afterwards discovered that King Billy was not thoroughbred, having the blood of a New South Wales Aborgine in his veins. I only refer to this matter at present, because not only was the scandal attached to the removal of the head a source of great trouble to Truganini, but the episode was thought worthy of a theme for his muse in a humerous poem by Australia's greatest poet, Brunton Stephens. (See his 'Convict Once,' and other poems).

Truganini's idea of religion, like those of her race, was dim and misty. She believed in a great Spirit Rowra, to whom she looked up, but she had also a vague idea of a wicked Spirit of the same name who tempted to evil. Rowra (the 'ow' pronounced as in cow), seemed therefore to be the name of a Spirit whether of good or evil. This belief was in no way due to contact with the whites. It may here be stated that the natives, when feeling very ill and near death, objected to the presence of a white man. They also disliked under these circumstances to be on a bedstead and always endeavoured to get down on the floor and lie in front of the fire.

As to the general character and disposition of our herione, "poor Lallah," to use the words of her kind guardian, "was very passionate, sulky, and (when she was his wife) very jealous of King Billy, but very kind-hearted and very faithful. Her grief after her husband's death was something terrible. She was passionately attached to her dogs." Though unable to read, she was delighted with pictures, and always evinced keen interest in the illustrated London papers. Her notions of surgery, derived from native teaching, were very decided. For headache, lumbago, and some similar affections of a painful character, she regarded local bleeding as the sovereign remedy. The bleeding was affected by scarifications with sharp fragments of glass, and she herself was recognised by her people as an accomplished operator. When as much blood as required was obtained, hæmorrhage was stopped by the application of moist clay, which, I have no doubt, was thoroughly efficacious. For the relief of other local pains again, she had much faith in the efficacy of the small bone (radius) of the arm of a dead chief, King Tippo. The bone in the first instance had been charred in the fire, and when used was applied to the affected part and firmly bound upon it. Tooth extraction was occasionally effected by tying a tendon from the tail of a wallably to the peccant tooth and then jerking it out. Although perfectly willing, however, to adopt somewhat vigorous, if not heroic measures in the treatment of her friends, she always evinced in her own case a profound repugnance to medicine. The only form in which she could be induced to take it was that of a pill, during the exhibition of which she was wont to exhibit a very distinct vein of humour, which I think interesting, not only as a trait in her own character, but possibly in that of her race. On the part of my previously quoted informant "the giving of this pill meant about an hour's hard work," the process being described as follows :—"Lallah opened her mouth to the widest extent. I placed the pill as far back on the tongue as possible and pushed it onwards with a lead pencil. After this performance had been successfully completed, Lallah would give a little gulp and exclaim, "Artful fellah, that. You think him gone. Here him is again," at the same time putting the pill out in her hand. This would be repeated a number of times, till at last she would ejaculate, "Pah-wah now him crackney fine one," which signified the pill at last had reached its destination! She seldom required medicine, however, as her health was generally very good. Her appetite was large. She was stout in figure, about twelve stone in weight and five feet three inches in height. She enjoyed tobacco, and beer she took, but never to excess, except when induced to do so by injudicious friends. She liked hot ale with sugar and ginger at bedtime "which made her contented and easily managed." As for the fire-water of the pale-face, she never took it at all.

Poor Truganini firmly believed the spirits of her friends would come to her before death, and shortly before that event she calmly stated she knew she was about to die because her people had appeared to her. Her last illness was brief. During the morning which ushered it in, she sat up in her chair, smoked her pipe and physically seemed much as usual, but very sad and depressed in mind. When spoken to by her guardian about going to a new house, "Missus," she said, "I never go to new house with you, I see my people last night." During the day she expressed much concern about what her guardian would do when she was gone. In the evening she suddenly screamed, and then holding out her arms, called out, "Missus, Rowra catch me, Rowra catch me!" Her friend rushed to the bed and seized her hands, but she spoke no more. Soon afterwards she became insensible and remained so for two days, only becoming semi-conscious an hour or two before her death. This occurred in the month of May, 1876. Thus passed away, at the age 73, the last survivor of the Aboriginals of Tasmania.

For the above brief notice of a few points in connection with Truganini's history and character I am mainly indebted to Mrs. C. E. Nowell, of Hobart, whose former husband, Mr. Dandridge, had official charge of the natives for a period of their residence at Oyster Cove, and who herself afterwards had sole charge of Truganini during the later years of her life. I send photographs of Truganini and Billy Lanny. (Pls. XXXII. and XXXIII.)

3.—SOME NICETIES OF EXPRESSION IN THE LANGUAGES OF THE NEW HEBRIDES.

By the Rev. J. Copeland, M.A., Sydney.

(Communicated by the Secretary of the Section.)

There is a wide spread impression that the dialects of barbarous tribes are meagre, simple, and therefore easily acquired. This is far from being the case, and there can be no greater mistake than to conclude that any man, provided he be pious, will make a good missionary. If scholarship wide and exact is desirable in ministers in civilized communities, it is indispensable in one who goes to civilize and christianize rude tribes. The first missionary to such a field finds no helps such as grammars and dictionaries. The language has to be reduced to a written form, and the gathering of it up from the lips of the natives is a tedious and laborious work.

Not only are the dialects of barbarous tribes far from being meagre, but they abound especially in cencrete terms, and they have niceties and peculiarities not found in the more widely spoken languages of the globe. In giving a few of these niceties and peculiarities I shall confine myself to the dialects of Aneityum and Futuna, two of the most southerly islands in the New Hebrides group, though my remarks will apply more or less to the other islands, and to other groups. The language of Aneityum belongs to the Papuan class and abounds in consonants, whereas that of Futuna is allied to the Malayan, and every syllable ends with a vowel. The two dialects in question are very concrete, and they are deficient in abstract terms; sometimes for the noun the verb has to be used, *e.g.* "he is justified," rather than "his justification." The lack of abstract terms, such as goodness, righteousness, &c., is very marked. In translating the Bible and other books, this difficulty is often met, and the utmost skill and research are required to supply the deficiency.

The English language has borrowed words from many other languages, and it has been enriched thereby. The dialects of the New Hebrides also are growing by additions from without. In the tropics there is no snow, ice or hail, and till lately the New Hebrideans knew nothing of horses, cattle, dogs or cats, of swords, wheat, books; thus the question arises, when new terms must be introduced, from which language are they to be taken? In the Pacific the tendency was at first, in translating, say, the New Testament, to take the corresponding Greek word and modify it so as to be pronounceable by the natives. Latterly the tendency has been to use English words, as English is the foreign tongue of which they know most, and which may yet become the common or universal language of the islands.

As the pronouns have four numbers, instead of the two in English, it is easy to see that greater nicety must exist. There are pronouns and corresponding parts of the verb "to be" for "we two," "you two," "they two;" "we three," "you three," they three" (the Dual and Trial numbers); also for "we," "you" and "they," when they stand for four or more. One accustomed to English, with its comprehensive plural, does not take kindly at first to the seeming hair-splitting of the New Hebrides dialects. If you are speaking of two persons, though it be a horse and its rider, you must use a particular word; and if of three, another word, and if of four, yet another word. For example, in Gen. I. v. 26, it is said—"Let us make man in *our* image, after *our* likeness." This when turned into Futunese and re-translated into English runs thus: "Let us three, make man in the image of us three, after the image of us three." If the plural pronouns were used, the doctrine of the Trinity would not be expressly implied. The baptismal formula appears thus:—"I baptise thee in the name of His Father and of His Son and of the Holy Ghost of them two." Why not say the Father, and the Son, and the Holy Ghost? Just because the dialects have no such terms; the Father must be the Father of some one, the Son must be the Son of some one, and the Holy Ghost must be the Holy Ghost of some one. The translator has thus to take a side on the great question which separates the Eastern or Greek, from the Western or Latin Church as to the "Procession" of the Holy Spirit. Hence we say the Holy Ghost of them two, holding that he 'proceeds' from the Son as well as the Father.

Another peculiarity of the dialects in question is the use of the "double we"—we inclusive, and we exclusive, as it has been called. This 'we' is perplexing, for though there is a dual in Sanscrit and Greek, this 'we' is a novelty. If I say, speaking to a number of my fellows, "we are mortal," I use we inclusive; but if I say in prayer, "we have sinned," I use we exclusive, because God, not being a sinner, is excluded. The dual, trial, and plural have separate words according as the person spoken to is included or excluded The dual in Aneityumese has akaijau and aijumrau; the trial, akataij and aijumtaij, and the plural akaija and aijama. The translator, therefore, has to consider, when he meets a *we* or an *us*, whether first it is dual, trial, or plural, and then whether it is inclusive or exclusive. If this is not done, the translation or the spoken address will mislead.

Owing to these fine distinctions many nice points come up for settlement. Take the exclamation of the disciples when in the storm on the Lake of Galilee, to Jesus, "Lord save us, we perish" (Matt. VIII. 25). Did they mean that they, the disciples only, would go to the bottom, or that Jesus too would perish? If the former, then it would be in Futunese, akitea kakero; if the latter, akimea kakero. I give only one other example, "For he liveth *our* nation, and he hath built *us* a synagogue" (Luke, VII. 5). Is 'our' in "our nation" inclusive or exclusive, and to whom does 'us' apply? The 'our' is inclusive (uja), not exclusive (unyama), for the deputation to Jesus regarded Him as a Jew. But the *us* is exclusive, for the synagogue was for the use of the people of Capernaum, and Jesus belonged to Nazareth, and had a different language. Therefore, the exclusive (cama), not the inclusive (caija), would be used.

3.—A COMPARATIVE VIEW OF SOME OF THE CUSTOMS AND SOCIAL HABITS OF THE MALAYAN AND PAPUAN RACES OF POLYNESIA.

By the Rev. S. Ella, of the Loyalty Island's Mission.

The islands of Polynesia, north and south, are inhabited by distinct races, commonly classified as Malayan, Papuan, and Negrillo, to these may be added that with which we are more especially acquainted—the Australian. The distinctive characteristics of these are very marked, and their locations, with few exceptions, are as distinctly separate. In the Fijian we recognise a union of the Malay and Papuan, and Fiji seems to be the boundary or dividing line of the two races; for eastward of that group the Polynesians are of the Malay race, and westward of the Papuan and Negrillo. The origin of these races is at present hidden in mystery. Although the Malayan race can be readily traced to its source—the Malay Archipelago—the origin of the remaining races is very obscure, und the multitudinous differences of languages and varieties of customs render the task of associating them with any of the nations of the large continents very difficult and perplexing. Some ethnologists have (I believe, erroneously) included all these distinct races under one common origin—Asiatic; but such a hypothesis will not stand the test of examination or experience. Until further light is thrown upon the subject it will be safest to affix the origin of the Malayan tribes to that part of the globe to which it has hitherto been assigned—the south-eastern coast of India; and to infer that the remaining races have come, by some unknown and untraceable means, from the African continent. Such an inference will not appear overstrained when we remember that Madagascar, on the south-east of Africa, is peopled by the Malay race, with some remains of the African—probably the early inhabitants; and the language spoken there has many words found in the Malay-Polynesian dialects.

Some writers, treating of the origin of the people of Polynesia, have attempted to trace it to the Toltecs and Aztecs of Mexico, and to the ancient inhabitants of Peru. They are met by another perplexity, and one opening up a deeply interesting inquiry—Whence did the Toltecs, Aztecs, and Incas derive their origin? a people so remarkably superior in intelligence and civilisation to the ancient aborigines of America, as seen by the vestiges they have left of stupendous monuments, pyramids, temples, and monoliths, and records of their public and religious institutions. The inquiry cannot be touched in this paper. One well-known fact favours this hypothesis, that while the prevailing winds—south-east trades—would facilitate emigration from the Pacific coast of America to the South Sea Islands, they would oppose rudely constructed vessels sailing from the Malayan Islands to the Pacific. It must be borne in mind, however, that from November to April these south-east trade winds are rarely met with. Marsden, in his "History of Sumatra," relates that during this season, the Malays made voyages to some large islands in the south-east, which he supposes were New Guinea and Australia.

The question of the origin of these distinct races is a deeply interesting one, and worthy of careful research and investigation. It would be vain to attempt, in the limit of this paper, to enter upon even an introduction to the subject. I would now simply recognise the object of the honour conferred on me by your Association in asking me to read a paper on the customs of the Polynesians, and confine myself to a few brief sketches of what I have observed during a residence of twenty-six years among people of the Malayan and Papuan races, pointing out as I proceed the palpable marks of Oriental and African semblances and characteristics.

Modé of Life.—We shall consider first their mode of llfe. Both the Malayan and Papuan natives have adopted settled abodes, dwelling together in their several tribes. In this respect they differ materially from the Australian aborigines, who are conspicuously a wandering people. The Malay races show a decided preference for the sea-board, while the Papuan spread themselves more diffusedly over the country. The Malays dwell close together in villages, but the Papuans live in a more scattered manner, occupying separate plots near their gardens or plantations. In some cases, for mutual protection against the attacks or depredations of enemies, they form themselves into tribal communities, and live in a more compact state. In New Guinea, it may be remarked that the natives of Malay origin occupy the sea shore, or banks of the rivers near the sea, while the pure Papuan (probably the original inhabitants of the country) reside in the interior, and from that cause are rarely met with by travellers. A deadly feud evidently exists between these separate races on that island. Some Polynesians occupying small coral islands are accustomed to make excursions to neighbouring islands when pressed by famine. This is the only form of a migratory habit prevailing among this people.

Physiological Characteristics.—In these there is a very marked distinction between the Malayan and Papuan races. The Malay Polynesians are generally tall, well-formed, muscular, and comparatively a handsome people, very closely resembling the Singhalese and natives of Travancore. They may readily be distinguished from the Hindoos and people of Northern India. The skull of the Malay approaches the shape of the Caucasian; the frontal bone is not so receding as in the Negro and American Indian, or so flat as the Mongolian. The colour of the skin is olive, or rather that of dingy copper. The hair is straight and lank, often of a coarse texture, and worn long. Hair on the face is generally lacking. This may arise from the objection to that adornment, and thence the habit of plucking it out by the roots, by means of fish scales gummed to the forefinger and thumb (an operation more painful than their ancient method of shaving with shark's teeth). The features are soft and well-formed. The nose is somewhat long and aquiline, flatter and broader at the nostrils than those of Europeans. The lips are broad, the teeth formerly strong and healthy. The eye is bright and intelligent, the iris of different colours, but mostly of a dark brown, and the conjunctiva clear, except where tinted with biliary matter, not infrequent with those whose food consists chiefly of cocoanuts and fish. Their diet for the most part is not at all limited. Esculents abound, and the soil on most of the islands produces a large variety of fruits. The sea, lakes, and rivers supply abundance of fish, and the woods and forests plenty of wild fowl. Pork and poultry are eaten only on special occasions—"red-letter days," such as public feasts and entertainments.

The Papuan presents quite a different physique. They are seldom tall, and have rather an ungainly figure. The limbs are sinewy and far less plump and well-formed than the Malayan. The hips and legs are thinner, and the toes turn inwards, heels large and prominent. The skull is more of the negro cast, with a broad and receding forehead, high angular maxillary and malar bones, and strong teeth. The colour of the skin is dark brown, almost black. The hair is black, curling, and bushy; whiskers and beard of the same colour, and generally profuse. The perspiration emits an unpleasant odour, like the negro's. The nose is flatter than in the Eastern Polynesians, and the lips are broad and projecting. The ears are larger than ordinary and elongated; the lobe is often perforated and extended to admit large rings and other ornaments. In New Guinea the natives perforate the septum of the nose, into which they insert a pearl shell ornament, protruding on each side, sometimes resembling pig's tusks. The dialects of the Malayans are soft and mellifluent, while those of the Papuans are harsh and gutteral.

Dwellings.—Considerable difference may be observed in the houses of these distinct races, from which we may gather some idea of their original habits. I have already remarked that the Malays are of a more gregarious character, and dwell together in villages, while the Papuans prefer a scattered existence. We may take the Samoans as an example of the Malayan race. Their villages are generally very compact, forming a line along the sea coast, or lagoon, and here and there their dwellings are erected in a circle or square, surrounded by cocoanut groves. The houses of the best construction are built in a circular form, which some have compared to huge bee-hives. Without any stretch of imagination, one can easily suppose that the Eastern tent was the original model of these houses. Two tall pillars, nearly close together, form the centre and main props of the house, on these a short ridge-pole is placed, and from this ridge-pole a circle of fine rods radiates around to a considerable distance, about a hundred feet in circumference, supported by jointed beams in parallel circles to four or five feet from the ground. The last tier, of a strong construction, is supported by a circle of small posts fixed in the ground. The spaces between the posts are filled by curtains of plaited cocoanut leaves, which can be drawn up at will, and leave the whole house open and exposed. Ordinarily only a space in what may be called the front of the house is left open. The roof is covered with either pandanus or sugar-cane leaf thatch, twisted on to reeds, and tied to the rods with cinet cord. The house, thus constructed, has quite an Oriental tent-like form. These dwellings can be detached in parts and removed to a distance, even from one island to another. There are other kinds of dwellings of an elliptical shape, but in like manner partake of a tent form, quite open in front.

The Papuan constructions are of an entirely different character, and we recognise in these an African model. Some resemble merely the roof of a house placed on the ground, and afford little more than sleeping accommodation, or protection from the weather, This is the general character of the huts in the New Hebrides Islands. In New Caledonia and in the Loyalty Group, the better class of houses are built in a high conical form, and are adorned at the apex with a tall finial, ornamented with shells, or a rudely-carved model of the human figure. The edge of the roof reaches three feet from the ground, and is there supported by thick posts ; and both roof and sides are thatched with long grass. There is but one opening, a narrow doorway ; and the houses of chiefs are distinguished by carved grotesque figures of men or animals at each side of the entrance. These figures are roughly coloured with black, red, and white pigments. The houses are usually surrounded by a strong palisade or pah, enclosing the large house and three or four small huts for the family, and a space under the shade of trees which serves as their living and reception room. There are some other habitations which closely resemble a superior class of Australian gunyahs, such as are met with in Northern Queensland.

Between these dwellings of the Malayan and Papuan races there is a very striking distinction. The Malay houses develope an Oriental origin, but the Papuan show an entirely different model, which may be traced to an African source. In New Guinea the African mode of building huts on the thick branches of trees is frequently met with. On the sea coast, there the habitat of the Malay race, the houses are large, and erected on high stakes, often over high-water mark of the strand. Similar constructions are found in Borneo, and the islands of the Malay Archipelago.

Cultivation of the Soil.—In this matter also considerable difference exists between the two races. The social tendency of the Malays is very conspicuous. They act much on the co-operative system, with their family plantations often united. Extensive tracts of ground will be cultivated by a tribe or family. The Papuan, on the contrary, jealously guards his individual plot or garden, and surrounds it with a fence, however small or large it may be. Among the Malay population, the males chiefly perform the agricultural work, while the Papuans leave that and other manual labour to women and girls. To help to support the male portion of a family, a young girl will be early espoused to a boy, and be required to provide food for her little prospective husband. The Papuan women are slaves or beasts of burden in the family, but the Malay-Polynesian females are treated with considerable deference and regard. They generally manage to hold their own, and a little over. The agricultural implements are of a very primitive order among all the Polynesians; a long wooden dibble performs the work of plough and mattock. The Papuan sometimes uses a cocoanut shell to shovel up the earth, though this operation is more frequently performed by the bare hand. To this cause may be attributed the horny hands and thick kuuckles of the females. They carefully crumble the earth in their hands, and by a similar manipulation spread it smoothly, patting it down and brushing it over with the palms. Their gardens are generally cleanly and well kept. There is, of course, a vast difference in fertility between the soil of volcanic and coral islands.

Social Life.—The diversity in the habits of the two races is more strikingly apparent in the family and social life than in any other respect; and no one at all acquainted with the usages of each would confound one race with the other. Among the Malayans the infant is carefully nourished and nursed by its mother, and in its early years the child is the mother's special care, though both parents are remarkably fond of their children. The birth of a child makes very little difference to the Papuan mother. During pregnancy some care is shown her, lest any injury should happen; but a few days after giving birth the poor woman has to go off to her daily toil as usual, and the father stays at home to nurse the child, and feed it with the expressed juice of a cocoanut; or should he feel more disposed to go out fishing or feasting, &c., the mother must bind the infant to her back while engaged in her work in the plantation, or gathering firewood, or however occupied. On the birth of a child, the mother loses her own name, and is now called the mother of so-and-so—whatever the child may be named. Here we recognise a

South African custom. Some will remember that Mrs. Moffat was called by the Bechuanas "Ma-Robert" after the birth of her eldest son Robert. Among the Malays, the birth of a child is celebrated by feasting and rejoicing, and presents are interchanged in the families of father and mother. Only in the case of a son's birth is anything like pleasure shown by the Papuan parents. Children are much neglected by the parents, and are left without control or discipline, to congregate together or roam at large in company. The girls are early initiated in daily labour, while the boys grow up in idleness and mischief. The Malayan mother carries her infant on her hip—a custom observed by Marsden among the natives of Sumatra. The Papuan woman bears her child in a bandage on her back, often in conjunction with a bundle of sticks, basket of vegetables, or other burden. In New Guinea we saw children carried in a similar manner by the women, a net being employed for the purpose, suspended from the woman's shoulders.

A kind of circumcision was practised among the Malay-Polynesians, and is still in existence among the Papuans. The rite is not treated as a religious ceremony, nor is it accompanied with any formality. At the age of eight, or nine years, a few lads will unite and go to the operator, a native doctor, who simply makes an incion in the præputium.

Tatooing (or tatauing) is practised to a large or smaller extent by the various tribes of the Malays. Among the New Zealanders, Marquesans, and Hervey Islanders, the whole body was tatooed. The Samoans tatoo the lower part of the body from the waist to the knees. In some islands the face and body are slightly marked, and in others the marks are confined to the breast and arms. Generally the males only are tatooed, but in some of the tribes the women are so adorned, and the men are exempt. In New Guinea, the women mostly are thus distinguished, though this adornment is not confined to them. In Fiji the women alone were tatooed. Among some of the Papuan tribes, a different mode of tatooing is performed on the women; raised marks made on the flesh by scarring or cicatrizing the skin, by cutting or burning with rough shells, or pointed wood heated.

Marriage takes place at an early age. With the Malayans the event is celebrated with a great deal of ceremony, which space will not permit me to particularize. The Papuans, with rare exceptions, enter on the conjugal relation with very little thought or ceremony. This may arise from the betrothals having been made in early childhood, and such a thing as courtship is unknown, the match had long since been settled for them by their parents. Polygamy exists among both races, but to a limited extent with the Malayans. As in the Papuan tribes wives are little more than slaves, to provide for the wants of the "lords of creation," the larger number, therefore, a man possesses, the more help he receives to minister to his comfort; hence chiefs and men of importance multiply their wives without limit. Chastity among the young people is very slightly observed, and this fact applies to both races; but adultery is punished with jealous vengeance in the case of the weaker sex, the Papuan in this respect, showing the greater and more implacable rage. In the New Hebrides married women are often ruthlessly murdered on lightly-founded suspicion.

The aged are respected and well cared for among the Malayans by their children and relatives; but this regard is sadly lacking in the Papuans. In Eastern Polynesia, although a native teacher will readily leave his children to the care of relatives, in order to go to a distant sphere, he will hardly abandon an aged parent or foster-parent who needs his care: "Suffer me first to bury my dead," is no vain excuse with him.

The rights of sepulture are solemnly observed by the Malay race. Chiefs of distinction are often embalmed, and the body is preserved in a house erected for it, and is held very sacred. The burying places are equally regarded with something like super stitious awe. They have no cemeteries, but bury their dead on their own grounds. In Samoa, if a body be lost beyond recovery, as at sea, the near relatives seek some insect or animal, whichever comes first upon a cloth spread for the purpose, into which they believe the spirit of the deceased has entered, and that object is then carefully wrapped up and buried with some ceremony and lamentation. The Papuans treat the dead with scant respect, in some cases the body being cast into the sea, or thrown indifferently into cavernous holes in the bush; in others the dead are placed in various postures in caverns set apart for the purpose. In the Loyalty Islands there are several Petræs.

Mourning is differently observed. Among the Malayans burnings for the dead (not cremation) were continued for some days, during which periods the relations kept a strict fast. The ordinary apparel and all ornaments were laid aside by the mourners; at times, in a frenzy of grief, they were violently torn off and destroyed. The near relations would often cut and bruise themselves with shark's teeth and stones. In the New Hebrides the relatives painted face and body black, with charcoal and oil, which "mourning" they wore for many days. In New Caledonia and the Loyalty Islands mourners smeared their bodies with white wood ashes. In the New Hebrides widows were strangled to accompany their dead husbands, and sometimes mothers, to follow their infants to the other world. Time will not allow details of customs in other parts of Polynesia.

Space will permit a brief view only of some domestic habits of these races. In Eastern Polynesia the cooking is performed chiefly by the males, even chiefs will take part in the culinary operations. The firewood and small hard stones required for their ovens are collected by men. A great variety of tasty dishes are prepared by them, and both the preparation and the cooking are very cleanly. The ovens are formed by small stones interspersed with the wood in a heap in a hollow on the ground. After the fuel is consumed, and the stones thoroughly heated, the latter are removed from the surface, and the food in separate wrappings of leaves is placed between layers of bread fruit or banana leaves and carefully covered with the heated stones. The Papuans leave the cooking and all its preparations to the females of the family. The coral islands of the Loyalty Group not supplying suitable stones for such ovens as just mentioned, the natives cover their food with heated earth and ashes. Here the food is cooked in a hotch-potch manner,—fish, fowls, vegetables, and fruit are baked in one large bundle, and very little care is taken in cleansing anything.

It is a usual thing in a Malayan family for all the members to eat together; but with the Papuans the females take a "back seat," and must often wait till the males have selected what they chose, and have satisfied their hunger before they can get their meal from what is left. Sometimes separate dishes are cooked respectively for the male portion and female members of the household.

A distinction may be observed between the modes of sitting of the Malays and Papuans. The former is comparatively graceful —with crossed legs, the heels gathered beneath them; but the latter squat in an inelegant position, with the knees drawn up to the chest.

A generous spirit of hospitality characterises the Malay-Polynesian. Strangers are welcomed and warmly entertained. A custom prevails in Samoa, which often reminded me of Abraham and Lot, viz.:—The headman of the village sitting in front of his house, inviting passing strangers to enter and rest, take a little food, and refresh himself before going on his way. In every important village or township a house for travellers—a native caravanserai—is erected in the centre, where travelling parties are not only lodged but also freely entertained, however numerous the party may be. It is understood, however, that, unless particular business calls them to that place, or the weather is unpropitious, the travellers are expected not to prolong their stay beyond one night. No such provision is made in Papuan settlements, and strangers will rarely obtain lodging or food there without a *quid pro quo.* We have often been grieved by witnessing the greediness and selfishness shown by the Loyalty Islanders, in such painful contrast with our experience of the hospitality and generous conduct of the Samoans, among whom the children even will share their food or dainties with their companions without stint or reluctance.

The clothing of the Malay-Polynesian is comparatively decent. The long tapa robes of the Friendly Islanders, Samoans, and Society Islanders, made from the bark of the paper mulberry *(Morus* *papyrifera)*, impress one with the idea of the Roman toga and Oriental robes of ancient times. Fine mats of a plaited grass are worn on state occasions, and also a shaggy mat woven from the prepared bark of the *Hibiscus liliaceus*, bleached white or coloured with a native dye. On some islands the maro, a long narrow plaited girdle forms the dress of the males, and a shaggy petticoat of long grass or *Hibiscus* bark is worn by the women. The Papuans generally despise clothing. A very slight covering was worn by the New Hebrideans, but in New Caledonia and the Loyalty Group the males went nude, and affected only some covering to the head, like a Persian cap or turban. The adult women wore a small covering or fringe of grass or bark. In New Guinea, the males go naked, but the females wear a long apron extending to the knees. Space will not allow more than a bare remark on the ornaments worn by each race ; in these a difference of taste is manifested respectively by them. The Malayan rejoicing chiefly in dressed feathers, flowers, and strong-scented seeds, while the Papuan adopts a profusion of ornaments of feathers, shells, and pig's tusks, &c., and luxuriates in paint and pigments, as did the Fijian in former days.

It would be interesting to notice their furniture, implements, manufactures, modes of transit, also (which are more important) their political economy, forms of government, laws, orders, mode of warfare, and legendary lore ; but it is not possible here to treat of these even cursorily. Still, before bringing this paper to a close I must speak briefly of their religion, mythology, and superstitions. The subject of this paper treats of matters of the past more than of the present phase of things, and although using the present tense we must be understood to refer to former conditions and state of things. The introduction and spread of Christianity have produced a wonderful change throughout Polynesia, and the consequent advance of civilisation has almost obliterated primitive customs and habits, and the condition of these people is vastly improved, though there remains abundant room for future progress.

The Polynesians east and west were idolators, with "lords many and gods many." Some were wholly given to idolatory, and slaves of most degrading superstitions. Idolatory saturated the whole framework of society, and every circumstance of life ; particular deities were supposed to preside over every state and condition of men, and govern the destinies of nations, families, and individuals. Human sacrifices were offered to these gods, often of a most sanguinary character, especially in times of danger or distress. In this respect the Eastern Polynesians stand forth most conspicuously. The annals of the Sandwich Islands, and of the Society and Hervey Groups give many a dark record of human sacrifice to propitiate their hideous idols, or appease their wrath. These gods were generally represented as implacable and vengeful, and the authors of all calamities. The native mind seems never to have entertained the idea of a beneficent and compassionate Being in any of their deities. They were objects commanding their fears and not their affection. In Samoa, there existed a higher state of civilisation and intelligence, and some notion of a Supreme Being prevailed, yet there were many tutelary deities and subordinate spirits, represented in natural objects, to which much deference was paid and worship offered. At the opening of their fonos (or Parliamentary meetings) the presence of the Supreme Being was first acknowledged. At the evening meal the head of the family would, before the meal was partaken of by any, first make an offering of food to the god of the family. At the kava-drinking, in like manner, the first cup was poured out on the ground, or into the fire, as a drink-offering to their god. Children were named after their respective tutelary deities, to whom they were thus consecrated; and a mother on giving birth to a son, would call on her god, and say, "I have got a man for thee!" The help and protection of these tutelary deities were supplicated in every important undertaking; or rather, they were entreated not to bring disaster—in house-building, planting, voyaging, and especially in war. The Samoans and others had some notion of a future state, of a native Hades and Valhalla.

The Papuan religion and mythology are of a coarse and sombre character. Idolatory exists only in some tribes, in others it is difficult to discern any notion of a god-demon-worship in the prevailing form; and a dark and torturing superstition regarding evil spirits, sorcery, and witchcraft renders life miserable, and exposes many, innocent of evil design or power, to suspicion and dread. Remnants of food must be destroyed or hidden from sight lest they be employed as sorceries to bewitch the eater. Certain weird spots in the bush, or on the mountains or seashore are tremblingly passed or avoided, as the dwelling-places of demons and spirits of the dead. A fetish will scare the strongest-minded, and a curse pronounced by a malicious member of the family will sometimes terrify even to death. These degrading superstitions are such as prevail among the South African races, and it is very easy to trace their origin thence.

To notice the legends and mythology of these races would occupy considerable space, and I must, therefore, pass over these subjects and conclude this paper by simply remarking that the spread of the gospel among the Polynesians has worked wonderful changes in their religious characters and social life. Missionary work was commenced in the Pacific Islands at the close of the last century. Now, throughout Polynesia, from east to west, the Scriptures have been circulated in the various languages, and European and American missionaries have laboured with increasing success, so that heathenism is rapidly dying out before the growth of Christain light and life.

Section H.

SANITARY SCIENCE, AND HYGIENE.

President of the Section, Mr. Joseph Bancroft, M.D., of Brisbane.

THURSDAY, AUGUST 30.

The President delivered the following Address:—

VARIOUS HYGIENIC ASPECTS OF AUSTRALIAN LIFE.

To know something of Medical and Sanitary affairs is one thing, but to compose an interesting and readable paper worthy of your attention, necessitates abilities to which I lay no claim, and much as I may desire to present to you any tolerable sketch of these ever increasing branches of knowledge, at which many of the most enlightened intelligences in Europe and America are now labouring, I must rather be content to say something of experiences gained in the Australian colonies, leaving the far greater stores of investigations to be illustrated by abler hands. To be able to cure a sick man is a power of the highest order, no knowledge seems greater or more desirable, but to lay down rules of guidance intelligible to the masses by which disease may be avoided is a yet higher attainment, and worthy of the name Sanitary Science. The removal of a frightful ailment, and the restoration of a diseased person to health, seems more of the nature of a miracle, and for which service no payment appears too great, but to say to your patient as Elisha did to Naaman, "wash and be clean," is a prescription for which at first sight no fee should be claimed, and it is not to be wondered at that the Health Officer working at purifications, ventilation and disinfection, is looked upon as occupying an inferior position, and as he does no particular medical and surgical duties, that his services may be dispensed with whenever he stands in the way of small economies.

In this Address, Sanitary topics therefore, will be perhaps more necessary to dwell upon than Medical and Surgical advancement, which latter being better able to claim a just reward for its services needs less help from Governments or Learned Societies striving for the advancement of Science, which is the object of our meeting to-day.

The more continued efforts of our Colonial Universities will, however, do much to prove to the rising generation of men and women in Australia the truth of the old adage:—"Prevention is better than cure"—a verity clear enough to one standing in the open air of the mountain, but less obvious to smoke-beclouded intellects struggling in the crowded thoroughfares.

Disease against which we contend is manifold, and to live and die without a day's illness is most desirable, but rare enough to be phenominal, to arrive at a great age in these warmer countries is not rare. In Brisbane, two persons whose cases fell under my notice, had lived over a hundred years, the warmth of summer was said to be very agreeable, and one patient aged one hundred and two enjoyed great activity. Early deaths are, however, very common, and the records of children who perish under five years of age, are high enough to be startling. Against this it may be noted that the births are numerous and in excess of our experiences in Europe. Want of attention and imperfection in housing infants among the working classes leads to great mortality. There is abundance of food for the children; the hardy ones survive and the delicate ones die.

If this high rate of infantile mortality is to be reduced, more care, at least in Queensland, will have to be taken in improving the dwellings. Often the house of the labourer is his own, it is very small and he roofs it with corrugated iron in order to obtain pure drinking water. The temperature of the ray of the summer sun ranges high—140° to 160° Far. The hand can only endure a momentary contact with surfaces so heated. I tell parents at times that when their children are brought up under such roofs they will have no difficulty in enduring the climate of New Guinea. A double layer of iron for roofs and walls of houses as you have in the Fever Hospitals at Little Bay, is a form of dwelling well worthy of study. The former Medical Adviser to the Government of New Sonth Wales, Dr. Mackellar, took much interest in this building, and the recently published records of success in treating fever cases in this Hospital are most encouraging. As a lining to a room iron is less absorbent of all forms of putridity than paper, wood, or plaster; it is also fire-proof; it can be easily washed, easily dried, and cheaply painted. To the form only of the corrugations can exceptions be taken, and ironworkers might wisely study to improve the appearance of the sheet metal used to line rooms. The iron age has yet many advances to make, and there does not appear to be any great mechanical difficulty in adapting such marvellous plastic metal to our wants in this respect. The single layer of iron is intolerable in cold or hot weather; the double, with suitable packing in the interspace, meets a requirement which health demands. In buildings of iron more attention will need to be paid to ventilation than is required in the more porous wooden houses. In the study of buildings to shelter us from the heat and cold of the seasons, we have not to cope with the inclemencies of the European or North American winters, but our dry westerly winds are sufficiently injurious to animal life to call for attention in many details. Our cattle find sufficient protection in the timber to carry them through the severities of the seasons, and it is found that towns largely planted with pines and other trees have the aridity of the air moderated to an appreciable extent. The planting by Baron von Mueller of Conifers and Eucalypts, in the City of Melbourne, is a monument to the foresight of that great botanist. Dr. Schomburgh makes a park round the City of Adelaide, and one sees in the gardens of Sydney what embellishments nature has in store for those who love her. Sanitary science has, however, not much power in rectifying the severity of climate; it can, however, point out healthy sites for houses, and those who have suffered from the hardships incident to the inland plains and areas, will find on the eastern sea-board a climate and surroundings more in accordance with what nature demands. Where do we see more lovely sea-coast than in the journey by steamboat from Sydney to Brisbane? A region of little hills and valleys on the shores of the Pacific with its ever-varying breezes; with abundance of fish ready for catching; and a reliable rainfall for the cultivation of the vine and orange, only requiring the iron-horse to open it up to the toilers in our crowded cities. Sanitary text-books tell us much of how to live in towns, of albuminoid ammonia in our drinking water, and defects in the construction of soil pipes by which typhoid fever has spread from drains to dwellings.

Let us leave these for a period and speak of our houses in the country. What considerations will helper us in determining a favourable site for building upon? The eastern and western slopes have a different appearance from each other. In timbered country there is abundance of shrubbery where the morning sun shines on the opposite side of the hill; the Eucalypts are gaunt, naked, tall and straight, with no undergrowth. A house built on the eastern aspect below the crest of the ridges escapes the severity of the westerly wind. We notice on driving in the evenings how cold the air strikes our face in crossing the swampy valley, and how warm it feels on ascending the rising ground. The cattle do not camp here during the winter nights, but get on the higher land. We should leave some gum trees near our house, the flowers of which will attract flocks of paroquets. The incessant twittering of these honey-seekers will make the place lively, and the wise talk of the friar-bird will amuse, if it fail to instruct us. It may not be advisable to dig or dung gardens near our doors, but rather to have grassy lawns, on which our tame cows can feed, the scythe being occasionally used to reduce any herbage growing too rank. It will be necessary to have some underground pipes laid to drain the land and carry our kitchen water down the ridge. On this drain of slop-water we can plant vines, and with posts and wire construct a shady avenue which will lead to our garden on the lower and richer soil. There we shall dam the creek, dig a water-hole, or sink a well, so that we can irrigate our kitchen garden, and as this water may be required for other purposes we must take care to exclude all sewage.

Our house should be raised a distance from the ground, and our dormitory erected if possible on a second story to secure the purest possible air during sleep. Couch and buffalo grasses will cover all the ground around the premises, and so any malaria will be battered down out of harm's way. A wind-mill or other pumping engine will lift the well-water to an elevation, if the tanks catching roof water are not considered ample. Stabling, cow sheds, and piggeries will stand on the slope a trifle above the garden, so that the water from these places may enrich the cultivation. In a long division sum an error in the first line can never be rectified in lower figures, so in our house-building we should guard against the radical error of making refuse fluid gravitate towards our dwelling. If we are not afraid of mosquitos, we can train grape vines to protect the verandahs from the glare of the sun, these will be preferable to passion fruits or other evergreens, the leaves of which perpetuate colonies of scale and other parasitic insects. To plant a small vine in such position, seldom leads to success, as the domestic animals break the foliage, so it will be better to have a tall plant of three years growth transferred, the upper shoots of which will be long enough to reach the eaves ; this is not difficult. I have successfully transplanted a vine in the middle of summer, indeed when covered with foliage, by removing the roots carefully from the ground by the aid of water, and keeping them continuously wet during their journey to their new resting place. Vine branches can be regularly trained on galvanised iron wire, can be pruned and washed in winter, at which time of year their sheltering foliage is not wanted. It is a healthful piece of duty to arrange the fruiting stems and tendrils, and as a reward for the labour we shall secure an unlimited supply of grapes for family use, a little waste water thrown on the roots growing among the grass being all the plant asks in return. Foliage about the house no doubt tends to harbour mosquitos where these insects, by insanitary neglect, are allowed to breed, but it is possible to prevent, in a great measure, the genesis of these creatures. Our water tanks around the house should be covered with wire gauze, a precaution much neglected in the supply-tanks indoors in Sydney. Waterholes in the country should be stocked with little fishes, the gold carps can be bred without difficulty, it will eat the wriggling larva. Stagnant swamps should be drained or converted by excavation into fish-ponds. Brisbane formerly swarmed with mosquitos in summer, now it is freer from these insects than any Australian town I have visited ; it has all the natural watercourses paved or cemented, and so the mosquitos are kept moving on to their death among the fishes of the river.

In the continuous rains of summer, when every shallow is converted into a pool, it is not possible on a wide stretch of land to prevent the breeding of mosquitos, and numerous gutters are required to keep the surface dry; but mosquitos take two or three weeks to develop into flying insects. It is curious to see in the evaporating shallows the mosquito larva lying folded up like turnip seeds in the depressions and cattle foot-prints the last to dry up. In country sanitation it is necessary, among other things, to pay attention to milk—to construct a dairy on strictly sanitary principles is not an easy matter. The Chinese neither keep cows nor use milk for their children, yet are the most numerous race on the face of the globe. If they have to feed a motherless child they use rice, gruel, and sugar, a mixture I have often found more satisfactory in practice than the substitutes for milk food brought out from Europe. How then shall we manage the milk difficulty proved so fruitful in carrying disease from house to house? Let us not lose sight of the fact that it is the usage to let milk stand in shallow open pans—no form of vessel is so well constructed to collect the germ-bearing dust that falls everywhere, or to absorb emanations from the sick man's bed or poisonous gases. In nature milk is never so exposed; until this dangerous custom is rectified, the consumer should protect himself to the extent he can, by boiling the milk. But milk is not the only moist material absorbing putrescent and possibly pathogenic organisms, our slaughter yards and butcher's shops are defective in sanitary contrivances, and to the student of pathology it is indeed wonderful that animal food distributed by such methods, does not convey disease far and wide among the people. Cooking again helps us, by which the superficial parts which absorb most of the offensive matters are modified by the heat applied. The European house-fly, now established in all Australian settlements, is a most troublesome insect, it is bred in the refuse heap, one moment it settles on decomposing substances alive with vibrios and bacteria, the next on our food, and it is notorious that places where house-flies abound are those where fever cases frequently occur. A few weeks ago, visiting the famous silver-mining country at Broken Hill, where a typhoid epidemic was raging, flies were noticed in great numbers in the houses, places in the rooms were black with them, and it was difficult to keep them out of food. Much of the comfort of a house, to say nothing of its sanitary state, is interfered with by the presence of the house-fly; it breeds most extensively in stable dung, and its little hard pupa cases may be picked out of the dried parts of the pavement adjoining the walls. It is the custom of sanitary authorities to think little of the accumulations of stable dung on town premises, and by-laws allow it being stored for long periods. If your house is alongside of stables, visitations of flies will be found very troublesome, and it is here the domestic fowl comes to the rescue; nothing so choice a morsel to the chicken as the larva of the house-fly. In towns horse dung should be put under shelter from the rain, and the fowl yard can be wired in so as to include it. In Australian towns it seems to me that a weekly removal should be imperative, and all storage places should be cemented on the floor, and roofed in against rain. The expense of such contrivances is trifling compared with the comfort attained. A method of getting rid of flies from dwellings has been used in my house for many years, for as a child I was an entomologist in a small way, and undertook to clear out the flies of my parents' house with the entomologist's net. Years later it was found convenient to stretch across each room near the ceiling, two or three straight and tight bands of white toilet fringe, about three inches wide, in the rooms where food is used. Kitchen, dining and sitting room flies take up their abode and settle on the band of fringe in the evening; a fly-catcher is conveniently made of mosquito net, with a hoop of cane or crinoline wire, eighteen inches in diameter; the handle, a stiff piece of light wood a yard long, is tied across the hoop of the net, so as to stiffen it, and the tail of the mosquito net tapering to a long point. When the flies have gone to rest in the evenings on the fringe, sweep the net smartly the whole length of it, nearly all the flies will be caught, and going over the band a few minutes later will capture those that remain. The collection of flies in the tail of the net is to be immersed in hot water; the scalded flies will be relished by the chickens in the morning. Cockroaches in kitchens and bakeries can be got rid of by boiling water applied with a large garden syringe. Fleas, by washing your dogs every day or two, with soap and warm water. There is a wide field in Australia for the application of sanitary science, particularly with regard to cleanliness. Wooden pavement to streets of towns is a great comfort and sanitary advantage. like the mallet of the mason it bears long repeated concussions without disintegration, but the expense is no doubt considerable, and beyond the means of many Municipalities. The noise in Sydney produced by the great distance between the blocks and the transverse position, causing the wheels of vehicles to fall at once into the same groove is a defect capable of rectification. I remember wood pavement in St. Ann's Square, Manchester, as one of my earliest recollections. The blocks were of pine set on end, carriages passed over them without producing sufficient noise to warn passengers of the proximity of danger, and so accidents happened. It will be possible by management to avoid these extremes. The peril to horses over the Eucalypt wood worn slippery is great, would it not be possible to make a sufficient roughness by diagonal grooving after the blocks have become polished by use? Or a set of circular saws driven by engine-power in a heavy frame like a steam roller, might be made to corduroy the wood work when too smooth, a process that could be repeated as the blocks become slippery, or smaller blocks laid obliquely across the streets might effect the same object.

The removal of refuse matter becoming offensive—how is this to be done? Can we learn anything from the Aborigines? How do they accomplish such work? Not by scavenging certainly, but by a far more effective method, and when their camp in a few days becomes foul, they pack up all their valuables and set up shelters on a new site where there are neither fleas nor bad smells to trouble them. This method is not convenient to a white man who has spent money and labour on his house and allotment, but physicians do not doubt the value of travel, and drive people from their insanitary homes by prescribing change of air. The local features of the residential site wil determine how the cleanliness of the place is to be maintained, as all towns cannot have a water-closet system. Adelaide the first to adopt this luxury, is built on rising ground from which water gravitates without engineering difficulty; so also in Sydney, and the public farms of these places are most interesting, though not free from bad smells, and the study of cultivation with sewage may under wise direction be carried out so as to be a guide to irrigating science in the country at large. The simple form of the distribution in the Botany farm under the management of Mr. Oxley, deserves particular attention as tending to solve one of the chief difficulties. In both Adelaide and Sydney the area of land under irrigation appears so far too limited for the fertilising element, and additional water supply is desirable. At Botany, the pumping appliances formerly used to supply Sydney with drinking water, could be used to supply additional water to dilute the sewage, and so more area could be laid under crops. The consideration of what plants could be profitably grown on the sewage-irrigated areas is of some importance, and if such works do not promise to be profitable farms in a pecuniary way the interest in the development languishes. To this end botanists and horticulturists should visit the farms and make suggestions for experiments. Sydney has a different climate from Adelaide, and local knowledge of plant life will be important information. The cultivation of *Sorghum halepense,* a coarse wild grass that grows on the banks of the Brisbane River and elsewhere in Queensland yields immense quantities of fodder, and is highly spoken of by Mr. Colebatch, the manager of the Adelaide farm. I have suggested to him the importance of making trials with the foliage that grows on the canes of *Arundo donax,* as cattle might be allowed to crop off the blades of grass for themselves. This grass is much relished by horses and cattle in Queensland during winter, and the canes browsed upon by the animals soon throw out a fresh development of leaves. I believe that when planted in suitable places near water, it will yield more fodder than anything so far introduced. Rice too, being an aquatic grass, may prove valuable on the sewage areas as a fairly good yield of grain can be collected from rich alluvial flats in Queensland coast country during the rainy season without special irrigation. Where it is easy to carry sewers into deep sea, municipalities can hardly be blamed in this stage of our knowledge for so conveying their waste matter; but where rivers and shallow bays adjoin a town there can be no justification for polluting them with sewage. In many Australian towns there is at times a scanty water supply, and where such contingency may happen it will be inadvisable to construct water-closets. The removal of excreta by a dry method, as far as I know, has never been carried out in any town in these colonies according to sanitary principle. Much has been left to municipal authorities acting in a careless manner, and frequently no dry earth or absorbent powder is used. This is the case in Melbourne, a little red carbolic dust being cast into the pan and so the odour is slightly disguised. A common English usage new arrivals adopt in building their houses, is to dig a pit and set a closet over it. The first rain that falls fills the pit with water, and the resulting fermenting solution becomes a breeding place for flies and mosquitos. The smell of such closets can be noticed for twenty yards or more, and all neighbouring lead paint is more or less blackened. There is great scope for improvement in sanitary usages with regard to these matters; the most fundamental necessity being to construct the closet a little above the level of the ground on a concrete floor with walls of iron, such closets can be cleansed and disinfected so as to completely remove all chance of disease spreading from that source. A system of removal of town refuse and excreta by railway, as is done in Dunedin, merits attention, a large area of land being set apart for the reception of it. In Australia land can be had cheap a few miles out of any town, railway trucks can be made to receive the bodies of the collecting carts, which when once closed need not be opened till arriving at the farm, and before returning all materials should be cleansed with boiling water, which can be then used for irrigation, whilst return trains can be laden with virgin soil, dried and ground to supply the earth closets; a scheme of this kind would do much to eradicate typhoid. Much has been said of typhoid fever being disseminated by the use of contaminated water and milk, but there also appears a cause of the spread of this disease to which little attention has been paid. I allude to the walls and furniture of the rooms in which typhoid patients have slept. After the treatment of a fever case I have been in the habit of recommending the painting or varnishing of the walls and floor on which the contagious particles mixed with dust have fallen, to lock in the element of the disease. Dr. McCrea, for many years Health Officer of Melbourne, has for a long time been giving the same advice; he also scorches the walls by setting fire to kerosene painted on in small patches at a time. Dusting and sweeping rooms in which contagious fevers are treated, should be conducted with judgment. After an experience here of over twenty years, my views are that typhoid is carried into bush settlements, and when a number of people have suffered from it, the disease becomes located in the houses, and perhaps the soil of the place, redeveloping as weather permits. The spread of typhoid is increased by the arrival of persons from ships, and the larger towns, who, though not suffering from active manifestations of the disease carry the contagion in their persons and clothes, as in towns there is little hope of the stamping out of typhoid. The English theory of pollution of water from the drainage of cesspits does not apply to these communities; there are neither cesspits nor wells in Brisbane, yet typhoid is common enough, all our regulations and by-laws are made conformable to the English theories and are more or less wide of the mark. The view that typhoid spreads from evacuations leads to attention to that point, and to the neglect of all other necessities from cleanliness, and typhoid spreads without let or hindrance, as would scarlet fever or measles. Once modify the theories held by British educated medical practitioners, and place typhoid in the same list with the other contagious fevers, and it will tend to disappear from our communities in the same way that scarlet fever is stamped out by the harmonious working of medical man, nurse, and patient.

Our water supply for the city of Brisbane is from two large watercourses impounded among the hills. There are no residents on the collecting ground of the watersheds, so contamination at the source is almost out of the question. Rain water collected from roofs in corrugated iron and other forms of iron tanks is relied on when pipe-water is not to be had, and water from excavations in the rock, from cemented tanks below the level of the ground, and from wells, is now rarely used, and when used is generally boiled beforehand and employed in the form of tea, the common drink of the thirsty. The bush traveller, station hand, railway and road labourers, rarely drink water without this form of preparation, consequently hydatid disease, so common in the southern colonies, is rare in Queensland. One need not urge Australians to drink tea, as it is already consumed to an extent far beyond experience in other countries; and though the Chinese may not be liked here as settlers, their tea-leaf is a commodity in the present aspect of our civilisation that we cannot dispense with. Is it beyond the bounds of possibility that we have no indigenous foliage capable of supplying this want? We have of trees and shrubs thousands, in the genus *Eucalyptus* alone, the Acacias are equally numerous, and the varieties of foliage are beyond estimation. In usages we follow each other like cattle through a scrub-track, but will no one lead us out of this tea-drinking folly? Tea and coffee have for their active principle empyreumo-aromatic crystalline bodies—theine and caffeine, which chemists say are identical, but about their creation of these substances by roasting very little seems to be known. The chief sanitary advantage in the use of tea is the circumstance that the water has been sterilised by boiling. This operation kills most, if not all, deleterious living germs, there are few pathogenic micro-organisms that do not meet death in the kettle. I have found as much satisfaction when thirsty in the bush by drinking boiled water mixed with preserved milk as by taking tea. The Paraguay tea grows to the height of twenty feet in the Botanic Gardens of Brisbane.

Reverting to the more important subject, the spread of typhoid fever, can we narrow down the inquiry so as to apprehend more correctly the working of the contagion of typhoid and so discover the neglected sanitary precautions? In the present state of our knowledge few will be disposed to deny that the essential element of typhoid is a contagious virus, and that the emanations from the spontaneous decomposition of organic matter, whatever else they give rise to, will not produce this special entity, bacillus, micrococcus, or whatever in the long run it may prove to be of typhoid fever, the addition of the evacuation of typhoid patients to some forms of decomposing organic matter may possible infect them and the typhoid microbe may there grow and multiply. This we assume to be the case, but more evidence is necessary to prove it. If such were so, how is it that in the low-lying parts of towns where fever cases have resided in the past, where the soil is rich in organic debris and moist from the continuous irrigation of slop-water, that we do not find more cases of fever? If we collect the statistics of such a scattered place as Brisbane, we shall find rather that typhoid is more frequent on the tops of dry ridges far away from the valley of drainage. Children re-admitted to schools after recovery from typhoid at times distribute the disease; of the truth of this statement I have good evidence.

Our rising Colonial Universities give us good ground for hope that advancement in Medical and Sanitary Science may be reasonably expected. The excellent medical work done at the University of Melbourne calls for our warmest admiration. and the perfecting of the class-rooms and laboratories is now being proceeded with regardless of expense. The extent to which Adelaide has developed medical teaching at its University astonished me much, and I felt as if it would be a great pleasure to stop a session to listen to the information to be gained from Dr. Stirling, Professor Watson, and the hospital surgeon. A great advantage Adelaide possesses as a scientific school is the proximity of the Botanical and Zoological Gardens, the Hospital, the Museum, and Literary Institute, with each other. The absence of confusion created by great mercantile affairs will also act favourably on mental culture. The late M. Miklouho-Maclay, in his wanderings selected Sydney as the most suitable spot in Australia for the erection of a Zoological Station, and we all know of his efforts in this direction at Watson Bay, but with all his labours how premature was found the time for carrying out the noble idea. Still, one cannot doubt that the judgment concerning the fitness of this place—opening as it does into the great Pacific and receiving contributions from many lands was correct and manifest to all. Your University will make good use of this wealth of material, will investigate and demonstrate the science pertaining thereto. The Australian Museum here shows a marvellous collection of natural history which will increase as years go on, and Sydney as a teaching school of science will be unrivalled. With a climate more favourable to health than any European centre can boast, with a cheap, abundant, and varied food supply; with unlimited fields of recreation by sea and land; with the English language everywhere ready to comprehend all the requirements necessary for his comfort, the student of medicine and natural science will find here a field for the development of his health and faculties unsurpassed in the world. And to conclude, it is to be hoped that this Association will be of great use in combining the wealth of your rich men and the energy and foresight of your philosophers, patriots, and men of taste, so as to produce that high education so necessary for the Advancement of Science in this great and glorious country.

The following papers were read:—

1.—ON THE CLASSIFICATION OF PERSONS WHO HAVE BEEN EXPOSED TO THE INFECTION OF SMALLPOX SO AS TO SHOW THE RELATION BETWEEN THE INCIDENCE OF THE DISEASE AND DIFFERENT DEGREES OF PROTECTION BY VACCINATION, OR BY A FORMER ATTACK.*

By J. Ashburton Thompson, M.D. Brux., Dipl. Public Health, Camb., Chief Medical Inspector of the Board of Health, and Deputy Medical Adviser to the Government of N. S. Wales.

Vaccination is a branch of the science of disease-prevention with which all especially interested in that are perfectly familiar. It seems best, therefore, that I should state a series of brief propositions to which explanatory notes are appended.

PROPOSITION I.

The principle of classification is to decide all the cases in which any of the necessary data are defective or wanting, so that they weigh against the protective power of vaccination.

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* This paper was written at the wish of the late Sir William Smart, K.C.B., M.D., R.N., for presentation to the Epidemiological Society of London; but that gentleman having died, to the loss of epidemiological science, soon after his request was communicated, I feel I cannot do better than present it to this Association.

Note on the Principle of Classification.—The purpose in view is to bring the protective power of vaccination as now practised to the test of experience; and that in the face of some lingering scepticism on the part of a section of the public, and of a few eccentric members of the medical profession. It is most necessary, therefore, that records intended—not to show the efficacy of vaccination against small-pox, but still farther to test it, should be scrupulously compiled; and that in those cases in which certainty cannot be arrived at, the doubt should be recorded as against vaccination.

PROPOSITION II.

The elements of classification of persons who have been vaccinated in infancy or childhood are (*a*) character of scar, (*b*) area of scar, and (*c*) age of the subject.

Note on the Classification of Scars by Character.—The characteristics of "good" and "indifferent" scars have been defined by Marson in words which are as forcible to-day as when they were first uttered nearly forty years ago. A "good" scar, he says, may be described as distinct, foveated, dotted or indented, in some instances radiated, and having a well, or tolerably well-defined edge; an "indifferent" cicatrix as indistinct, smooth, without indention, and with an irregular, ill-defined edge. But it will be observed that before deciding whether a scar is good or indifferent, it is necessary to inquire into its origin. This is a question which has hitherto received little attention. Vaccine scars have the appearance described by Marson; but is that appearance exclusively theirs—have they in reality characteristics? As soon as I began to examine cases of suspected small-pox, in judging which the fact of former vaccination or non-vaccination is occasionally an aid to diagnosis—as soon as I began to examine witb this object great numbers of persons of all nationalities and all conditions both on shore and on shipboard, I was struck with the very large share that position, and the verbal evidence offered by the subject, in reality have in forming an opinion as to the cause of the scar in very many cases. Especially was I struck with the frequency with which firemen and engineers show small scars which are "distinct, foveated, dotted or indented, having a well, or tolerably well-defined, edge"—scars which nevertheless are not due to vaccination at all, but to mere superficial burning. A different kind of difficulty arose, such as the following:—A woman who had been exposed to infection fell ill while under observation, and suffered quite clearly from small-pox, although in a much modified form. In the face of her reported statement that she was unvaccinated—a statement she supported with circumstantial details of an unsuccessful attempt to get vaccinated made within her recollection, the modification of the disease was remarkable. I therefore examined her myself, and I found in the usual position on the upper arm one oval, indistinct scar, entirely wanting in foveolation, and having a very ill-defined edge. She knew nothing about its history; and from the objective signs alone it was impossible to ascribe it to vaccination. How was the case to be classified? I communicated with the patient's mother, and she replied "that she thought her daughter had been vaccinated." Then, and then only (to my mind), it seemed just to conclude from all the circumstances together—the position of the scar, its faint resemblance to a vaccine scar, the verbal evidence of the mother—that the patient probably had been vaccinated. Another test applied itself at the outset of this necessarily careful and systematic observation of alleged vaccine scars. As an Englishman accustomed to have shown him as vaccine scars always two, three, or more cicatrices in a particular situation, and arranged there with uniformity of figure, I found it extremely puzzling at first to pronounce to my own satisfaction—that is to say from the objective signs—on solitary scars pointed out on several unusual parts of the body; on the leg, the thigh, the forearm, the abdomen, and even the back of the hand or foot. In fine, I am not at present ready to admit that a scar can be certainly attributed to vaccination by examination of the objective signs alone. I am prepared to find that perfectly typical cicatrices can thus be diagnosed; but as yet I have not, I feel, examined with a sufficiently critical eye a sufficient number of scars undoubtedly otherwise produced and more or less closely resembling vaccine scars. I arrive, however, at this important conclusion: That in a very large proportion of cases the question—Has this person been vaccinated at all? can be answered only with the assistance of such indirect evidence as position and a verbal statement afford. But if the answer be in the affirmative, it is not difficult to classify by *character* cicatrices thus admitted to be due to vaccination. The essential characeristic of a scar known to be due to vaccination is, I believe, its foveolation; neither recently nor in former years have I had sufficient experience of the radiated variety to say anything about that. It is rare. Now, I believe that all scars may and should be divided into only two classes; "good" and "bad." I do not for the present purpose admit Marson's rather dubious term "indifferent." If after consideration it seems that the subject has really been vaccinated, then if there is anything characteristic about the cicatrix at all — and that I submit practically means if there is any foveolation at all—I classify it as a "good" scar; for I believe that a more or less foveolated scar alone constitutes evidence of a vaccinia which has run a tolerably normal course, which may be relied upon therefore for the production of some constitutional protective change. These are broad lines of judgment, and they are so designedly. A vaccination which has not produced a well-foveolated, depressed cicatrix, having a fairly well-defined edge, and visible several yards away, is a vaccination which has not conferred on the subject all the protection which a primary vaccination is capable of giving; nevertheless, I am content to classify as "good", scars which show some, although not perfect foveolation, although scientifically they are something less than good, in order not to overstate the case for vaccination. All scars without foveolation—from mere smooth ill-defined cicatricial whitenings of the skin, such as are due to imperfect vaccination by puncture, to the sharp-cut deep scar with a raised and often livid centre, which is the result of ulceration of the vesicle—all these I classify as "bad."

Note on the Classification of Scars by Area.—Jenner's vaccinations from spontaneous cow-pox by puncture would classify but low on any scheme hitherto projected or at present possible; yet their protective effect was such as withstood the severest tests, including inoculation with variolous matter. (An Enquiry, &c.," "Further Observations, &c," and "A continuation, &c.," reproduced in facsimile from the 2nd Edition for the Government of New South Wales, 1884.) Marson's statistics have shown that the protection conferred by vaccination as now commonly practised is in relation to area as well as to character; all classifications must, therefore, essentially resemble his. But I venture to suggest that his four categories of area which were possible and proper in his day, because, I suppose, vaccination was then ordinarily done by puncture, are now become inexact and inappropriate. As long as operation by single puncture was in vogue, statement of the number of scars constituted in fact a sufficiently accurate statement of area; for good vesicles so produced result in scars which usually measure .12 of a square inch, and seldom fall below .1; an observation for which we are indebted to Dr. Burdon-Sanderson, and which I have verified for myself. But the operation by puncture having been superseded (at least among the English) by scarifications, abrasions, or multiple punctures, this auto-mensuration by mere reckoning of the number of scars is no longer possible. Moreover, the area of a scar produced by puncture being no longer familiar, the estimate of larger cicatrices as equivalent to "two, three, or four scars, &c," must be recorded subject to considerable doubt. It appears to me, therefore, that for any such purpose as we are now concerned with, resort to actual measurement has become necessary. Three or four years ago I caused a gauge to be constructed on the lines indicated by Dr. Burdon-Sanderson, in his Vaccination Report, included in the Sixth Report of the Medical Officer to the Privy Council. It consists of a small metal plate having a trapezoidal aperture like the section of a truncated cone. On one longitudinal margin are written at several points the length of imaginary lines necessary to reach across the aperture to corresponding points on the opposite margin; while on the latter are written, in terms of a square inch, the areas of circles having diameters equal to the imaginary lines. This plate being laid on the skin, the cicatrix is seen through the aperture; and the point at which its circumference touches both the lateral margins of the aperture being found by moving the plate up or down, its approximate area may be read off. Doubtless the desirability of using some such appliance as this has suggested itself to others; and perhaps they may have been deterred by the fear I myself felt, that it would prove too troublesome to be often employed. This might well be the case if a nearly accurate measurement were necessary; but indeed this cannot be made, since scars are most often not circular But all that it seems indispensable to learn, if any such method be followed, is whether the scarred surface is more or less than half an inch in area; and this may be easily and expeditiously reckoned with the gauge. I propose, therefore, that the record should not be expressed in terms of a square inch, but that scars should be described as being of "sufficient" or of "deficient" area; that is to say, as having an area of more or less than half a square inch.

This point then is arrived at:—That scars of primary vaccination may be classified first, by their good or bad character; and secondly, as being sufficient or deficient in area. Thus four categories are formed, namely, area sufficient, character good; area deficient, character good; area sufficient, character bad; area deficient, character bad.

Note on Classification by Age.—It remains to classify the subjects already arranged in the above four categories by age; for liability to post-vaccinal small-pox is greatest between the ages of fifteen and twenty-five. Increased liability to post-vaccinal small-pox begins to show itself at the age of ten years; however, the majority of attacks occur between the ages first named, and therefore, each of these four groups must be sub-divided into three: comprising, namely, those persons who are under fifteen, those between fifteen and twenty-five, and those above the latter age.

PROPOSITION III.

Persons who allege re-vaccination should be classed as showing, or as not showing scars; secondarily as having been re-vaccinated above or below the age of ten-years.

Note on the Classification of Scars of re-vaccination.—Careful observation causes me to assert that in the matter of re-vaccination the patient's verbal statement must be relied on; or rather is the only available source of information, speaking generally. The cicatrices are of two kinds—either they are well-marked, when they cannot be distinguished from primary scars; or they are ill-marked, and can only be distinguished from those left by the primary vaccination if the latter happen to be well marked. In the course of quarantine work many people are now met with who have knowledge enough to represent themselves as re-vaccinated, and who believe that they get thereby a better chance of early release. As I have been brought to the conclusion that it is for the most part impossible to tell from objective signs alone and with certainty, whether a person is vaccinated or not, so I have come to see that it must always be impossible so to tell whether they have been re-vaccinated or not. This statement is not intended, of course, to apply to re-vaccinations done within twelve months or so; scars of that age usually show sufficient evidence of their recent formation. For these reasons I propose to head any table classifying these, "persons who have been re-vaccinated," but the reservation "as they allege" must be understood. They should be subdivided into those who do and those who do not show scars; and here again the subject's statement alone is the ground of distinction between those alleged to be respectively primary and secondary. Lastly, each of these two groups must be further subdivided by age; as having been re-vaccinated, that is to say, before or after the age of ten years (among Germans and some Northern nations children re-vaccinated at all ages below ten are met with).

PROPOSITION IV.

Unvaccinated persons; persons who allege vaccination, but show no scars; persons who have been inoculated, and who do or do not show unmistakable scars of a general eruption; persons who allege foregone smallpox, and who do or do not show unmistakeable traces of it, and in whom it was primary or post-vaccinal; these must form classes apart, of which the members should be distinguished by age.

Classification of Degrees of Illness.

PROPOSITION V.

All cases of smallpox should be classified as follows in respect of severity of attack; but cases of the primary disease and of smallpox after vaccination, after inoculation, or after smallpox, should be dealt with in separate tables. Attacks, during which not more than fifty vesicles appear, should be called "very slight;" those which show from that number up to two hundred or thereabouts, should be called "slight"; those cases usually discriminated as "discrete" (being those in which the number of vescicles is such as conceivably might be counted) should be called "moderate"; while the semi-confluent and confluent degrees should be called "severe," and should be farther divided under a sub-head, showing which of them were "fatal."

Note on the Classification of the degrees of Illness.—In this respect I propose a change with greater diffidence. But as we now say that vaccination tends to avoid death rather than attack (implying, as well, that it avoids the serious constitutional damage so common after the primary disease), and as it is certainly known that vaccination does modify the disease with some limitation as to time, the important question now seems to be—"How much did the patient suffer?"

I now ask attention to a few tables which show this scheme of classification brought to practical test; they are copied from my report to the President of the Board of Health, on the case of the mail steamer Preussen, which was presented to the Chief Secretary at the beginning of the year 1887. But before they are examined I think it advisable to repeat what is already said in the title of this communication, namely, that it is a scheme for showing the incidence of smallpox upon persons who have been exposed to infection and their different degrees of protection by vaccination as at present practised. Whatever it may be worth, its value, and that of any similar scheme, is but secondary—but an expedient by which an actually existing practice may in the end be rendered a little less uncertain than at present in individual cases it is. Consideration of Jenner's practice and of his results shows clearly enough that quality of lymph is the thing; and that if the large proportion of post-vaccinal smallpox now witnessed be capable of reduction, that reduction will be effected by improving, not methods of operation, but methods of lymph-cultivation.

(Extracted from "A Report upon an outbreak of small-pox on board the ss. Preussen, Anno. 1886.")

Analysis of the state as to vaccination of, and the incidence of small-pox upon 312 passengers landed at the Quarantine Station, Port Jackson.

NOTE.—In considering the following figures it must be always remembered that the numbers dealt with are extremely small; and that although statements of percentages are made they have no significance of general application. The influence of vaccination upon susceptibility to small-pox has been deduced from many million observations, and the results of this unparalleled experience may be stated as laws. But their application is true only of large numbers of persons. The fate of individuals or of small communities cannot be foretold by them.

Passengers Unvaccinated.

There were nineteen persons who had never been vaccinated.

TABLE I.

CLASSIFYING nineteen unvaccinated persons by their ages, and showing the number that escaped, the number attacked, the degree of illness in each case, and the number that died.

Percentage attacked, 78.9; percentage of attacks fatal, 60 per cent.

	0-1	1-5	5-10	10-15	15-20	20-30	30-40
Number at each age	4	3	3	2	1	3	3
Number escaped	1	1	...	...	...	1	1
Very slight	...	...	...	...	...	...	...
Slight...	...	...	...	...	...	...	...
Moderate	...	2	...	1[1]	...	...	...
Severe	...	...	1[2]	1[3]	..	1	...
Fatal	3	...	2	...	1	1	2

1. This child was successfully vaccinated Dec. 27, and fell ill Dec. 30; the rash aborted at the 5th or 6th day. 2. This child lost one eye. 3. This child lost both eyes.

Passengers alleging vaccination, but showing no scars.

There were sixteen persons of whom vaccination was alleged, but whose arms showed no scars; fourteen of them were over twenty years of age. Two were attacked, and both recovered, One, a man aged thirty-eight, suffered slightly, developing only about one hundred vesicles in all. The other, a girl aged seven, was re-vaccinated December 28; and as the operation seemed likely to fail, it was repeated on January 2, with ultimate success. But on January 5 she fell ill; six or seven vesicles appeared, which aborted at an early stage.

Passengers who had been vaccinated and re-vaccinated.

There were fifty-five persons who had been vaccinated and re-vaccinated before embarking. They are classified in the following table:—

Table II.*

Classifying the re-vaccination of persons vaccinated and re-vaccinated before embarking, and showing the incidence of smallpox upon them, and the degree of illness in each case.

Total, 55; attacked, 4; percentage attacked, 7.3; mortality, nil.

	Showing scars of revaccination.					
	Number.	Very slight.	Slight.	Moderate.	Severe.	Fatal.
Done { Under 15 ...	12	1	1	......	......	......
Done { Over 15 ...	15	1	......	......	......	......
	Revaccination alleged; showing no scars.					
	Number.	Very slight.	Slight.	Moderate.	Severe.	Fatal.
Done { Under 15 ...	14	......	2	......	......	......
Done { Over 15 ...	14	......	......	.....	......	......

* In this table the age 10 years should have been used instead of 15 years.

Passengers who showed scars of vaccination.

Table III.

Classifying of the vaccination marks of two hundred and nine persons done in infancy or childhood, showing the number attacked with smallpox, and the degree of illness in each case.

Class I.—(Area of scars, sufficient; character, good).

Total, 103; attacked, 20; percentage, 19.4: deaths, nil.

Age.	Number.	Cases of Small-pox and degree of illness.				
		Very slight.	Slight.	Moderate.	Severe.	Fatal.
Under 15	35	......	......	......	......	......
15-25	38	8	1	1	1	......
Over 25	30	4	......	4	1	......

CLASS II.—(Area of scars, deficient; character, good).
Total, 47; attacked, 9; percentage, 19.1; deaths, nil.

Age.	Number.	Cases of Small-pox and degree of illness.				
		Very slight.	Slight.	Moderate.	Severe.	Fatal.
Under 15	14	1	......	......	......	......
15-25	11	......	......	......	1	......
Over 25	22	5	1	......	1	......

CLASS III.—(Area of scars, sufficient; character, bad.)
Total, 27; attacked, 5; percentage, 18.5; deaths, nil.

Age.	Number.	Cases of Small-pox and degree of illness.				
		Very slight.	Slight.	Moderate.	Severe.	Fatal.
Under 15	6	......	......	......	......	......
15-25	5	1	......	......	......	......
Over 25	16	1	1	1	1	......

CLASS IV.—(Area of scars, deficient; character, bad.)
Total, 32; attacked, 11; percentage, 34.3; died, 3; percentage of attacks fatal, 27.2.

Age.	Number.	Cases of Small-pox and degree of illness.				
		Very slight.	Slight.	Moderate.	Severe.	Fatal.
Under 15	7	......	......	......	......	......
15-25	12	......	2	......	1	3
Over 25	13	......	1	......	4	......

H 1

SATURDAY, SEPTEMBER 1.

Dr. J. Ashburton Thompson, M.D. Brux., &c., in the Chair.

The following papers were read :—

1.—THEATRE-HYGIENE.

By WALTER E. ROTH, B.A., Oxon.

"THEATRE-HYGIENE" may be described shortly as an investigation into the sanitary and psychical conditions of stage-life generally. It comprises a study of the best structural and decorative arrangements to be adopted in the construction and fitting of theatres, music-halls, and kindred establishments, together with a consideration of the legislative enactments bearing on the same. The object of such an investigation is the health, comfort, and safety, not only of the theatre-going public, but of all the players and other people employed.

The earliest literature at all worthy of record, and that illustrative of only a special branch of the subject, comprises the researches of Tripier on the Ventilation, Lighting, and Warming of Theatres, published at Paris in 1859. Since that time several other monographs have appeared by various authors in the several special departments, such as the writings of Geary on Theatre-Law, Fölsch and Shaw on Fire Prevention, Fitzgerald on Scenic Illusion, &c. It was not until two years ago, however, that Theatre-Hygiene began to be treated as a separate study in itself, and an attempt made to popularise it by the publication of a series of articles written anonymously in the *Stage* newspaper. The first work dealing systematically with the subject as a whole was published by Roth in London early in the present year.

The ignorance of the Sydney public concerning the dangerous state of the theatres they frequent is apparently shared in some cases even by the managers themselves. It was only on the first of this month that Mr. Rignold, of Her Majesty's, wrote to one of the morning papers to vindicate the character of that edifice, the most modern in Australia, which he claimed in effect, to possess all the reforms which the law either suggested or demanded. According to the Report of the Royal Commission appointed in June, 1886, and Parliamentary Paper, however—the latter drawn up by the Colonial Architect and published as late as last November—this particular theatre would seem to bear the odium of faulty construction equally with that of the other Sydney play-houses.

For instance, though there is a skeleton iron-work frame, with asbestos cloth curtain—the only fire-proof curtain in Sydney, it is true—there is at present no means adopted for lowering or raising it. On both sides of the proscenium party-wall there are openings to various parts of the edifice. Fireproof doors are absent in the passages and doorways leading from all parts of the house, excepting the amphitheatre, to bars and saloons. The winding stair from the third gallery is dangerous in case of panic. Lighting arrangements are equally defective, the electric engine being situated in the basement under the dressing rooms with the floors above not rendered fireproof, while the gas meters are located inside the main building, not easy of access, where there is not the slighest ventilation, and where they are dangerous in case of fire. The six water-tanks, placed on a grid-floor, are inadequate in that they would only yield one hundred and fifty-nine instead of two hundred and fifty gallons per one hundred people. The dressing rooms, which usually come off worst, are constructed of three floors, the second and third being reached by a winding wood staircase, with the result that the inmates could not escape if fire or smoke entered the stair. If defects such as these are to be found at Her Majesty's, the so-called premier theatre of Australia, the faults and failings of the remaining structures can be better imagined than described.

The fact that certain buildings not originally designed or constructed as such, have been subsequently converted into play-houses will account for many deficiencies with regard to site, proscenium, external and party-walls, and the location of scene-dock, workshop, property-room, or store-room within the precincts of the building. Thus, the Gaiety Theatre was originally erected for a Hall for the Society of Guilds, with level floor and no stage; the Standard for a Royal Foresters' Hall; the Opera House designed originally as a Music Hall; the Alhambra Music Hall primarily erected for a Bazaar or Auction Room; while the Academy of Music (lately the Victoria Hall) was actually built for and used as a billiard room. In addition, owing to want of space and increasing value of building land, the accommodation in all directions has become limited, and many devices resorted to, such as lumbering up the basement under the stage with property sent down through the traps, having portions of the buildings set aside for hotel, shop, or other business purposes, placing the orchestra under the stage, the dressing-rooms under the auditorium, and trying other expedients alike incompatible with health and safety. In other cases, the licensing authority is to blame, as in the case of the Theatre Royal, of which building the Colonial Architect says, "no portion of this house is fireproof, and if a fire takes place, a few seconds only can pass before all will be in flames:" and in the case of the Criterion where the recommendations made by the Commissioners have been totally ignored.

It is of course impossible to treat fully, within the limits of a short paper such as the present, all the various structural details of a healthy theatre, although there are a few essentials which must be drawn attention to.

The site should admit of the building being free on all sides, not only for egress to the open air, light and ventilation, but also for the safety of adjoining buildings in case of fire, to allow of room for the operations of the fire-brigade, and to permit of the construction of a system of external balconies, as at the Flemish Theatre in Brussels. The proscenium-wall also requires special features of construction.

Entrances, but most certainly exits, from the more expensive portions of the building should be situated in the narrower thoroughfares, and those from the cheaper parts in the wider ones. The end in view of this arrangement is to lessen the magnitude of the crowd congregating; for instance, during ingress or egress there will be a comparatively large number of people collected outside the pit or gallery doors than there would be at the stall or box entrances. This cumulative wedging in of the victims at the entrance doors by the external crush was a very important factor in the terrible loss of life at the Vienna Ring Theatre.

After the width of a stair, whatever that may be, has once been fixed, it should be uniform throughout that stair, and on no account be reduced by the erection of a ticket-office, ventilating flue, or other contrivance, which only act as blocks to the passage-way.

With regard to the matter of seating accommodation, I have proposed a wholesale reform by which all the seats are placed either in single, double, or even treble file, vertically to the proscenium, with gangways intervening; thus, people may come out or in without inconveniencing either themselves or others who may be already seated. It must be distinctly understood that where once a building has been constructed to accommodate a certain number of occupants, any excess of that number is on no account to be tolerated. A building is intended to hold a certain number of people; the fittings, appliances, means of escape, amount of water in case of fire, &c., are all based and calculated on that number, and will naturally prove deficient and faulty supposing it to be exceeded. There was a grim satisfaction in knowing that the Theatre Royal accommodated eight hundred and eighty-nine more visitors than it was seated for!

All the world over, actors have the most abominable rooms to dress in, and Sydney unfortunately proves no exception to the rule. At the Criterion Theatre they are situate in the basement, under the auditorium, divided from each other by wood partitions, there is an alley-way encircling them, five w.c.'s and three urinals here, no light to the rooms except gas, very defective ventilation, and a disagreeable smell pervades the whole area. The dressing-rooms at the Standard are obstructed by a temporary building used for scene-dock and property-room, while at the Opera House, in case of fire on the stage, escape from these rooms would be impossibles.

Ventilation should be adequately provided for by mechanical means, and that of auditorium and stage should be separate. Physiologists tell us that 750-1000 cubic feet is the minimum space required for each individual, in order that the air may be kept in a salubrious condition—even then it must be changed three or four times an hour—and the best machinery employed to effect such change so that no draughts are felt. By means of some tables drawn up from official data, I have calculated within wide margins the number of cubic feet in some of the leading Sydney Theatres for every person therein assembled—this varies from 90.1 cubic feet at the Standard to 229 cubic feet at the Theatre Royal. Considering that with very rare, if any, exceptions no mechanical system of ventilation is adopted, the vitiated atmosphere baffles description. The position of the exits for vitiated air varies a good deal. Sometimes they are placed at the back of the stage or through the wings—often the exit is at no higher level than that of the dressing-rooms, which accordingly get filled with bad air. The ordinary funnel-shaped ventilators in the dome, worked by a ring of gas-jets are not always efficient, for the heated atmosphere from the central burners often overflows the opening and returns to the room. Similarly in the case of flues which, though perhaps well adapted by mechanical means for drawing off any vitiated air, are often put up in a building without any compensatory arrangement for the admission of pure air, except by doors and windows. Louvres are used in some of the theatres here, but unless specially constructed are apt to let in the rain and permit down-draughts. In the roof over the stage of the Theatre Royal there are no openings, louvred or otherwise, for the escape of smoke, &c.

It seems strange that with the good results obtained by constructing the roof on the sliding principle, as adopted at the Hippodrome in Paris, the Pavilion and Canterbury in London, or the Princess' at Melbourne, that such method has not come into use in Sydney, where the climatic conditions are incomparably superior.

A very common complaint, and one not at all easy to remedy, is the defective transmission of sound so often experienced. In defence, it might be urged that the acoustic principles, except the most fundamental, in so far as they are applicable to the play-house and concert room, have never received the necessary attention at the hands of any authority sufficient to warrant their introduction into the plans. It is rather hard on the performers to have to speak their parts with greater exertion than necessary, and equally distasteful for the public to keep their hearing continuously strained. Statements have been made to the effect that in those rare cases where the structural design admits of too marked and unpleasant an augmentation of sound, a successful remedy is to be found by fixing wires in particular directions across the upper internal portions of the edifice.

There is a remarkable tendency in the modern theatre to bathe both stage and auditorium in a mass of glaring light. On the stage there is certainly much too much of it: in the old days the greater portion of the stage was thrown into obscurity, the lights being directed on the performers, an arrangement which rendered the scenic illusion still more complete. For in everyday life, when witnessing any passing circumstance or event, what we are most struck with, is not the surroundings but the individuals engaged. In the auditorium again, the flood of light from the central chandelier, though defended on the ground of assisting in the expulsion of vitiated air, might easily be dispensed with, proving as it does a source of no small annoyance to the people in the upper tiers and gallery.

At present, the heated atmosphere and noxious products of combustion are strong objections to the use of gas. Gas footlights are a terrible ordeal to the poor actor; unless well accustomed to them his eyes are worried with the flickering glare, and his throat often parched up, at a distance of some few feet even, by the oppresive heat and combustion products arising; in addition, the various vapours resulting produce such rarefaction as to render it necessary for his voice to be considerably raised. In Spain, the latest regulations to hand prohibit the use of gas *in toto* after the next six months. Where employed at all, the gas pipes should be laid *in* the walls, and not external to them. The necessity of this method of fixing pipes is well illustrated by the fatal panic at Spitalfields (London) where the prime cause of the disaster appears to have been the knocking or pulling down of such a gas-pipe affixed *to* the wall. It is curious to learn that at the Opera House here, the tubing connecting the gas-lights on the flies is of rubber, the condition of which, according to the last report of the Colonial Architect, is described as decayed and dangerous!

There can be no doubt as to the expediency, from a health point of view, of resorting to electricity as the very best of illuminants, but even that is liable to danger unless sufficient precautions be adopted. For instance, at the new Burg Theatre in course of construction at Vienna last year, considerable damage was occasioned by a flaw in the cable, while a little over a month ago, a similar accident took place in one of the courts of the Melbourne Exhibition.

Whichever the source of light, meter or dynamo, should be situated outside the walls of the building, and at least, the lighting of the stage and auditorium should be separate. The gross dificiencies in this connection at Her Majesty's have already been referred to. At the Criterion, the meters, with tanks for oxygen, are located in the basement under the auditorium, where there is neither daylight nor ventilation. The Gaiety also is to blame for having its gas storage within the main building, under the stairs leading to the balcony. The Opera House has its supply situated under the rear of the stage, and in addition has its stage footlights very improperly protected. Worst of all, however, is the Alhambra Music Hall, where the meters are placed in a recess, under the stage, which is locked; beside it are three buckets of water, which could not be got at if wanted.

The *rôle* of the stage flooring being to act somewhat after the manner of a huge sounding box, it is desirable that the space beneath be unoccupied and not filled up with rubbish. The Criterion Theatre for instance has its basement under the stage, with the scene-pit lumbered up with property, sent down through the traps on the stage floor. The Standard also has the area under the stage at present filled with rubbish, has no ventilation, and is stifling and dangerous to health.

With regard to water supply, the water in the mains being at such a low pressure, cisterns should be provided containing at least two hundred and fifty gallons of water for every one hundred persons in the audience to be accommodated in the building. This minimum of two hundred and fifty has been determined upon, after mature deliberation, by the London Metropolitan Board of Works. These cisterns or tanks ought to be placed on the top of the proscenium wall or on the top of the outer walls of the staircases; indeed, in those situations where, in case of fire, they would be furthest removed from accident, and perfectly free to act. They may not prove of much value when placed up in an attic or on a grid-floor for the reason that, with the destruction of the wooden supports on which they are resting, they would probably speedily be overturned. The water in the tanks, as well as in the fire-buckets, being solely for use in the extinction of fire, should not be made subservient to any other purpose whatever; the water must be there when wanted.

Many accidents arise in connection with defective stage-apparatus and appliances; so severe are these occurrences occasionally, that they may lead to permanent disablement of the sufferer, if indeed they do not prove to be immediately fatal. Among such accidents may be mentioned the giving way of a trap-door or rotten rope; this latter danger is especially apt to occur with performers on the flying-trapeze, rope-dancers, &c., and could always be prevented by careful examination previous to an entertainment. Similarly the blankets or rope-netting used in connection with actors when throwing themselves over a bridge, &c., into the waters below, should all be carefully tested beforehand. Battles on the stage are common enough, and cannon and musket are discharged with good effect, a sort of drawing-room cartridge made of phosphorous having been invented specially, which on explosion leaves no trace. Great caution, however, has to be observed in the use of firearms, and in the French Theatres the ramrod is always fixed by a chain to the wall, as in the hurry it is often forgotten in the gun. Thunder on the stage is represented by a truck laden with shot wheeled along and which tilts over—it was less than a year ago that a stage employé at the Tyne Theatre, Newcastle, was killed by one of these shots falling upon him, The Oxy-hydrogen light again, has often proved dangerous owing to the irregular mixture of the gases,—I myself have collected particulars of five such cases within less than as many years. It will be recognised that many of these accidents in connection with stage-apparatus, of which the above will serve as typical examples, are in a great measure preventible, and therefore ought to be as far as possible guarded against. There are certain sources of accident however which only special legal enactment would seem able to cope with, the prohibition indeed of any public exhibition or performance whereby the life or limbs of the players are endangered. There is exactly the same skill in walking on a tight-rope three feet from the ground, as there is when the rope is fixed at thirty, with the addition that in case of a fall, it would be but trivial in the former case, possibly fatal in the latter. Morbid craving for such sensational displays ought certainly to be checked ; if the management insist on having the rope fixed at a dangerous height, the law ought certainly to insist upon there being a network provided beneath.

So far as scenic illusion is concerned, there is on the stage itself great room for improvement in connection with footlights, the scenic apparatus, and the scene-shifting. Footlights might advantageously be abolished, and a reversion made to the old system of illuminating from above and from the sides—the natural order of things in everyday life; if, however, they be insisted on, they ought certainly to be sunk below the stage level, and thus rendered invisible to the audience. The old system of flats, side scenes, and borders, has of late years been tentatively replaced by elaborately built-up scenery, an unhappy innovation, in that the rules of perspective and distance cannot be properly carried out. Change of scene ought certainly to be effected noiselessly, speedily, and in obscurity. The unnecessary glare of light in which the stage is bathed has already been alluded to. Among other conditions interfering with the illusion, and of which the reform lies in the hands of the management, may be mentioned the following, viz. :—The custom of pitching flowers on the stage, or handing them over the footlights, and the interruption to the action on the stage by artists advancing to the front to receive these demonstrations of the audience. Nothing is more irksome than the delays which thus often occur in the most interesting part of a play, and all such practices, as in Austria, should always be most rigourously prevented and suppressed.

Similarly in the auditorium, scenic illusion is well-nigh impossible to a spectator the martyr of a seat much too small to sit upon, a draught from some ill-fitting door presumably closed, playing the harbinger of a long doctor's bill, and an atmosphere of so stuffy and contaminated a nature as to threaten imminent suffocation, in addition to the several lesser evils existing on every side in an ill-constructed and badly-fitted place of entertainment. The public have only themselves to blame sometimes, as on the disturbance consequent upon certain of the spectators entering after the commencement, or leaving before the completion of an act. As in all other walks of life, so here in the histrionic, the individual becomes ultimately more or less imbued with the ideas and sentiments peculiar to the exercise of his profession. Such people as Garrick, Mrs. Siddons, and several others have borne ample testimony of the obscure yet certainly recognisable changes in the moral tone and character which slowly but surely follow on in the wake of self-deception which the actor in the earnest fulfilment of his duties has so continually and repeatedly to play. George Combe, in his treatise on Education, states the case very clearly thus: "One effect of the constant practice of players in calling up and exhibiting the natural language of the feelings, is to render some faculties habitually prone to action in themselves in private life. The great tragedian, who may be said to wield a magician's power over the propensities and sentiments of his audience by means of natural language, suffers in his own mind many tragic feelings from the trained activity of his organs. Many are irritable in consequence of the trained action of combativeness, destructiveness, and self-esteem—the stock elements of heroic and tragic characters. They are often melancholy and desponding from the trained action of cautiousness, which furnishes the perturbed and distracted countenance, the horror-stricken look, the shriek of despair, and sometimes the madness that petrify us when represented on the stage. The higher sentiments and intellect of the actor may govern his deportment in public, so that his general acquaintances may not observe these effects; but the close spectator recognises them, and the actor confesses and laments them to his bosom friend."

This physical influence of acting upon the actor has a very important bearing in connection with the employment of children on the stage. For, granting the possibility of certain significant changes arising in a nature fully matured, there is every prospect of these taking strange and deeper root in a character still developing and adolescent. Recognising, therefore, how easily a child's education might be tampered with, it becomes a momentous question whether juveniles should be permitted to undergo a histrionic training at all, and this quite independently of stage morality, &c. If the children are to be permitted, it would be well for the law to step in and enforce some form of apprenticeship which would ensure their being well cared for and looked after. Many a sad story could be told of the brutal and inhuman treatment that has been doled out to the young acrobat or tight-rope dancer, whose marvellous feats are possibly night after night drawing the acclamations of a crowded house, ignorant alas, of all the pain and sorrow underlying the gloss and tinsel. The only law, and that is in England, of which I am aware, bearing directly on the employment of children in theatres is in connection with dangerous performances—42 and 43 Vict. c. 34—wherein it is made a punishable offence for any person, parent, or guardian to cause any child under fourteen years to take part in such performance.

In a general way the health of an actor may be spoken of in very favourable terms. There is not too much, but yet quite sufficient study to keep his mind healthily occupied. The amount of exercise, with rehearsals by day, and performances by night, is quite ample to keep his physical powers actively engaged, while, with a moderate amount of excitement, both are maintained in good repair by plenty of change in association, ideas, and dress. Various circumstances stand in the way of careful and reliable enquiries being instituted as to any diseases or afflictions common amongst the profession. Among other sources of information there would probably be a fruitful field of search in the books of the various English sick-fund, provident, and benefit societies. Mortality statistics are also difficult to get. Judging from the lives of some of our eminent actors and actresses, the practice of their art appears on the whole to have had little or no effect in curtailing the normal natural existence, though it is possible that other things equal the longevity may be ascribed to the constant mental application exercised. As far as my limited experience goes there are no reported cases of the complaint popularly known as "clergyman's throat"; an explanation of this is easy when we bear in mind that whereas the parson usually harps more or less on the same note, which necessarily, sooner or later, becomes strained, the actor is continually employing a very varied series. Eyesight among actors is usually strong, the eyes can be long fixed without the slightest blinking. Short sight is exceptional, but this is only what we should have been led to expect from the very nature of the requirements of the profession. The different phenomena comprised under the term "stage-fright" are very far indeed from being thoroughly understood, though possibly these are all explicable by sudden want of confidence brought on by various causes; whereas in the olden days performers had often to be content with a day or two in getting up their parts, it is quite common nowadays, thanks to a plentiful market and long runs, for actors and actresses to have the full advantage of a four or five weeks' rehearsal.

Change of dress during the progress of the evening is an excellent one from a hygienic point of view. As a rule, an actor generally manages two or three changes, each time feeling his body refreshed and spirits revived. As regards dress material, we may mention that cases have been reported where the colouring matter of the stockings or 'tights,' has exerted certain deleterious influences on the subjacent skin; such examples fortunately have been so few and far between that the publicity given to them when recognised will, it is to be hoped, prove a sufficient obstacle to their recurrence in the future. Happily, the employment of lead, mercury, bismuth, or zinc, in the manufacture of the various cosmetics and paints requisite for histrionic portraiture is every day becoming more and more obsolete. In London it would seem to be under the authority conferred by Section 14, 6 and 7 Vict. c. 68, that the Lord Chamberlain might regulate the dress of performers.

As to the question of smoking in theatres, the exigencies of modern nature point to the early introduction of the fragant weed within the precincts of the play-house walls. We shall probably soon hear of a non-smoking, in contradistinction to smoking theatres. In making the suggestion that some sort of reform might be met half way, it may be mentioned that at a London theatre lately visited, one of the upper galleries was used as a smoking-lounge, and yet the evidence of tobacco-smell in the lower portions of the buildings was inappreciable. It is only fair to state, however, that the system of ventilation was complete, and everything to be desired. Should the novelty of such a plan produce too strong a revolution of feeling, we might well take a lesson from certain of the continental theatres where two or more evenings are specially set aside each week as smoking-nights. On the other hand, it must be borne in mind that the chief officers of the London Fire Brigade are strongly opposed to smoking in these places of amusement.

Turning now to the question of dangers from fire, the terrible disaster at the Ring Theatre in Vienna; at the Opera Comique in Paris, and still more recently at the Exeter Theatre in England, afford ample illustration of the dangers to which both audiences and performers are, and assuredly will continue to be exposed, so long as the system of reform in theatre-construction, supervision and management is so outrageously neglected as it is at present. The same causes, the same sequences of events which co-operated in the wholesale destruction of so much life there, are precisely similar to those which are liable any day to arise here. The structural condition of the buildings was notoriousiy defective, the doors were kept obstructed, the staircases were badly construced, and the exits far from adequate. Unfortunately the example set before us in this respect by the central city of the whole civilised world is even one to be avoided, not followed, for at the present moment there is not a single London Theatre which structurally can be considered perfect, which obeys the prescribed regulations, and which maintains all its appliances and arrangements in thorough working order and repair. In Sydney a gross structural defect in the proscenium party-wall, which, with but one exception, is unprovided with an iron fire-proof curtain—and in that solitary case is practically valueless—which contains openings, some of them without doors, leading to various parts of the house, and which generally is of the ordinary stud and board, or canvas construction. The experience derived from the study of theatre-con flagration has been to shew that no matter how well organised, human agency cannot implicitly be depended on. The London Alhambra was lost by the fireman attending a supper given by the players after the performance was over. At the Paris Opera Comique, on the memorable night in question, the iron drop curtain was never lowered, and though there were certainly water-pipes in the building, not a drop of water was directed on the flames till half an hour after the alarm. Such examples are numerous. For the prevention of fire we must look round for some apparatus that is independent of human assistance, that will always be ready, will never sleep, and will invariably act when required—among the nearest approaches to prefection might be mentioned the inventions patented by Carson and Sinclair. In addition, uninflammability should be the order of the day for all decorative work, both in front and behind the scenes.

In connection with fire and panics, it may not be out of place to note what was contemplated in the new Flemish Theatre at Brussels, now I believe completed. Here there is a system of external balconies or outer galleries corresponding to those in the interior of the building with which they communicate by no fewer than a hundred different doors, twenty-five to each tier. These balconies are further connected with each other by iron stairs of good width and easy descent, and the lowest of the four is capacious enough to give standing room to the entire audience.

A fire at a theatre, under certain circumstances, does not necessarily mean such pecuniary loss to the management as might be supposed, for it would appear to follow from the decision in Taylor *v.* Caldwell, that if a manager engaged performers to play at a particular theatre, and it was burnt down, the manager would not be held liable to the performers for salaries. Again, in Scott *v.* Howard, the decision was of similar import.

Legislation is essential in order to ensure effective arrangements for the control and management of theatres. In a certain sense it is true that theatres, public exhibitions, &c., in Sydney are licensed, the method of procedure being as follows:—When applications are made they are usually referred in the first instance to the police to see if there is any police objection to the applicant, or to the locality; then, they are referred to the

Colonial Architect for report as to ingress, egress, and general safety of the building proposed to be constructed, and if all is satisfactory the Colonial Secretary grants a license for twelve months. During this period the manager or proprietor is practitically his own master. He can apparently make any alteration in the building that he chooses; he may block up the doors, he may obstruct the stairways and corridors, and otherwise render the structure absolutely dangerous to life and property: the only check on these misdemeanours being a threat from the Colonial Secretary to refuse an application for renewal of his license, should he require one.

2.—THE PRESENT SANITARY CONDITION OF SYDNEY AS COMPARED WITH THE PAST.

By J. M. Smail, M. Inst. C.E., of the Government Sewerage Department, Sydney.

We are informed by the historians of the colony, that the inducements which led Captain Phillip, the first Governor, to select the site upon which the City stands, as the place to found the first British settlement in the Southern Seas, was the existence of fresh water streams discharging into deep water inlets or coves, also well-wooded slopes rising with easy grades from the running streams.

The colony was founded on January 26, 1788, so that in little over a century the primitive settlement has developed into the city of to-day.

The city is divided into two main drainage areas by a well-defined ridge extending from Ben Buckler on the seaboard, in a westerly direction to Botany-street, and then in a south-westerly direction towards Newtown. The drainage on the north flowing towards Port Jackson, and on the south into Cook's River and Botany Bay.

From the main ridge various spurs extend, separating the main watersheds into minor drainage areas, the water from these flowing into various coves, viz., Blackwattle Bay and Cockle Bay, now Darling Harbour, on the west side; Sydney and Farm Coves on the north; and Woolloomooloo and Rushcutter's Bays on the east side.

The first settlement was made on the shores of Sydney Cove and extended up the banks of the Tank Stream. This stream for many years supplied the early settlers with water, but as population increased and the settlement developed into a town, the source of supply gradually disappeared—became polluted and finally was utilized as the vehicle of carriage of the refuse and filth of the community.

The first water supply was brought from a place near the city, called Lachlan Swamps, by Mr. Busby; the supply was by means of a tunnel which ended at the junction of Oxford and College Streets.

Before the advent of the Botany water supply this tunnel supplied the wants of the inhabitants. Up to the year 1850, the water supply by reticulation was limited. From a report of the City Water Committee, it would appear that the domestic supply was chiefly drawn from private wells or public fountains; the applications for supply to houses did not exceed four hundred and seventy-six for a year, the revenue derived from same, being £423.

Macadamised roads, with the exception of the principal thoroughfares, was a dream of the future. Access to what might be termed the near suburbs, was to a great measure by unformed tracks—this to a large extent was due to the greater part of the population settling down near the centre of the city, the outskirts being but sparsely populated.

No system of underground drainage worth the name existed—a few detached drains for conveyance of storm-water or house slops from street gutters were constructed. The sanitary arrangements were of a primitive kind—the common cesspit, with its attendant abominations, was the rule—the refuse water passing by either formed or unformed channels into the nearest water-course, or over rocks as the case might be. Noxious trades of all descriptions were carried on in the heart of the city, which, from their very nature, could not be otherwise than detrimental to the public health.

The Public Abbatoirs were within the city boundary, on the shores of Darling Harbour, but these have been transferred to more congenial places.

Street lighting and scavenging were confined within certain limits. Street lamps were few and far between in 1850. The Lighting Committee of the old City Council could not recommend more than six lamps to be erected during the year. Scavenging was confined to the principal thoroughfares—the house refuse being disposed of in the most convenient manner possible. It should be mentioned that the unoccupied area bore a good proportion to that built upon—this, to a great extent neutralized the effects which, from the surroundings, could not have been salutary.

I have briefly, and am afraid imperfectly sketched the condition of old Sydney with its imperfections, and will now describe the condition of the city which was the outcome of a new order of things.

The old City Council was abolished by Act of Parliament and was succeeded by a body termed City Commissioners. To these gentlemen the city is indebted for the first movement in the way of improving, and providing for the sanitary wants of the community. This movement commenced about thirty-six years ago, and it is within that period that any progress in Sanitary Science has been made.

Under the City Commissioners a system of sewerage was devised with the view of intercepting the sewage from the slopes rising from the valley of the Tank Stream and discharging it at a point remote from the principal shipping centre.

The main sewer starts from Fort Macquarie and extends through the Government Domain to the Exchange, receiving the sewage from branch sewers in Macquarie, Phillip, Elizabeth, Castlereagh, Pitt, and George Streets.

The system was not carried out without considerable trouble and expenditure of funds owing to the natural formation, through which the bulk of the work was constructed, being sandstone. The sewers were designed in accordance with the best principles known at the time, and have answered the purpose for which they were carried out.

On completion of the work houses were connected thereto and the old cesspit gradually disappeared, although there were not a few instances where the facilities afforded were not availed of, the old order of things being adhered to.

The system commenced was gradually extended to other drainage areas of the city, but under different authority; the City Commissioners being replaced by the present City Corporation in 1857. Considerable progress has been made since the City Corporation assumed control of civic affairs in Water Supply and Sewerage, in forming and macadamizing roads, streets, &c., in kerbing, guttering and paving, in constructing markets, warves, forming parks and other recreation grounds, providing public drinking fountains and urinals, cleansing and watering streets, &c.

It was found necessary, owing to the growing requirements of the city, to extend the source of water supply, the limited catchment of the Lachlan Swamps being inadequate to meet the demand. The increased supply was found in the Botany Swamps, and by impounding the water by a series of dams between Randwick and Botany roads, a daily supply of 5,000,000 gallons equal to twenty-five gallons per head of population was available, the catchment area being about six square miles. The increased supply enabled the authorities to extend the sewerage works to all parts of the city and to provide such conveniences for the public as materially tended to improve the sanitary condition of the metropolis. The gradual extension of sewers has to a very large extent abolished the cesspit nuisance and the antiquated and abominable system of cleansing. Almost every street within the city boundaries has been provided with a sewer and the facilities afforded for carrying off quickly all offensive matter has in a measure contributed to the comparatively low death rate of the city.. The total length of sewers laid in the latter is sixty-one and three-quarter miles.

The removal of house refuse has been for a considerable time worked in a systematic method, but the manner of disposal leaves room for considerable improvement.

Various low-lying areas in the eastern and western sides of the city, which in former years were hot beds of disease, have been reclaimed and formed into parks, thereby increasing the lungs of the city.

The change in the character of the buildings in the last twenty years is worthy of note. It might, in all truth be said, that during that period Sydney has been re-built. The main thoroughfares have entirely changed—scores of small tenements have been absorbed by large spacious warehouses, offices, &c. The various places or courts, ill-drained, badly ventilated and fever-breeding haunts, have, with few exceptions, disappeared. On the western side of the city this change is gradually taking place.

The facilities for traffic have increased greatly. From published returns it appears there are about one hundred miles of streets in the city to cleanse, for which a small army of scavengers is required; this work is reduced to a system and materially contributes towards maintaining the public health. The introduction of improved roadways will no doubt in time exercise considerable influence on the health of the community; the question should be considered from a sanitary as well as a constructive standpoint.

The death-rate of the city for the past fifteen years as compared with the suburbs is very marked. The mean rate being—city, 23.37 per 1,000; suburbs, 18.00 per 1,000, a difference of 5.37 per 1,000. When the yearly rate is observed it will be seen that in the years 1885-86 the death rate of the city was .67 per 1,000 and 3.98 per 1,000 respectively lower than the suburbs. The city having a higher standard of health than the suburbs may be accounted for in several ways:—

(a) *Increase of Population.*—The city has, in sixteen years, increased 57,353; suburbs 140,778 or 2.5 times more. The decrease in Sydney owing to absorption of tenements for business purposes has added to the suburbs.

(b) *Deficient drainage.*—The greater part of the suburban area is without any means of conveying the offensive matter from their midst; here history is repeating itself. What was the condition of the city in the earlier days is repeated in many parts of the suburbs at the present day. Many other causes may lead up to the solution of the question, but as this paper does not treat of the suburbs, but of the city, it may not be out of place to compare the death-rate with other countries. Taking some of the principal cities—say London,* 21.4; Boston, 22.0; Paris, 26.3; Berlin, 26.4; New York, 30.6; Montreal, 27.12; Sydney, 21.36, per 1000. These figures are for the year 1884—the rate for the city for 1886 is 17.06 per 1000.

It will be seen from the foregoing figures that the health of the city will compare very favourably with the leading cities of the world.

The completion of the new scheme of water supply and sewerage, together with proper legislation will tend greatly to improve the comparison.

An increased supply of water, affording facilities which cannot be overestimated from a sanitary view, and available for the smallest tenement in the suburbs, cannot but be productive of good results—the necessity of drawing the domestic supply from wells very often contaminated with fœcal matter and decomposed organic filth, will be dispensed with.

The interception of sewage from the harbour and inlets, and the discharge of the same into the sea, or disposed over land, will also materially contribute to the public good. The crowning point to be attained is the efficient ventilation of our public and private sewers. The three great factors of opposition to be met with on this head are—ignorance, sentiment, and greed. The first can be disposed of by educating the objectors up to the natural laws which govern health; the second is the most difficult to deal with; the third can be met by proper legislation. The object to be attained in all sanitary works is the preservation of the public health; a low death-rate means a saving to the State, a high death-rate on the other hand is a loss. In an article in one of the daily papers, the writer says, in connection with sanitary matters that—"We are not hopeful that anything that can be done will bring the general mortality of a crowded city with so many conditions unfavourable to health, within the range of a death-rate of a population who breathe pure air and exist in the favourable circumstances of the country. But we are satisfied that much may be done to reduce the mortality of our growing cities."

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* Trans. Inst. Civil Engineers, Vol. LVXXI.

"The question of the improvement of sanitation has long been been one of great concern among the Borough Corporations of the mother country. It is the attention which has been devoted to it which mainly accounts for the low rate of mortality enjoyed by the towns of the mother country in comparison with those on the Continent of Europe."

"The severity of pestilential visitations has been greatly mitigated where it has not been entirely averted by the sanitary measures adopted."

DEATH RATE, CITY AND SUBURBS, 1871-86.

Year.	City per 1000.	Suburbs per 1000.
1871	20.67	14.46
1872	23.03	14.15
1873	22.37	14.63
1874	25.16	16.59
1875	31.65	21.47
1876	28.87	20.79
1877	22.43	15.13
1878	25.05	17.37
1879	23.47	15.83
1880	27.26	19.16
1881	21.50	17.07
1882	23.30	18.71
1883	19.76	18.65
1884	21.36	21.14
1885	21.14	21.81
1886	17.06	21.04

3.—SANITARY SEWERAGE.

By J. B. Henson, C.E.

Whenever human beings congregate, and form settled communities as in cities and towns, certain results follow which are inimical to the health of the individuals. Chief amongst these is the rapid production of organic and putrescible refuse, which, if not regularly and completely removed, accumulates and contaminates the soil, the air, and the water; through these media the vital powers are assailed, the standard of health lowered, and diseases are therefore easily contracted and propagated. Many of the old cities of Europe and Asia have, in times past, suffered terribly from this cause. In those days, however, there were neither the knowledge nor the appliances to effectively cope with the evil such as in these days are available. In England, which may justly be regarded as the birthplace of sanitary science, the ravages made by epidemics were found to be aggravated and intensified by the unsanitary condition of the areas affected, countervailing measures were instituted, which constantly advancing in efficiency by experience, and assisted by the wonderful discoveries in science, have proved of inestimable value to the British race.

It has been said of a leading sanitary engineer in England, that the reduction of the death-rate, in districts in which he had carried out sanitary works, represented the total saving of 200,000 lives.

It was recently stated by the Government Statistician that the sanitary improvements effected within the City of Sydney have resulted in an estimated saving of six hundred lives per annum, whilst the increasing density of population on the suburban areas without concurrent sanitary precautions, has caused an advance in the death-rate of the suburban population which represents the loss of eight hundred lives per annum. Sanitary science is progressing, and the improvements in the design, construction, and consequently the efficiency of sanitary works indicate more satisfactory results in the future. Deaths from febrile or zymotic diseases are generally preventable, and with a perfect sanitary system such diseases should have no place in a community.

The death-rate of this city (Sydney) for the year 1886 was 17.06 per thousand, and for 1887, 14.62 per thousand; these are very favourable reports, and no doubt are largely due to the general adoption of the water carriage system of sewerage. It is found, however, that the proportion of deaths due to zymotic or febrile diseases is about thirteen per cent., and this indicates that the sewerage system is not as efficient as it should be.

Experience has shown that the water carriage system of sewerage properly applied is capable of effecting immense improvements in the sanitary condition of populated areas. This system has often been assailed and condemned, yet it is constantly being resorted to with greater or less measures of success. It is true that in far too many instances the results have not been very satisfactory, and if the system did not admit of greater efficiency than these examples exhibit, the condemnation hurled against it would be justified. But the system must not be judged in this manner, because in these instances where it has proved inefficient and unsanitary, the designers were either ignorant of, or imperfectly understood the first principles upon which a sanitary system is based, or having some acquaintance with these principles did not know how to apply them to practice. And it must be borne in mind that these principles and the best methods of applying them have been developed gradually and are the outcome of the experience of the past, combined with the results of scientific research.

"Science moves but slowly, slowly creeping on from point to point" said Tennyson, so has it been with the development of the water carriage system of sewerage. An investigation and study of the lines along which the most important advances in sanitary engineering have been made, clearly indicate the first principles which govern the construction of a sanitary water carriage system of sewerage. Briefly stated these principles are as follows :—

(a) As to collection and removal of sewage.

1. Rapid and complete removal of sewage from dwelling houses and factories, and its transmission beyond the limits of the populated area.
2. Impermeability of sewage conduits.
3. Thorough ventilation of the conduits.
4. Exclusion of rain-water from sewage conduits.
5. Adjustment of the sizes of the conduits to the quantities of sewage to be removed by them.
6. Exclusion of diseased or fermenting matters from conduits.

(b) As to disposal of sewage.

7. Non-pollution of sources or possible sources of water supply.
8. Non-pollution of the atmosphere.
9. The restoration to the soil of the fertilising matters contained in the sewage.

According to the degree in which these principles are observed in practice, so will be the measure of success, not only from a sanitary point of view but from an economic one as well.

Before proceeding to explain these principles and the benefits to be derived from their observance, it will be necessary to have a clear understanding of what is meant by the word "sewage."

By sewage is meant the waste liquids from dwelling houses and factories, and consists chiefly of the water which having been used for culinary and sanitary purposes, and for processes of manufacture, has become charged with putrescible organic and mineral matters and other waste products. In quantity it is practically equal to the amount of the water supply, and varies as the consumption of the water varies.

Fresh sewage is comparatively harmless, but it contains a great power for evil. It will remain fresh long enough to enable it to be got rid of completely before harm ensues, if the right means be adopted. It must be set running and kept running until it is properly disposed of. The mischief of sewage is that if it does not run, or does not run fast enough, it ferments and corrupts, and corrupting breeds poisonous miasma, so that they who live in the neighbourhood inhale disease at every breath.

Thus it will be seen how very important it is to ensure the removal of the sewage before putrefaction sets in. The demands of the first principle must be complied with. In the comparatively cool climate of England a velocity of flow for the sewage of 2′ 6″ per second is found to be necessary, in the warmer climate of this country the velocity should be three feet per second. These velocities must be obtained in every instance where sewers are laid down, and under no circumstances whatever should sewage be allowed to stagnate if the greatest efficiency be desired. Failure to obtain these velocities has been a far too common occurrence in the past, and evil results have followed, but now, owing to recent advances in hydraulic and pneumatic engineering, the most desirable velocity may be obtained under any circumstances whatsoever. Up to the present time sanitary engineers have graded the sewers laid down by them according to the natural features of the site. If the surface slopes happened to be favourable the sewer grades were also favourable. If the surface happened to be flat, the sewers were laid with inferior grades and hence became unsanitary. A rapid flow is also necessary to prevent silt lodging in the sewers; the velocities before-mentioned ensure this result.

House sewer connections should discharge their contents quickly into the sewers. There should be no places in which sewage may find a lodgment and stagnate. All water traps should contain the least amount of liquid necessary for perfect trapping, and should be so constructed that their contents may be renewed at every discharge into them. All water used for sanitary purposes should be discharged into the house drain immediately after it has taken up the burden of filth for the removal of which it has been applied.

All refuse water from operations of manufacture should be removed before fermentation has set in. To ensure this quick and efficient removal all sewer connections should be carefully laid and graded. With the before-mentioned velocity of flow which is about equal to two miles per hour, the sewage may be quickly passed to its destination outside the populated area whilst comparatively fresh.

The impermeability of sewage conduits is essential. If the sewers be leaky or porous, sewage will pass through into the surrounding ground where it will stagnate and putrify. The resulting gases will penetrate into the sewer and contaminate the air therein. A reverse action will occur in water laden soils. The water will penetrate the sewer, and augmenting the volume of sewage overcharge the system

It has been shown how very necessary it is to prevent stagnation of the sewage, it is of equal importance to prevent stagnation of the air contained in the sewers. Systematic ventilation of the sewage conduits is imperative. It may be effectually done. Many objections have been raised against ventilation of sewers on account of the offensive odours which have been found to flow out of some of the ventilators. These objections too often are founded upon facts, and these offensive odours indicate, badly graded, foul sewers, ill-designed house drains, and putrid sewage. The cure lies not in closing the ventilators or erecting tall flues—these may mitigate the evil—but in such improvements to the sewers and house drains as will hasten the removal of the sewage before decomposition has set in. The system of ventilation may be defective, insufficient openings being provided.

The advisability of separating the rain water from the sewage can no longer be questioned. The Royal Commission on Metropolitan Sewage Discharge (London) have approved of this course. In several instances where sewage works have been designed and executed in accordance with this principle they have proved eminently satisfactory. The common or combined system has always proved unsatisfactory and always will do so. This system arose in a very natural manner in the old cities where numerous drains and sewers existed for the purpose of removing surface water. These sewers formed very convenient receptacles for house slops and refuse of all kinds which it was thought would be effectively removed by the recurring rains. But while awaiting this removal the refuse matter decomposed and proved very hurtful. No wonder rain was looked upon as a welcome and necessary scavenger for the sewers, and a strong feeling prevails to this very day that it is absolutely necessary to admit rain water to all sewers for the purpose of cleansing them. There is a system known as the partially separate system in which elaborate precautions are taken to admit only a certain percentage of rainfall to the sewers. This system appears to be based upon the popular idea that rain water must be admitted to sewers in order to keep them clean. Sewerage systems can now be designed, having sewers which will keep clean without the aid of rain water, and such are very desirable in climates where rain falls at long and uncertain intervals. It will never do to depend upon the rain to keep the sewers clean in this climate. All sewage should go to the sewers, and rainfall to the natural channels. The exclusion of sewage from the rain water channels permits of a different method of construction, and instead of the separate system proving a greater expense than the combined, it may be constructed more cheaply and bring untold benefits in its train. The exclusion of rain water from the sewers enables them to be proportioned in size to the quantities of sewage to be removed. The quantity of sewage to be removed from a known population on a given area can readily be ascertained when the amount of the water supply is known. This amount can always be ascertained, and the velocity being fixed at three feet per second, the size of the sewer, and the grade are both readily determined.

In many instances the natural conformation of the surface will render the desired grade unattainable in the ordinary manner, especially if the area be flat. This grade must be obtained—sanitary science is unyielding in its demands—therefore, under such conditions the hydro-pneumatic, or hydraulic ejector system, must be resorted to.

These systems are of recent development, and have been designed to enable the sanitary engineer to command gradients to the sewers under all circumstances that will be suitable to the quantity of sewage he has to deal with, irrespective of the natural inclination of the surface. Thus, low-lying localities may, as regards sanitation, be placed on an equal footing with the most favoured localities.

It has been the custom to look upon sewers as proper receptacles for all manner of filth which it may be found necessary to get rid of. If sewers are to be sanitary, they must be treated in a different manner to this.

The dejecta of persons suffering from contagious diseases should be disinfected before it is admitted into the sewers. Decomposing and putrid matter should receive similar treatment. Offensive water from processes of manufacture should be deodorized and disinfected before being passed into the sewers.

It may be found impossible to exclude matters full of contagion in isolated cases of disease, but the drainage from hospitals should most certainly be disinfected before being discharged into the sewers.

The principles affirming the necessity of ensuring the non-pollution of sources or possible sources of water supply and the non-pollution of the atmosphere, when the disposal of sewage is under consideration, cannot be taken exception to, and their realisation in practice depends largely upon the observance of the preceding principles.

When sewage is delivered in a fresh condition at the outfall in regular quantities undiluted with rain water, its disposal on land for irrigation purposes no longer presents the difficulties that are met with in those instances where the admixture of rain water yields an unmanageable quantity.

If the exclusion of the storm water be rigidly adhered to, the reduction in bulk of the sewage will enable it to be disposed of at will. No science advances alone. The mechanical engineer assists the sanitary engineer and shows him how to accomplish his desires. Already new possibilities in sanitary engineering, sewage disposal, and sewerage economics present themselves, and the time is at hand when it will be found expedient and profitable by delivering sewage on to the land to restore to the soil those fertilising matters originally taken from it.

The realisation of a sanitary water carriage system of sewerage depends upon the skill and judgment of the engineer, in the practical application of the principles which have been enunciated to the physical condition of the locality where a sewerage system has to be constructed.

SECTION I.

LITERATURE AND THE FINE ARTS.

President of the Section, Mr. E. Vaughan Boulger, M.A., D. Lit., Professor of the English Language, Literature, and Mental and Moral Philosophy, in the University of Adelaide.

THURSDAY, AUGUST 30.

The President delivered the following Address :—

[*Abstract.*]

THE President asserted that Art was as necessary to man's well-being as Science. Science ascertained and marshalled the facts, without a knowledge of which, man must fight a losing battle against the forces adverse to his material welfare. Art supplied that, without which the fight would not be worth fighting at all, for what was life without joy, and it was precisely joy that Art strove to impart. Art included all works of man which reflected moral or physical beauty. The essence of beauty was incomprehensible, because beauty had no fixed type. The Platonic and Darwinian theories as to the origin of the sense of beauty were then discussed with impartiality. The speaker held that Art was more than imitative ; that in the very process of imitation the artist introduced something especially his own. Whether this something was a reminiscence of ante-natal perception, or the result of a special faculty developed by evolution the speaker could not say. With Ruskin he believed that the Fine Arts might be limited to sculpture and painting, and suggested that at the next meeting of the Association the existing Section should be sub-divided into three independent Sections, namely, (i) Literature, (ii) Fine Arts, (iii) any other Arts such as Music, which the Council might deem worthy of consideration. Rejecting Schlegel's definition of Literature as too wide, he defined the term as the artistic verbal expression of thought and feeling, and contended that Literature was the cheapest and most effective form of mental recreation. For a couple of shillings a man might buy a copy of Shakespeare, and find therein intellectual food for a life-time. He deplored the neglect of literature in Australia, but believed that the Governments of the different colonies had done all that they could to provide Literature and the Fine Arts. What was really needed was a higher ideal of life in each individual. Finally, he commended to every artist the *dictum* of a great poet and a keen critic :—

"Think clearly, feel nobly, and delineate firmly."

The following paper was read :—

1.—MODERN METHODS USED FOR THE REPRODUCTION OF PICTURES.

By JOHN J. HORROCKS, Editor of "The Illustrated Sydney News."

SYNOPSIS.

Introductory.—Photography, the chief agent in all modern process work. *Chemical Engraving*, brief history and reference to Chemitype, Paniconography, Zincography. *Photo-Zincography*—Dawson's Type Etching, and direct Photo-Etching; the processes explained. *The Meisenbach*—Hints to artists working for process reproduction. *Day's Process Films, &c. The Callotype* and *The Autotype*.

It is the ideal rendering of nature which is generally accounted the peculiar purpose of art, but the fact remains that the ideal of the greatest painters and sculptors is never far removed from the literal and natural.

The ideal easily recognised and appreciated is not far removed from nature, but is the expression of the taste in the selection and combination of familiar scenes and objects.

Photography is the chief factor called to our aid in modern processes of reproduction, and it is often urged for photography that its intense realism is a strong argument in its favour—but does the pencil of light faithfully translate nature upon the sensitive film—that is light as it is presented to our normal vision? Is not nature falsified by the incorrect rendering of colour into monochrome? To illustrate this :—

In the photograph we see that the upper part of a tower or steeple is in much stronger light than the bottom, whilst in a painting or engraving, the higher part is darker than the lower.

Which is correct? Does it not stand to reason that a high tower against a cloudless sky, exercises *greater illumination* at the top in the broad expanse of light than at the bottom? Does the painter violate nature to create artistic effect? Surely his method is the more pleasing and picturesque, but how can it be contrary to nature and yet true and beautiful?

Why does the high tower against a cloudless sky show the upper part dark to our vision? It is due to a peculiarity of the retina which shows itself when we exercise the eye, and has influence in works of art—if we place a bright silver coin upon the table and centre the eye upon it for a few minutes, and then remove the coin for an instant, there is a white spot in its place which almost immediately seems black. This I believe, is explained by supposing the nerve to be so exhausted by the continued action of the special rays that it momentarily becomes insensible to their influence, and the effect of the rays of an opposite kind is transmitted to the brain.

We know the highest part of the tower *is* in the brightest light, but it does not appear so to the eye. The reason is obvious when we look at a tower or a church steeple, a great part of the retina is opposed to the light of the sky, and on shifting the eye to any particular point, the light which is reflected from the part falls upon the retina where it has been exhausted by the direct light from the sky, and consequently that part appears *dark.*

This peculiarity of the eye is taken advantage of by painters, and they create an effect not only by the contrasts of light and shade, but also by contrast of colour, and in the application of photography to re-produce pictures, the faults of photography have been, to some extent, corrected by the artist's final touches and by the use of gelatine films and shading mediums. To these I will refer later.

The methods of automatic and mechanical engraving are, in trade parlance, described as "*process work*;" these processes are either chemical or photographic.

It is not more than fifty years since, that for all purposes of book and newspaper illustration, wood engraving was supreme. In a treatise on wood engraving, published in 1839, the authors claimed that wood engraving had then practically superseded copperplate engraving, which for centuries preceding had held sway.

More recently it has been said that by the aid of photography modern *processes* would supersede wood engraving, but so far this has not been effected, and better copperplate engraving and more beautiful wood engraving are now produced than ever, each art being stimulated by the competition that has arisen.

The earliest form of automatic engraving was *etching*, which, properly speaking, does not mean biting a picture by means of acid on to a plate, but first drawing and then fixing the picture on the plate which is to be bitten—a clever mechanic can manage the biting process—it requires an artist to *etch* the picture.

Chemical engraving or etching was practised in England forty years ago, for at the Great Exhibition in 1851 specimens of work were shown under the names of "Chemitypy" and "Paniconography."

Of all chemical processes, Zincography is the best known in England, it obtains its name from the zinc plates which are used for printing the designs. It was invented by a M. Gillot, of Paris, in 1850, and was called "Gillotage," and those who worked it were called "Gillotens." In 1855 M. Gillot received for his discovery the reward of Honourable Mention at the Paris Exhibition.

In Zincography the zinc plate is about one-eighth of an inch thick, and is either polished or grained, the picture is laid down on it, with lithographic ink from transfer paper. An acid-resisting ink is then fixed on the parts of the plate which are to be protected, and the plate is then subject to the *first* biting in a bath of dilute nitric acid, which is kept *rocking* so as to prevent particles of nitrate of zinc being deposited on the edges of the bitten parts. After a quarter of an hour the lines must be still further protected. The plate is sponged, dried, and heated until the ink runs and spreads over the lines. After cooling, powdered resin is dusted over the surface, and the biting continued in acid baths of increasing strength, when finally the plate is dried, and the greasy ink is removed by benzine—a finer process.

Photo-Zincography is the term applied to the process of transferring the drawing enlarged or reduced to the zinc plate by photography. An ordinary negative on glass is taken of the picture, it is applied to a sensitised zinc plate, and by the action of light printed on it just as C. D. V. is on sensitised paper. Zincography and Photo-Zincography reproduce only drawings in line and are seldom satisfactory methods for portraiture; the fault lies in the printing surface.

A wood engraving of the best kind is not always perfectly *level.* The engraver raises some parts to depress others, by this means he obtains *tones* and a *softness* in one part, and a firmness and emphasis in another. Now a "process" block from the very nature of its production must be exactly *level* in its general surface. The flatness of a zinco block is therefore a drawback to its advantages for pictorial effect. For mechanical work the reproduction of architects drawings and line work it is unrivalled, and the rapidity with which the blocks can be produced is another great advantage it claims over wood engraving.

A finer process is that known as—

Dawson's Typographic Etching, in which acids are not used, but a brass plate is prepared with a white organic wax ground, somewhat as in the old form of etching. The picture is drawn on it with an etching point, invented for the purpose by Mr. Alfred Dawson, and which is more like a graver than an etcher's needle, this cuts furrows in the ground, and when the drawing is made the lines show the surface of the plate, the wax which remains representing the future whites of the picture, between the lines are the ridges of wax—these spaces are strengthened by melted wax being poured on them—when the wax ground is so built up that the furrows are sufficiently deep, the plate becomes a mould, an electrotype is taken, which forms the actual printing surface.

This is a delicate process, yet so certain that not a line or stroke is lost, and is proved by the multitudinous touches of an etching effect. This process is particularly adapted for landscape work and figure subjects. A number of the illustrations in Cassell's books, such as Old and New London, the Educator, and Cassell's Magazine, are produced by the Dawson process.

The Direct Photographic Etching Process is pre-eminently one of the most successful now in operation. Its zinco blocks are obtained direct from the artist's drawing through the agency of photography. Mr. Hentschel, who has the manipulation of this process in London, and who has greatly improved upon the Parisian methods, prints his negative on sensitised carbon paper.

This is laid face down and fixed on a polished zinc plate, which is placed in a bath in which all the carbon paper, except that which holds the lines of the drawing is washed away. The plate is then bitten in an acid bath.

In America it is claimed that Mr. Frederick Ives, of Philadelphia, was the first to bring this process into successful operation, and to adapt Mr. Woodbury's plan of suspending a fine gauze in the camera between the picture to be photographed and the sensitised plate, thus producing a series of delicate lines on the negatives, expressing half tones on the *printing surface.*

The Meisenbach Process produces blocks which, as yet, give the best half-toned. The method is a patent, and is worked by a company who have very extensive works near London. I find it difficult to obtain reliable information as to the *modus operandi.* It must be admitted, however, that even this excellent process is variable in its results.

The good effect desired depends greatly on the photograph from which the block is prepared—at times there will be a superabundance of light in one place, or the figures will be indistinct through shifting. When there are extremes of light and shade in the photograph there is extreme difficulty in making a good block. The Meisenbach process has a great future before it, and we may anticipate its adoption for the purposes of book and newspaper illustration, particularly where photographs are alone obtainable, and a sketch from nature cannot be made.

Where blocks are prepared by photography from original drawings and not from photographs *direct*, much depends upon the paper or card used, and the treatment. Artists should be careful to use a dull enamel card with a very slight china clay surface for pen and ink sketches, and the drawing should be for *reduction.* In most cases it is better to draw for about one-third reduction, as by so doing a much better result will be obtained than if the drawing were to scale. The quality of the ink is of importance. In regard to the style of the drawing the utmost care should be taken to make the lines firm and clear, and the shading should be kept open.

It is not desirable to use washes of any kind in drawings required for reproduction by ordinary process. A very simple and beautiful method is now in operation to aid the "process artist" in rapidly putting on his shading and stipple effects by the use of semi-transparent films made of prepared gelatine, these are known as

"*Day's Process*" *Films.*—These fine plates or films of gelatine can be purchased to reproduce shading in line, cloud effects or sky, foliage and water effects. The films are stretched and fixed in a wooden frame, and are then rolled with an ordinary inking roller. To place the shading film over the drawing is the next operation, and then an agate burnisher is passed over the reverse side of the medium leaving the impress of the tint or shading on the drawing. These films or shading mediums are semi-transparent, so that the effects and outlines of the drawings are in constant *view* through the film when working. The stipples are doubtless produced originally by hand, for they are most artistic and correct, and save the artist much tedious labour. They are largely used in America and can be obtained in many varieties.

PRINTING.

A few words are not perhaps out of place on this subject, for however perfect a block may be, the result will be unsatisfactory if carelessly printed.

In America far more attention is bestowed on the printing of illustrated works than here, or even in England. Much longer time is allowed for "making ready" and for "bringing up" at press. Much higher wages are paid than we are accustomed to in Australia, and the result is a higher standard of work. The perfection of printing attained in the American magazines is largely owing to these causes, and to the superiority of the American printing machines.

Having mentioned the methods that may be called the "modern processes" applicable to printing on a letter press machine and with type, I may briefly refer to some of the latest processes available for book illustration or for the reproduction of pictures, but which must be worked by special kinds of processes, hence they are only used for more costly work, and when long numbers are not required. There are the carbon-type, the Woodbury-type, the collotype, and the autotype. We will take the two latter which, I believe, are the more modern.

The word autotpye is intended to convey the reproduction of the artists' work in monochrome unaided by the eye or the hand of another—the only means used being the actual forces of light and chemical affinity. This process is carried on by the Autotype Company in London. Their reproductions may be taken from any photograph engraving or printing in monochrome.

Callotype printing claims to be the latest and most promising invention, bearing as it does a closer relation to both lithographic and relief printing.

The pictures by this process are printed from gelatine surfaces, which one would think most unlikely to stand the wear and tear of a machine. Now, gelatine soaked in cold water swells up—in hot water it dissolves—if gelatine is mixed with bromide of potassium and exposed to the light it becomes brown in colour. What is strange and curious about this material is, that the exposure to light robs it of its property of swelling in water. Further, it becomes of an apparently greasy character—water will not mix with it. Now if we print on a piece of paper coated with bichromatised gelatine and put it in water, the exposed part will not swell, nor will it absorb water. The unexposed parts on the other hand will swell as ordinary gelatine, the swollen parts will not mix with fatty printing ink, but the unswollen parts will readily receive it, and here is the basis of the collotype process.

Briefly, it is this—a glass plate or a metal plate may be coated with a uniform layer of bi-chromated gelatine, and this is exposed to light under a negative. Certain parts become quite insoluble by the action of light, others remain soluble and capable of absorbing water.

The plate is damped and a roller charged with fatty ink is passed over it. Those parts which refuse the water refuse the ink; and a piece of paper being applied with pressure the ink sets off on the paper forming a print; but more than this occurs, as we have an infinite number of grades between the two extremes of water-taking and of ink-taking parts. Those parts which had but a slight exposure to light, being capable of receiving both ink and water, the proportion in which each is received depending on the extent to which the part has been acted upon by the light.

Under exposure in a photo-printing frame the gelatine coating turns from an even yellow to a faint brown. It is then soaked, during which the exposed parts become reticulated or grained. Before being used, the plate is soaked in water and then it is laid on the bed of a machine or press and is rolled up with an ordinary lithographic roller and printed in the usual way.

The progress of callotype printing will be greatly influenced by the fact that the machines can be adapted readily to any ordinary lithographic or letterpress machines, and by the simplicity of the process and ease with which a printer may, by the aid of a camera and a few chemicals and plates, make his own surface and produce his illustrations without the services of artist or engraver.

We cannot possibly anticipate to what extent these illustrating processes may yet develope—each is a study, and has cost its author ceaseless thought and care, but nearly all may, I think be regarded as in their infancy.

Of one thing we may be sure, wood engraving is not likely to become a lost art, but on the contrary the many processes in vogue, whilst they serve to make an existence impossible for mediocrity, stimulate good work, and the true artist in wood engraving will have more appreciation and scope than ever.

FRIDAY, AUGUST 31.

The following papers were read :—

1.—THE ESTABLISHMENT OF THE FIRST LIBRARY IN AUSTRALIA FOR THE GENERAL USE OF RAILWAY MEN.

By GEORGE MACARTNEY, President of the Victorian Railways General Library.

THE railway interests of Australia are becoming of such magnitude, and the mental qualifications of the employés are of such importance to the well-being and comfort of the community at large, that the meeting of the Australasian Association appears to me a fitting time to place on record the fact of the existence of the Victorian Railways General Library—the first of its kind, so far as I have been able to ascertain, in the Australian Colonies. So many of the sciences with which the Association deals may be considered a necessity in the education of railway men, that I need not make any apology for occupying the attention of its members for a few minutes.

The necessity for the establishment of a comprehensive library in connection with the railways of the sister colony was first submitted to the consideration of the Commissioners about two years ago, and a favourable promise was obtained on condition that it be shewn there was a widespread desire for such an institution; a committee was nominated consisting of representatives of branches (7) and the various grades of men on daily pay (17), while a circular was issued to all employés throughout the service now numbering over 10,000 persons of all ranks. The answers to this circular were very satisfactory, a large majority being in favour of the proposal. A progress report was then submitted to the Commissioners stating, amongst other things, that the Committee's intention was to charge only a nominal subscription of 5s. per annum and 2s. 6d. for juniors receiving under £65 per year (this fee is based on the practice obtaining in England), that the Library should be both circulating and reference, and that a subsidy from the railway funds would be required.

The Commissioners promptly approved of the proposals, and very generously gave a subsidy of £300—£200 for the purchase of books and £100 for furniture, &c. In addition to this subsidy they gave the free use of premises—two commodious rooms--one a Library, the other a Reading Room, adjacent to the Spencer-street Railway Station, and also allowed many minor facilities, free transit of book parcels, &c., &c. On it being pointed out by the representatives of the Library that the supply of literature was inadequate for the number of subscribers, within the last month they readily gave a second subsidy of £300, making a total of £600. Roughly stated, the income from subscriptions is £250 per annum, so that the Victorian Railways General Library, now in existence five months, started with a credit of £850; £300 of this sum is as yet unspent, for the balance the catalogue shews a total of 2,500 volumes, exclusive of the usual supply of pamphlet, magazine, and periodical literature. About five hundred of these are for reference, comprising works on the various arts and sciences, Cyclopædias, Dictionaries, Catalogues, Guides, and Proceedings of Societies, while the 2,000 in the circulating branch include Arts and Sciences, Biography, Fiction, History, Miscellaneous, Natural History, Poetry and the Drama, Religion, and Voyages and Travels, under a systematic classification—A, B, C, D, E, F, G, J, and K.

The number of subscribers now enrolled is 1,080, and these are scattered all over the colony, many being found in survey parties in the remotest corners of the "bush"; about three hundred parcels of books are sent to these country subscribers each month, many of these parcels consist of several works, and it is very creditable to the traffic authorities who supervise the transit, that during the five months the library has been in existence not a single loss has occurred.

I suppose it is seldom the public take thought of the lonely life a stationmaster or porter leads hnndreds of miles away from centres of population, where he may have only some two trains a day to attend to (for some people stationmasters and porters only exist—like the donkey—to be kicked), but this same public is certainly aware of the solace and comfort to be derived from a good book. Employés of all ranks, no matter where they may be in the colony, can, for the very moderate subscription fee, avail themselves of the books (which will shortly be increased in number to 4,000 volumes), and thereby begile the tedium of their hours, while adding to their stock of knowledge; when this is considered no explanation is necessary to make the general public understand the great value of a large and comprehensive library in connection with railway services.

On our perusal of the Catalogue it will be found that the committee are indebted to many gentlemen, both in New South Wales and Victoria, for valuable donations of books and money; it will also be observed by the rules and bye-laws preceding the Catalogue that the admission of members is practically unrestricted—employment in the railway service, good behaviour, and payment of the nominal fee is all that is required to secure the great advantages. The committee, from the outset, took the broad view that true learning was essentially and in the best sense democratic, and on crossing the threshold of our Library all men, from the lowest employé to the highest officer grasp the hand of fellowship and unite for one object—the pursuit of learning.

2.—ART EDUCATION IN AUSTRALIA.

By John Plummer.

During the last few years there has been a marked extension of popular art taste throughout Australia, one illustration of which is afforded by the vast improved character of many engravings appearing in the pictorial journals, as contrasted with those which formed the rule some fifteen or twenty years ago. Another illustration is furnished by the largely increased circulation in Australia of British and other art publications. If a third were required, it would be found in the remarkable degree of success attending the production of a recent somewhat expensive illustrated work, descriptive of the various Australian colonies, which deservedly takes rank with the choicest British or Continental publications of a similar character. These are a few only of the many indications of a general art-awakening in Australia; of the existence of a natural love of art, which, properly encouraged and developed, may aid in the creation of an Australian school of art, a school as thoroughly distinctive in its leading features as any of those which have arisen, in ancient or modern times, in the older centres of civilisation. All nations possess, more or less, a natural love of art, but it is more readily developed in some than in others. But under any circumstances, the work of development is, at first, necessarily slow.

No art student deems his education complete until he has visited Italy and become familiar with its countless art treasures; but although the climate and scenic features of that lovely country irresistibly aid in inspiring the soul of the artist with a keen sense of the beautiful, very many years elapsed before a real Italian school of painting became established, and the way prepared for the production of those wonderful creations of the pencil, which form the despair of modern art. There must be a beginning to everything; and to this rule there can be no exception. Especially is this true of popular art education. But much depends on the nature of that beginning. The progress of the English school of painting was much retarded by the slavish fashion in which its earlier members sought inspiration from the works of other schools, rather than from the world of beauty by which they were surrounded in their own land. The English landscape was represented with an Italian sky and classical accessories, which gave it a most unreal appearance. But as English artists, while studying the best works of continental schools, learned to rely more and more on their own skill, to create, instead of copying, they gradually acquired a distinctive style, and, in course of time formed the English School of Landscape Painting, which is unreservedly admitted to be without a rival, so far as the artistic delineation of the natural features of natural scenery is concerned.

If we are to have real national art progress in Australia, we must learn to profit by the example thus afforded. Our art students must learn to create, as well as copy; and they must seek inspiration from the wealth of scenic beauty by which they are surrounded, rather than from that of other lands. There is more of real artistic distinctiveness in Chevalier's "Race to Market" than in all the multitude of English paintings, prepared to order, by the same artist. In the one he stands the representative of a new school; in the other he becomes lost in the artistic crowd. Although the scenery of Australia is frequently described as being dull and monotonous, it is so only to the superficial observer. Under the influence of the gorgeous autumn sunsets, the landscape becomes invested with an indescribable glory of crimson, gold, and purple, which impresses even the dullest imagination, and would awaken the wildest enthusiasm of a Ruskin or a Turner. But we rarely behold these scenic marvels reproduced on paper or canvas, in imperishable colours. Claude never painted rocky gorges more romantic or more awe-inspiring than those which are to be found in many parts of Australia, and there are portions of the Nepean which, in their stately grandeur, rival, if not surpass the picturesque castellated heights that bound the lordly Rhine. We have, in fact, here in Australia all the essentials for the creation of a purely Australian school; but, at present, they remain virtually unheeded, and will continue so until the present system of popular art-education is placed on a sounder basis.

In all countries in which art has made substantial progress, it has been aided during the earlier stages by the State in various ways, principally in the shape of money grants or special privileges to those engaged in the work of art-education. The reason for this is to be found in the fact that much of the preliminary work is of an unremunerative character. As the work advances, as a popular art taste is formed, and the artist finds the creations of his pencil commanding a market, the assistance of the State becomes less necessary, and, in course of time, may be dispensed with altogether. The English Royal Academy was for many years largely dependent upon State aid; but it became the parent of the numerous art associations which now exist in the United Kingdom. In Australia, the State has yet to properly recognise the claims of art. It is only within the last few years that New South Wales has possessed a National Gallery; and the Art Society of New South Wales is of even more recent date. But the oldest of the Australian colonies is certainly the least generous, so far as the State recognition of art is concerned. It's assistance is grudgingly rendered, and may at any moment, under the pressure of political influence, become withdrawn. Australian artists, if they are to aid in the work of popularising art taste, must be independent of the art fashions of the hour. They must be enabled to battle with the whims of an imperfectly developed appreciation of true art, and in this task they should receive the cordial co-operation of the State. There are many ways of doing this, one of the simplest and most effective being to vote a sum of money annually for the purchase of Australian pictures by Australian artists.

At each exhibitiom of the Art Society of New South Wales there are at least a dozen works which, with all their actual or supposed demerits, would materially aid in forming the nucleus of a real Australian Art Gallery. Why should not these be purchased for that purpose? The fact that the painter of a really good picture would have a chance of disposing of it at a remunerative price, would naturally encourage him to exert his skill to the uttermost, thus exciting the emulation of his brethren, and awakening the true spirit of rivalry, the burning desire to excel, which is so indispensable to national art progress. More than this, it would stimulate the work of art-education. As there can be no success without excellence, the art student speedily learns the importance of persevering attention and industry. To some extent, this stimulus is afforded by means of art unions, in which the prizes are selected from the pictures exhibited. But there are many objections to this, which is, after all, a most precarious system. Moreover, the purchase of selected pictures by the State would achieve a double result; it would both encourage the Australian artist, and aid in the work of developing popular art taste. The great difficulty in the latter direction consists in the paucity of art surroundings in Australia. The multitude have little or nothing to aid them in forming a taste for art. In the great cities of Europe and America there are Art Galleries and

Museums open to the poorest; but in Australia, these are conspicuous by their absence. Yet the humanising and refining influences of these institutions are unreservedly admitted, and if these influences have been productive of good in those parts of the world, would it not be the same here? After all, the State might do worse than aid the cause of Australian Art.

Addendum.—Since the above paper was read, the Trustees of the New South Wales Art Gallery have been furnished with the means of making annual purchases of suitable pictures from the periodical exhibitions of the Art Society of New South Wales, such purchases being added to the National Art-collection.

SECTION J.

ARCHITECTURE AND ENGINEERING.

President of the Section, Mr. W. C. Kernot, M.A., C.E., Professor of Engineering in the University of Melbourne.

WEDNESDAY, AUGUST 29.

The following paper was read :—

1.—THE DEEP DRAINAGE SYSTEM OF ADELAIDE— ITS RESULTS AND MISTAKES.

By the Hon. ALLAN CAMPBELL, M.D., M.L.C. (S.A.), Adelaide.

THE position of Adelaide is unusually advantageous for economical drainage. It stands upon a sort of flat mound sloping towards the four directions of the compass. No difficulties exist in sinking to any depth. Prior to 1883, when a large portion of the drainage system was brought into operation, the city was in a very insanitary condition. It is no secret that it had acquired the unenviable notoriety of having the highest mortality rate of any city in Australia. The following is the official death-rate per 1000 of the population in 1881 :—Adelaide, 23.55 ; Hobart, 23.18 ; Melbourne, 19.32 ; Sydney, 19.12 ; and Brisbane, 18.82.

Adelaide has an ample and excellent supply of water for domestic and other purposes. This, although a great and inestimable boon in itself, increased the perils of bad or no drainage. This was felt for several years, when in 1876, the able report of Mr. W. Clark, Civil Engineer, was adopted by the City Council. For several reasons, but mainly because the water supply was in the hands of the Government, the carrying out of the scheme was placed in their hands. The "Sewers Bill" received the assent of Parliament in 1878. Under an experienced hydraulic engineer the works progressed rapidly till 1883, when nearly one-third of the houses in the city were connected. Since then the whole city and several important suburbs are included in the completed drainage area.

The system naturally divides itself into—the drainage of the city—and the disposal of the sewage by a sewage farm. The drainage system technically consists of the main sewer, the street sewers, and the house connections. It must not be forgotten that the leading idea governing the design, is to keep the waters from dwellings and factories separate from the storm water, and to provide sufficient means of escape for the first only.

The main sewer runs along the banks of the Torrens for some distance, and is altogether about four miles in length. It is oviform in section, varies in size from forty-two inches by twenty-eight inches, to sixty inches by forty inches, is constructed chiefly of cement, and for about three miles of its course is an open channel. The fall is one in 1000. It is designed to discharge 23,000 gallons a minute.

The street sewers vary in size from forty-two inches to six inches. They consist almost entirely of earthen-glazed pipes, laid at depths of ten feet to fifteen feet. The fall varies, but always sufficient to give a rapid flow. The design is to carry off the sewage of a population of 100,000. Fifty feet apart, ventilating shafts or lamp holes are placed. They rise to the level of the street, and the openings are covered by iron-grids having buckets underneath. (Pls. XXXIV.-XXXVII.[a]

The house drains or connections are chiefly four inches, but may be six inches in diameter. No direct communication exists, as a rule, between any drain and the inside of a dwelling. A water-closet inside a dwelling-house is a rare thing in Adelaide. The refuse-water falls into a trap or receptacle, duly trapped and ventilated. All house-drains are ventilated, they all converge to a common drain, which forms the connecting drain with the street sewer. Upon this connecting drain is placed a "disconnector trap," and from its position is more familiarly known as the "boundary trap," This trap is open towards the house-drains, but closed towards the street sewer; that is it acts as a ventilator to the house-drains, but not towards the street-sewer.

Just a word on the sewage-farm, or the second main division of the system. It has an area of four hundred and eighty acres, but is found to be too small. It is four miles from the city, and is about one hundred and ten feet below the highest level in the centre of the city, viz., King William-street. The sewage is passed through two large self-acting and revolving strainers. The solid part is removed, and the liquid is distributed by irrigation on the broad principle over the soil. This is done during the whole year, but in winter it has to have combined with it the intermittent downward filtration method in order to get rid of it effectually. The management shews a profitable return, last year after paying working expenses £1000 stood to credit.

At the end of 1882 the hydraulic engineer published in a pamphlet form the details of the system, with some excellent regulations. Immediately an important public discussion arose, particularly on the question of the probable inefficiency of the ventilation of the sewers, in which the author took an active part.* It is not needful to emphasize the importance of ventilation. In fact the hydraulic engineer himself, in the pamphlet referred to, says there is no means of preventing sewers becoming sources of imminent danger to the public health except by "ample ventilation." It was much doubted if such ample ventilation had been secured for our system. Many people, in 1883, went so far as to declare that in this new country, a huge blunder had been committed. The author constructed the following table, from which important conclusions were drawn:—

TEMPERATURE AND VENTILATION TABLE.

Month.	Air.			Soil.	Difference of soil over night temperature.	Increase of volume per 1000 cubic inches.	Ventilation.	
	Day.		Night.	Eight feet below surface.			Day.	Night.
	Mean.	Mean.	Mean.					
	Sun.	Shade.		9 a.m.				
Jan.	141°	91°	64°	66°	2°	4	None	Slight
Feb.	139°	91°	67°	69°	2°	4	None	Slight
Mar.	129°	80°	61°	69°	8°	16	None	Moderate
April	117°	71°	55°	68°	13°	28	None	Moderate
May	111°	64°	49°	66°	17°	34	None	Moderate
June	100°	59°	48°	64°	16°	32	Slight	Fair
July	103°	58°	43°	62°	19°	38	Slight	Fair
Aug.	110°	63°	47°	60°	13°	26	Slight	Fair
Sept.	111°	64°	49°	60°	11°	22	None	Moderate
Oct.	120°	69°	50°	60°	10°	20	None	Moderate
Nov.	126°	75°	53°	61°	8°	16	None	Moderate
Dec.	134°	84°	58°	63°	5°	10	None	Slight

The following were the conclusions deduced from this table:—

I. No ventilation existed in the sewers during the day, except slightly in the months of May, June, July and August.

II. The ventilation, such as it was, occurred during the night.

III. The ventilation was so imperfect, that sewer air, highly injurious to human health, was delivered at the street level or respiratory stratum of the atmosphere.

* "The Sanitary Aspects of the Deep Drainage System of Adelaide," by Dr. Allan Campbell, M.L.C. *Register*, February, 1883.

IV. As the sewer air was delivered into the respiratory stratum during the *night*, it was more inimical to human health than if delivered during the sunlight.

V. In narrow lanes or streets, where the ventilating grids were not more than six to ten feet from the doors of the residents, nothing short of laying on sewer air to their houses went on all night.

VI. Our narrow streets in particular should be ventilated by some method which would render the grids *inlets*, or the grids should be closed and a different method of ventilation adopted.

The confirmation of these views came about very speedily. Complaints were heard on all sides of the intolerable character of the smells that issued from the street grids. The President of the Board of Health (Dr. Whittell) acknowledges in strong language "that the inhabitants of parts of North Adelaide especially, were obliged to keep their doors and windows closed" to resist the effluvia. Mr. Mestayer, who about the middle of 1883, became head of the Hydraulic Department, himself confesses that—"When I came out in 1883, the bulk of the great sewers had been laid, and about a fourth of the houses in town had been connected in the summer of 1883 to 1884. Complaints were coming in constantly of unpleasant smells arising from the street ventilators; and in North Adelaide in some of the streets the smells were so bad that people were unable to have their windows open at all during the evening. It was principally during the *evening and the night* that these smells were noticed. *I had been over the streets in the day-time, where complaints were strong, and could never find anything wrong; but in the evening and night the smells were very bad indeed from these ventilators.*"* The ventilation was manifestly a failure. In fact it was not ventilation at all, that is a circulation of air, *but an intermittent exudation of foul air*, its foulness arising chiefly from stagnation. The author had pointed out in 1883, that certain parts of North Adelaide would suffer most severely, because no means had been adopted to prevent those sewers with rapid gradients, from acting as upcasts to the main sewer itself.

The Hydraulic Engineer took two steps to amend this condition of things. One was to open or leave open in a small number of instances the sewer side of the "boundary trap," and place a ventilating tube upon it, and further to fix six-inch ventilating shafts at various points in the city and Park Lands, in direct connection with the sewers. The second step was to close nearly all the whole of the street grids. The first was inevitable, the

* Evidence before the Victorian Royal Sanitary Commission, 1888.

second doubtful. By these alterations the engineer has declared that the ventilation in the sewers has been improved, while the inhabitants are no longer assailed in their comfort or their health.

I will now pass briefly in review the whole position and indicate the direction in which something still remains at fault. It is to be clearly remembered that complete dilution of sewer air by atmospheric air is the only safe condition for any system of sewerage. And no portion of the system should remain untouched by a circulating atmosphere. If this is not done, stagnation and foulness will arise. The Adelaide system presents the the following features :—They are small in dimensions and have a good fall. Their contents are rapidly removed and permit no time for the formation of sewer gas. They are thus capable of easy ventilation. If by closing seven-eighths of the grids and adding a few six-inch ventilating shafts the ventilation is greatly improved, my last assertion is proved.

An important fact, which is not compatible with a perfect system of ventilation, must not be lost sight of, viz., that at least nine-tenths of the house-connecting drains lying between the street sewer and "boundary trap" are *unventilated cul-de-sacs.* Considering the large number of such connections, it is perfectly evident that a large portion of the system remains at present unventilated. In the house-drains on the house side of the "boundary trap" there is *through ventilation,* and no complaint has ever once been made of this part of the system, while it is equally notable that all trouble has arisen on the sewer side of the "boundary trap" where no *through ventilation* exists. Note also whatever improvement the engineer declares has been made, is by the further introduction of this *through ventilation.*

To attain through and therefore complete ventilation in the whole deep drainage system, two causes are possible—open in every case the sewer side of the "boundary trap" and attach a ventilating shaft to it—or abandon the "boundary trap" itself. In suggesting this latter course, I do not forget Professor Corfield's warning "that the traditional faith in the trap has been great, and it is not orthodox even to suggest a doubt of its usefulness." If we will only note clearly the fact that small sewers, rapid removal of contents, and even a moderate amount of through ventilation, will not permit the formation of sewer gas, it is plain that by the insertion of an obstacle which the "boundary trap" undoubtedly is, we create that very condition which we wish to avoid. That is we get an accumulation of foul air, the "boundary trap" having become the creator of the necessity for its own existence. Every house possess a series of ventilating shafts, some more, some less. The sum of the matter therefore is this, by the removal of the "boundary trap" each of these shafts would be brought fully into play, and ample means of ventilating the *whole* system would be found. In summer, when the ventilation is most defective, these shafts, from the heated state of the atmosphere, and their direct exposure to the sun, would become powerful upcasts. As Julius W. Adams says in his work on "Sewers and Drains," they would enable the sewers to *breathe* and ventilate themselves at all times.

The result of the deep drainage system on the sanitary condition of Adelaide has been most marked. Barring the unhappy experience of 1883-4, the smells and nuisances have disappeared. Public health as well as comfort has been greatly promoted. There can be no doubt that the general amount of sickness during the last three or four years has been greatly lessened. The following mortality table confirms this statement:—

MORTALITY TABLE

SHEWING the death-rate per 1000 of the population of the City of Adelaide from the year 1879 to 1887, both inclusive.

	No Drainage.			Drainage in Construction.			Drainage Completed.		
	1879	1880	1881	1882	1883	1884	1885	1886	1887
A.		21.2	21.4	21.8	17.16	21.18	15.73	16.24	15.95
B.	28.8	30.7	23.5	27.5	23.9	24.4	18.9	18.9	19.75
Zymotic disease	3.6	4.4	3.8	4.3	3.5	2.7	1.6	1.4	1.1
Diarrhœal........	1·3	2.2	1.9	1.9	2.1	2.3	1.9	.9	1.4
Typhoid..........	.9	.5	.6	1.5	.9	1.0	.8	.5	.8
Diptheria........	.3	.5	.5	.3	.3	.4	.2	.2	.2
Phthisis...........	3.6	4.4	3.8	4.3	3.5	2.7	1.6	1.4	1.1

NOTE.—A is the death-rate exclusive of deaths in public institutions of persons not resident in the city.

B is the death-rate from all causes.

I admit the brief period over which the table extends, and would not press its conclusions very strongly. But I regard it as more than a mere coincidence that during the last period of three years, the death-rate fell so much.

In conclusion the drainage of Adelaide was undertaken none too soon. Since its completion there is no room for doubt, that the health and welfare of its citzens have been manifestly augmented, and let me also say, that even when the final word is uttered on the question of ventilation, there still remains the important fact, that from being notoriously unhealthy, Adelaide is now admittedly the cleanest city in Australia.

THURSDAY, AUGUST 30.

The President delivered the following Address :—

WATERWAYS OF BRIDGES AND CULVERTS.

THE determination of the requisite waterway to be provided in bridges and culverts draining given areas is one of the initial problems that meets the engineer engaged in the construction of railways, roads, canals, or any other works that stretch in long lines across considerable tracts of country, and generally constitutes the very first question of real complexity that he has to face—unless indeed he should be so fortunately circumstanced as to be able to locate his works entirely along a watershed line, a state of things met with but rarely.

The correct solution of this question is a matter of the highest importance, for on the one hand bridges and culverts involve, in their construction, a very large proportion of the total cost of many of our roads and railways, and a comparatively small excess beyond actual requirements will represent a most serious waste of money. While on the other hand, an insufficient provision may involve costly reconstruction sooner or later, beside jeopardizing the lives of travellers and others, and damaging property in the vicinity.

Beside being vitally important, this question is one of decided difficulty, and upon which the experience of a considerable number of years is needed before one can pronounce a given waterway certainly sufficient. The flow of streams in Australia is so variable, and the maximum discharge is reached so seldom, that it is quite possible for the designer to be greatly misled, and to go on for years providing waterways so small as eventually bring about serious disasters. Several years will frequently elapse during which the average flow of a stream will never equal one-fourth of its maximum, and during which, therefore, culverts and bridges of less than one-fourth of the proper size will suffice. The largest Victorian stream that I have had the opportunity of thoroughly investigating—the Barwon at Geelong—was in full flood in 1852, and then was comparatively harmless until 1880, when a flood, nearly equalling that of 1852 occurred. Suppose then the acquaintance of an engineer with this stream had commenced in 1853, he might have gone on for twenty-seven years building bridges of half the proper size and never found out his mistake until the 1880 deluge swept his works away wholesale.

The Yarra at Melbourne flooded enormously in 1863, but since then has been comparatively mild in its behaviour. The Goulburn, Campaspe, and other streams on the northern slope of Victoria, had their historic flood in 1870, and then subsided into comparative harmlessness. From this and other instances the conclusion is irresistible, that an experience varying from ten years in the case of small, to thirty years in the case of moderately large streams, is the very least that can justify an engineer in affirming, on the ground of local experience purely, the sufficiency of a given waterway.

This long experience of the behaviour of streams is generally available in old and thickly-peopled countries. Floods in time past have been watched, gauged, and are well remembered by those who have suffered inconvenience and loss. Existing roads and other works of old standing afford valuable precedents, so that the engineer cannot well go wildly astray without the inconsistency of his practice with what has gone before being noticed by the public. Hence I think it is that writers such as Professor Rankine and others, who are so clear and definite on other points, pay so little attention to this.

In new and thinly-peopled countries like the Australian colonies, this local information is often unattainable. The engineer has no local experience to guide him or precedents to follow. Hence the necessity for specially careful consideration. Further, it is to be mentioned, that in connection with railway work at anyrate, the small and apparently unimportant culverts need even more care and attention than large and costly bridges. A large bridge is almost invariably close to a centre of population. During flood time it is watched by many people; further, the floods of large streams rise gradually, and if a disaster occurs there is abundant warning, so that while an error in such a case may result in the destruction of a bridge, it is very unlikely to cause the wreck of a train. A small culvert, on the other hand, is often found in a remote and uninhabited place, the floods on its stream rise with extreme suddenness and fall with equal celerity, perhaps unobserved by any person. The bank may be washed away and a train plunge into the chasm as has already happened in one most notable case, and has nearly happened in another, without the slightest warning, the attention of the officials being all the while directed to some other menaced spot, and so diverted from the real point of greatest danger.

A method that has been too commonly adopted in fixing the waterways is the following:—The surveyor fixes his attention entirely upon that point of the stream where the road or railway crosses, but does not trouble to extend his enquiries up stream. He knows neither the area drained, the length of the water-courses, its average slope, the rainfall to be expected, nor the character of the surface of remote parts of the basin. The local high flood mark is sought, and either with or without the assistance of that venerable but very unscientific personage, "the oldest inhabitant," is *supposed* to be found. It is then shown upon the longitudinal section, and the area of opening is arbitrarily fixed by some one at the head-office, who very often has no real knowledge of the country and the streams, a large depression being favoured with a comparatively large bridge, while a small gap is provided with an insignificant culvert, no account being taken of the area drained, of the rainfall statistics, or the slope and general character of the ground. After a time heavy rains occur, culverts and bridges fail, traffic is impeded, perhaps altogether stopped, and costly re-construction takes place—in some instances followed by still further failures and yet more costly re-construction at a still later date Say not that this picture is exaggerated. Did I wish I could name the date and locality of its occurrence.

This too common mode of treatment is a most fallacious one. In the first place, the recollection of the "oldest inhabitant" is often of the vaguest kind. I have known apparently intelligent persons point out flood levels that other and indubitable evidence proved to be several feet in error within two years of the occurrence of a disastrous flood. They almost always exaggerate the height of the water. On the other hand, flood-marks consisting of rubbish caught in branches of trees, or lines of *débris* along the slope, may be, and often are too low. This is due either to the fact that the rubbish did not reach the locality where it was stranded until the flood had partly subsided, or that it truly marks the highest level of a recent but comparatively small flood, the traces of the great flood of several years earlier date having long ago vanished. Hence flood-marks and evidence of residents are frequently more or less misleading. Then again, in thinly-peopled districts it often happens that no personal testimony is available, and at the same time no distinct lines of *débris* are to be found, so that the surveyor is utterly without local data to go upon.

Further, the appearance of the longitudinal section of the road or railway is often deceptive. What bears the aspect of almost a river may merely be a local depression, a pond of still water that may be embanked across with impunity, while a comparatively shallow dip or narrow cleft may really be the sole outlet of the drainage of a large district, to curtail which in the slightest degree would be a most dangerous proceeding.

Having frequently had to deal with questions of waterway, I have made it my business to collect the best available information both in the way of rules laid down by authors, and in the way of local Australian experience, and I now propose to submit the results of my enquiry to the Association, in the hope that the facts may be of use, whether the references be so or not.

Rankine warns the engineer not to embank across flooded land unless assured that it acts as a mere reservoir, and as a channel for the flood waters, but does not tell how the engineer is to ascertain this fact if he does not actually happen to have witnessed the flood.*

Mr. Stanley, Chief Engineer of Railways of the Southern District of Queensland, recommends that an allowance be made for one inch of rain per hour, with an addition of twenty-five to thirty per cent. for contingencies. He does not state what limiting velocity he proposes through the opening, but as he allows an eighteen inch pipe for eight acres that may be computed. According to him then, the waterway should vary directly as the area drained, and should give from one hundred and twenty to one hundred and forty square feet per square mile of country. The velocity works out as seven feet per second, which even in very flat districts could be obtained without heading up the water more than a foot or fifteen inches on the up-stream side.†

Mr. M. E. Kernot, of the Victorian Railways, who has given this subject much attention, writes that a waterway of sixty square feet per square mile in steep and rocky districts, forty square feet per square mile in average undulating country, and twenty to thirty in very flat sandy areas works well in those parts of Victoria where the rainfall does not exceed thirty inches per annum for catchments not exceeding three square miles; and other Victorian engineers have verbally informed me that their practice roughly agrees with this.

A formula given by Mr. Cleeman as having worked well on the Richmond, Fredericksburg and Potamac Railway, U.S. America, reads as follows :—

Area of waterway in square feet $= C \sqrt{}$ area drained in acres, area drained in acres, where C varies from 1 to 1.6 according to circumstances.‡ In Jackson's "Hydraulic Manual," (p. 20), a similar formula occurs, in which the discharge from a given catchment varies as the square root of the area.

Mr. G. R. B. Steane, C.E.,§ gives the following :—

Area of waterway in square feet $=$ (area drained in acres,)$^{\cdot 62}$

as suitable for tolerably impervious surfaces, but stigmatizes it as "only a rough approximation." Others have thought that the discharge and catchment should vary as the two-third power of the area drained.

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* Civil Engineering, p. 718.
† See Royal Commission on Railway and Public Works of Tasmania, 1886, pp. 9, 65, 67.
‡ See Proc. Inst Civil Engineers, Vol. LVIII., p. 375.
§ Trans. R. Soc. Victoria, 1887, p. 154.

Colonel Dickens, as quoted in Jackson's "Hydraulic Manual," gives the following:—

$$\left.\begin{array}{c}\text{Discharge in cubic feet}\\ \text{per second.}\end{array}\right\} = {}^{\cdot}825\ \left(\text{Area drained in square miles}\right)^{\frac{3}{4}}$$

as working well in Bengal and Bahar, where the rainfall is about double what it is in most parts of South-eastern Australia.

Lastly, some authorities have endeavoured to take into account the shape as well as the area of the basin.

Mr. Burge, of the Madras Railway* gives—

$$\begin{array}{c}\text{Discharge in cubic feet}\\ \text{per second.}\end{array} = 1300\ \frac{\text{Area in square miles}}{\text{Length in miles.}\ \frac{2}{3}}$$

Mr. L. Jackson, author of the aforesaid "Hydraulic Manual," proposes a formula of the subjoined shape—

$$\text{Discharge} = C\ \frac{\text{breadth}}{\text{length}}\ (\text{Area})^{\frac{3}{4}}$$

and Mr. G. R B. Steane,† advocates the following:—

$$\left.\begin{array}{c}\text{Discharge in cubic}\\ \text{feet per second}\end{array}\right\} = \frac{\text{Area in square chains} \times 181}{\text{Length in chains}^{\ 1.23} \times 1{,}800}$$

from which the maximum safe velocity through the opening being determined, the waterway is at once known.

It will be seen that these rules group themselves into three classes—

1. Those of Messrs. Stanley and M. E. Kernot, in which the waterway varies directly as the area drained. Such rules are plainly inapplicable over any very wide range of areas, for there are many reasons why the discharge should not, and universal experience shows that it does not, increase nearly as fast as the area drained. Amongst these reasons may be mentioned the fact that the excessively heavy downpours are very transient and very local, and consequently affect large areas much less than smaller ones, also that owing to length of channel, bends and obstructions of various sorts, the water falling on a large area often takes several times as long to drain off as it takes to fall, a days rainfall of exceptional severity, taking for example a week to run off. Hence, this class of formula is very limited in its application, and Mr. M. E. Kernot very properly limits his rule to areas of not more than three square miles. What limit Mr. Stanley adopts I do not know.

The marked difference between these two rules, one giving about three times the waterway of the other, is probably connected with

* Jackson's "Hydraulic Manuel," p. 20.

† Trans. R. Soc. Victoria, 1887, p. 152.

the difference of rainfall of the two colonies, the one being tropical and the other temperate.

The second class includes that of Mr. Cleeman, one of those given by Mr. Jackson, Mr. Steane's first rule, Col. Dickens' rule, and some others. These recognise the fact that the discharge of large areas is proportionately less than that of small ones, and allow for it, but to a widely differing extent. The conclusion that I have come to from an examination of a number of actual cases is that with the exception of Col. Dickens', they overdo the allowance and make too great a reduction on the larger areas.

The third class includes the more complex formula of Messrs. Burge, Jackson, and Steane. These take account not only of the size, but also *of the shape* of the basin. This is undoubtedly most reasonable, and has been advocated by Von Kaven, Blohm, Craig, and other authors, which are quoted with approval in the valuable paper on "Flood Discharges," by Mr. G. Gordon, M. Inst. C.E., published in the "Victorian Engineer" of August and September, 1886. But on the other hand, it may as appropriately be urged that the formula are somewhat complex, and in consistency should also take account of the slope, the character of the soil, the cross section of the stream, and other elements, which to do is manifestly impossible.

My own conclusion is that for basins of an approximately oval shape, in which the length is from twice to three times the greatest width, a very usual case, a modification of Col. Dickens' formula as follows is easy of application, and corresponds as well as one can, under the circumstances reasonably expect, with the best accessible experience.

$$\left.\begin{array}{c}\text{Area of waterway}\\ \text{in square feet}\end{array}\right\} = C\left(\begin{array}{c}\text{Area of basin in}\\ \text{square miles.}\end{array}\right)^{\frac{3}{4}}$$

When C is 40 in average country land with ordinary rainfall, but may be reduced to 30 in very flat and absorbent areas and increase to 80 in hard, rocky, or extremely non-absorbent localities, such as occur in towns.

The practical considerations leading one to this conclusion I have endeavoured to show graphically in the diagrams submitted when horizontal measurements show areas in square miles, and vertical ones waterways in square feet, and where a round dot means a satisfactory case of long standing, and a cross that the opening has proved insufficient. The thick black lines are those corresponding to the suggested rule.

To detail fully all the particulars of each case would be tedious, suffice it to say that—

1. As far as I can learn no structure approximating to the size called for by the rule has failed to do its duty.

2. That those most deficient when compared with the rule, namely, Bridgewater in Tasmania (13 square feet to $2\frac{1}{3}$ square miles), Sandhurst in Victoria (190 square feet for 16 square miles), Cootamundra in New South Wales (53 square feet for 20 square miles), Plenty River in Victoria (440 square feet for 60 square miles), and Barwon River in Victoria (4,000 square feet for 1,700 square miles), have all been the scene of disastrous failure and costly reconstruction with greatly increased waterway. All these are shown by the rainfall maps to have nearly the same amount of annual rainfall, a statement which is roughly true of all the examples shown, no cases having been chosen from those zones of intense rainfall on the coast of New South Wales and in central Gippsland.

I, therefore, put forward this purely empirical rule as applicable in average cases, subject of course to reasonable modification at the discretion of the engineer in instances which are specially favourable or unfavourable as to rainfall, shape of basin, character of surface, or amount of damage like to ensue in event of failure. Of one thing I feel confident that the general recognition of such a rule would have prevented in the past such disasters as those at Bridgewater, Cootamundra, Sandhurst, or on the Plenty and Barwon Rivers, and further that it would have checked the expenditure of very large sums of money on structures that I could name did time permit, which can be shown by entirely independent lines of reasoning to be from twice to twenty times as large as is necessary to discharge the maximum flood of the stream passing through them.

In conclusion I would say, that I have been greatly indebted as to data for the present paper to Mr. Steane, whose labours to improve practice in these matters are beyond all praise, to Mr. Gordon, whose valuable paper has already been cited : to Jackson's "Hydraulic Manual," to the "Proceedings of the Institution of Civil Engineers," and the "Report of the Royal Commission on Railways and Public Works of Tasmania," to surveys and sections taken by Mr. T. B. Muntz, C E., in connection with the great flood on the River Barwon in 1880, and the litigation arising thereupon ; and to my brother Mr. M. E. Kernot, of the Victorian Railway Department.

I should feel greatly obliged to any member who would supply me with reliable particulars as to other cases, either failures or structures, that long experience has proved sufficient, but not excessive, which I can add to the diagrams, and so confirm or modify the conclusions already stated.

TABLE OF EXAMPLES OF WATERWAYS, CULVERTS, AND BRIDGES.

Note—In the subjoined cases the greatest breadth of the catchment area is usually from one-half to one-third of its length.

Locality.	Approximate Annual R'fall.	Height above Sea.	Character of Country.	Area of Catchment.	Area of opening.	Area proposed rule (c=40).	Remarks.	Sources of Information.
BRIDGEWATER, Tasmania	20 inches	Under 1,000 ft.	Steep and rocky	$2\frac{1}{3}$ sq. mls.	13 sq. ft.	75 sq. ft.	Failed disastrously	Royal Commission on Railways, 1886
Ditto	20 ,,	Under 1,000 ft.	Steep and rocky	$2\frac{1}{3}$,,	170 ,,	75 ,,	Standing	Ditto
BENDIGO CREEK, Sandhurst, Vict.	25 ,,	700 to 1,000 ft.	Undulating, lightly timbered	16 ,,	190 ,,	320 ,,	Failed repeatedly	G. R. B. Steane, Esq.
Ditto	25 ,,	700 to 1,000 ft.	Ditto	16 ,,	370 ,,	320 ,,	Proved ample	Ditto
COOTAMUNDRA, N. S. Wales	20 ,,	1,000 to 2,000 ft.	One-third hilly and rocky; renainder undulating or flat and moderately timbered	20 ,,	53 ,,	380 ,,	Failed disastrously	Evidence in case of Adams *v.* Com. of R.
MOONEE PONDS, Victoria	25 ,,	Under 1,000 ft.	Slightly undulating, very little timber	50 ,,	1,000 ,,	752 ,,	Proved ample	Personal experience of many years
PLENTY RIVER, Victoria	30 ,,	From 500 to 2,600 ft.	A small portion deep and densely timbered, the rest undulating and open	60 ,,	440 ,,	864 ,,	Failed disastrously	Trans. Roy. Soc. Vict. 1888, Pt. 2, p. 156
MERRI CREEK, Victoria	25 ,,	Varying up to 1,500 ft.	Undulating and lightly timbered	130 ,,	1,500 ,,	1,540 ,,	Sufficient	Personal experience
SALTWATER RIV. Victoria	30 ,,	Varying up to 3,000 ft.	Generally open & lightly timbered	560 ,,	4,500 ,,	4,600 ,,	Sufficient	Personal experience
YARRA RIVER, Victoria	35 ,,	Varying up to 4,000 ft.	All timbered, mountainous	1,500 ,,	8,000 ,,	9,640 ,,	Sufficient	Personal experience
BARWON RIVER, Geelong, Vict.	25 ,,	Varying up to 2,000 ft.	Lightly timbered, undulating	1,660 ,,	8,000 ,,	10,400 ,,	Not quite sufficient	Personal experience
Ditto Railway Bridge	25 ,,	Varying up to 2,000 ft.	Lightly timbered, undulating	1,680 ,,	4,000 ,,	10,496 ,,	Failed disastrously	Personal experience

REFERENCE TO PLATE XXXVIII.

Figs 1, 2, and 3 are intended to exhibit graphically the relation existing between area of catchment and area of waterway in a number of well-known average cases. The horizontal measurements give area of catchment in square miles, the vertical ones area of waterway in square feet. Sufficient waterways are shown by round dots, insufficient ones by crosses. The curves and dotted lines are plotted by means of the various rules or formula given by different authorities. For small areas of less than one square mile, the results are somewhat various and inconsistent, owing probably to variations in absorptive power of the surface drained. The larger areas being all country land grassed and timbered, are fairly consistent with the proposed rule.

In Fig. 1, all except No. 5 are in the City of Sandhurst, and are obtained from Mr. Steane's paper on "Rainfall and Flood Discharge" (Proc. Roy. Soc. Victoria, Vol. XXIV., p. 157); No. 5 drains Royal Park, near Melbourne; Nos. 2 and 9 are stated to be nearly sufficient, but not quite.

In Fig. 2, No. 1 is at Essendon, near Melbourne; No. 3 at Bridgewater, Tasmania; No. 11 Cootamundra, New South Wales; Nos. 13 and 14 on the Moonee Ponds Creek, near Melbourne; No. 15 on the Plenty River, near Melbourne. The remainder are in the vicinity of Sandhurst, and are from Mr. Steane's paper above mentioned.

In Fig. 3, Nos. 1, 2, and 3 correspond with 13, 14, and 15 in Fig. 2; 4 and 5 are on the Merri Creek, near Melbourne; 6 is a railway bridge over the Macdonald River in New South Wales; 7 one over the Saltwater River, near Melbourne; 8 and 9 are over the Macquarie River at Bathurst; 10 is at Collingwood, near Melbourne, over the Yarra River, while 11 and 12 are the road and railway bridges over the Barwon River at Geelong. The former of these proved not quite sufficient to discharge the last great flood, a small portion of the water flowing over the embankment, impeding traffic, but doing no further damage, while at the latter several hundreds of feet in length of embankment were swept away, and the waterway enlarged by the action of the river itself to nearly twice its original size.

The following papers were read :—

1.—RECENT PROGRESS IN SINKING DEEP FOUNDATIONS FOR ENGINEERING WORKS.

By Charles Ormsby Burge, M. Inst., C.E.

[*Abstract.*]

After a short Introduction, the paper refers to the extension of railways and the consequent necessity of bridging large rivers, as the chief cause of progress in deep foundations, and to the improvement in Portland and other cements as rendering chiefly such progress possible.

In earlier times timber piling was used exclusively for deep foundations, except in India, where a different method, to be adverted to presently, was pursued. The almost general substitution of iron for timber in engineering works led to the introduction of the screw-pile first used by Mitchell in 1834, since largely employed in bridging rivers and in marine piers, there being two forms, namely, hollow tubes of cast iron and solid forgings of wrought iron. These piles are, however, unsuitable for very deep foundations where the overlying material is soft or liable to scour, as it is impossible to brace the piles below ground, and the whole structure may therefore become unsteady. Instances of large bridges of this type, with which the author had been connected, are given, in which cylindrical piers had to be subsequently substituted for piles. Many marine piers have been constructed successfully on screw piles, as they are not subject to heavy and fast traffic. One at Huelva, in the South of Spain, is specially mentioned as embodying a novel principle of obtaining increased bearing surface, the area of the screw blades being considered insufficient. Large platforms were sunk round each group of piles, as far as they would go, when temporarily loaded with weights largely exceeding the permanent maximum load on the group. They were then strongly connected with the piling, and the temporary loading removed; the pier, therefore, chiefly rests on these platforms, the extension of the piles below serving principally to steady the whole.

Cylindrical foundations are next referred to, commencing with the primitive native Indian brick well, only large enough for a man to work inside of, built on wooden curbs, often cemented by mud only, and held together by straw ropes in sinking. Native divers descend in them to a depth of seventeen feet below water, excavating and bringing up basketsful of sand, and numbers of

these wells, sunk close together and filled with concrete, have been used for railway bridge foundations; the concrete in those sunk by the author being made in those days, of one part lime, two of brickdust, and four of broken stone. Such wells were sunk in India, complete including everything, for about sixteen shillings per lineal foot.

Larger brick wells and fewer in number are more in use latterly; they are eighteen feet and upwards in diameter, with iron curbs, and have been successfully sunk to over one hundred feet below beds of rivers. A description is given in this paper of a curious operation witnessed by the author at Cawnpore, when the remains of the submerged wells of a bridge previously carried away by flood, were blown away under the sand by guncotton, to make room for the foundations of the present Ganges bridge at that place.

Iron cylinders sunk and filled with concrete are then alluded to, as most generally in use out of India, and having the advantage over brick where deep water has to be dealt with, Mr. Barlow combining both systems in the new Tay Bridge, the foundations of which, and the mode of operations, being described in detail.

The stability of cylindrical piers against overturning by flood or drift wood is adverted to, and instances given of the two cylinders forming a pier being connected together by sol d plating in South African bridges to attain this object. Where the sinking is not guided by piles, tapering out at bottom of the clinders is strongly deprecated, experience amply shewing that this renders true vertical sinking very difficult.

Where water-bearing strata have to be passed through with obstructions which cannot be removed except by actual manual labour, and where the largeness of the area gives room to work in, the pneumatic process has been generally adopted. While applicable to, and often used in cylinder work, the method is indespensable in inverted caissons. The caisson is like an inverted box with the open side downwards, and the masonry is begun on the top, which is made specially strong, and is proceeded with as the caisson sinks into the ground, excavated by the men inside of it. Holes or shafts are left in the masonry for the passage of men and material to and from the caisson, and for the supply of the compressed air which is introduced to force out the water and enable the men to work. Each shaft is provided with an airlock, a contrivance for preventing escape of compressed air, which is fully described. When the desired depth is reached, the caisson is filled with concrete and left as part of the permanent work.

The pneumatic system has its limit at about one hundred feet below water level, as men cannot work properly under greater pressure than is necessary to sustain a column of water of that height.

In the great Brooklyn Bridge, the caisson is of timber strongly roofed, and in the deeper pier, which is founded seventy-eight feet below water, it is lined with iron. It was sought in this case to avoid the expense and delay of passing the excavated material through the airlocks, by constructing separate dredging tubes open to the air, which passed through the caisson and below the level of its cutting edge and of the compressed level of water.

The workmen excavated around the foot of these shafts in the caisson, so that the material sunk through the water and under the edge of the dredging tube, inside of which ordinary dredging grabs, working in the usual method, removed it; but it was not a success, as, notwithstanding the care that was taken to keep the foot of the tubes below water, there was a great loss of compressed air.

These caissons are among the largest ever constructed, being one hundred and two feet by one hundred and sixty-eight feet, each with nine feet six inches depth of chamber, the Brooklyn pier being founded on trap boulders embedded in clay and sand, forty-five feet below high water, and the New York one is sunk through quicksands to rock at a depth of seventy-eight feet below the same level.

Standing on this enormous structure which rises one hundred and thirty-five feet above the crowded river, with a span of nearly 1,600 feet, and turning from the magnificent view around, one can hardly realize, how the lower parts of the solid masonry of the huge towers could have been actually, so to say, floated and sunk with such steadiness and accuracy as to be effectual for their purpose.

In the Forth Bridge the caissons, which are of iron, are circular, seventy feet in diameter at the base; four of these forming one of the great piers. There is a seven feet working chamber at bottom, but the walls are carried up above the roof, and pockets inside the circumference of these upper walls are constructed so as to enable any point to be loaded with concrete, and the sinking to be regulated. Notwithstanding this, one of the caissons tilted over in sinking, and much trouble, delay, and expense were incurred before it was righted. The weight on these foundations, including the tilting action of a wind pressure of fifty-six pounds per square foot, is about six tons per square foot.

The foundations of the four legs or pedestals, of the great Eiffel Tower in Paris are similar in type, four caissons being used for each foot. The pressure, including the enormous leverage produced by the effect of wind on a structure nearly 1000 feet high, is estimated at under four tons per square foot.

The centre pier of the Harlem River Bridge, New York, supporting the thrust of a five hundred and ten feet arch on each side of it, stands on a timber caisson one hundred and four feet by fifty-four feet by thirteen feet deep, divided into three compartments by vertical partitions. These partitions, besides strengthening the caisson, afforded shelter to the men during blasting, as the bottom was rock of greatly inclined surface.

One of the most difficult feats in this kind of work was the sinking of a wooden caisson foundation for a lighthouse in Delaware Bay, an exposed position open to the full fury of the Atlantic. It was towed out with part of the cast-iron shaft upon it, and then further loaded and sunk. The compressed air in this case was also made use of to force out the sand up through vertical pipes.

Beyond the pneumatic limit, about one hundred feet under water level, all excavation must be done by dredgers, and special care is required, in the design, that no contingency shall arise at the bottom, which has to be dealt with by manual labour, diving operations being impossible. At these depths also the skin friction, unimportant in a cylinder of moderate depth, becomes so great that special arrangements for overcoming it must be provided.

There are four well-known railway bridges, two now in course of construction, and two completed, in which these difficulties had to be met. The Benares Bridge over the Ganges, the Poughkeepsie over the Hudson River, the Hawkesbury Bridge in New South Wales, and the Jubilee Bridge over the Hooghly in Bengal.

In the Benares Bridge the principal piers are sunk to a depth of one hundred and forty feet below water level, and are formed of oval brick wells sixty-five feet by twenty-eight feet, and as they had to be begun in water, the bottom lengths are cased in iron. Each is divided into three compartments in which the dredging is carried on.

In the Poughkeepsie and Hawkesbury foundations somewhat identical principles are adopted, namely, caissons divided into dredging and loading compartments.

In the American work the caisson is of timber one hundred feet by sixty feet by one hundred and twenty-five feet deep, divided vertically into forty cells, the sinking, which is to about one hundred and thirty feet below water, being effected by filling in some of them and excavating in others.

In the Australian bridge the caisson is oval and is of steel and iron forty-eight feet by twenty feet, splaying out at bottom two feet more all round, and it has three dredging wells in line at the centre, parallel with its length, and splaying out to meet the outer skin and each other at the bottom in a cutting edge. Between the wells and the outer skin,.which are strongly stayed together, the space is filled with concrete as the structure sinks. The greatest depth, which is also believed to be the greatest ever reached in a bridge foundation, is one hundred and sixty-one feet below water level.

In the Hooghly Bridge the caisson is somewhat similar in shape to the Hawkesbury one, but has a completely vertical outer skin, and the three dredging spaces extend right across the structure, occupying the semi-circular ends and the central portion. Weight is obtained by concreting the two fifteen feet intermediate spaces and by a brick lining around the semi-circular ends. In all these cases the wells are of course filled up with concrete when the bottom is reached.

This review, as to what has been done, is now brought down to the latest date, and a few remarks founded on practical experience, of several years standing, of the majority of the systems mentioned, may be made.

No general principle can be laid down as to the preference of any one system over another. As in medicine, so in engineering, and especially as regards foundations, not only does every disease require its own physic, but even the same disease in different individuals demands separate intelligent treatment.

Any remarks, therefore, that are made in this paper, must be considered as thoroughly subordinate to this general principle, that every case must be met and dealt with on its own merits.

Having this in view, it must be first remarked that great caution should be exercised in the use of screw piles. In railway structures of any size they should certainly be avoided, except under special circumstances favourable to their use. Not only does the objection of difficulty of bracing below scourable beds, already alluded to, arise, but the whole foundation is dependent on the comparatively perishable material of the screw blade, which in time may corrode unseen, and leave insufficient bearing surface. Subsequent settlement of one pile may distort and strain important parts of the upper structure.

Failures already alluded to within the author's experience and that of others have led to these opinions; failures arising from the system itself and not from any defects in the special designs adopted in these cases.

With respect to cylindrical or well foundations, it has always seemed to the writer strange that, with few exceptions, notably that of the Tay Bridge, the system of brick wells should be confined to India. There are plenty of rivers bridged elsewhere, in which sandy beds, dry nearly all the year round, point unmistakably to this expedient, in the Cape, for instance, where, notwithstanding iron is preferred. Brick cylinders have the great advantage of supplying their own weight, and of providing a more permanent coating to the concrete core than metal does. Nor will it be found, even when local skilled labour is expensive, that the former costs more than the latter.

The pneumatic processes are largely in favour on the Continent of Europe and in America, and illustrate a successful application of scientific knowledge to practical work. It is a pity that physical conditions limit the extent of the application. The effect of highly compressed air on the human system, is that the blood is driven in from the exterior and soft parts of the body to the central organs, especially to the brain and spinal cord, causing violent neuralgic pains and sometimes paralysis.

There is hardly sufficient experience yet of the system of a double casing with the weighting material between, employed at the Poughkeepsie, the Hooghly, and the Hawkesbury to enable the law to be laid down with regard to them, but the experience, so far gained by the author at the latter bridge, appears to show that where a great depth has to be reached there must be ample latitude given in the size of the caisson in plan, so as to allow for any divergence that may occur in sinking. Such divergence, trifling in a shallow foundation, may become serious in a deep one, and the enormous weight of the structure renders control very difficult. Such control may, in the opinion of the author, be given to some extent, in the first place as regards horizontal divergence, by the shape of the lower portion, which should be vertical on the outside. Any outward splay given to this part may intensify a lateral movement, however caused, in the direction of the splay on one side by a wedge-like action, while the similar splay on the opposite side has no counteracting influence. In the second place, to counteract any tilting action, the dredging holes should be sufficient in number, and so placed, that by dredging in any one, a "straightening up" effect can be produced, that is to say, there should be four at least, so as to control tilting action towards any of the four cardinal points. It must be remembered that in dredging these deep holes, the slightest tilt throws the dredging grab over to that side of the well, at the bottom, which, in order to recover verticality, ought to be avoided, as it tends to undermine that cutting edge which is already too low. It is different from the case of a foundation of a single large shallow well or cylinder, which can be dredged at any desired point, and that side sunk accordingly.

In the multiple tube system, as it may be called, on the contrary, each well must act for itself in regulating the descent on its own side, and its position should be so fixed in the design so as to lead to that result. As these caissons must necessarily be deep in proportion to their area, there is no chance by weighting them unevenly to restore their balance, except when the sinking is just begun.

2.—ON UTILISING WASTE UNDERGROUND WATER BY TUNNELLING IN THE HILLS.

By Thomas Parker, C.E., Port Adelaide.

I.—ABUNDANCE OF UNDERGROUND WATERS.

The existence of large quantities of underground water in South Australia has long been recognised, and they have been utilised to a great extent, both by the ordinary means of wells, and also by means of boreholes with artesian springs. There are, however, some drawbacks to these methods of obtaining water, arising from the cost of lifting it to the surface; and also in the case of artesian waters arising to the surface, in some cases being found only in small quantities, or at a low level not convenient for distribution over any great extent of country for irrigation purposes, and frequently found to be too salt for most purposes.

For these reasons I have been led to enter into the enquiry during the last few years as to whether it is not possible to avail ourselves of these subterranean waters by means of tunnels in the hills, and thus obtain larger supplies at much less cost, and at levels more convenient for distribution to our cities and towns, and for irrigation on the plains. I am now inclined to think the answer can be given in the affirmative, and my object in these notes is to give a few data and reasons in support of that conclusion, and to endeavour to reduce to a scientific form our present data respecting the underground waters of this colony.

I had an opportunity some time ago of examining the large district through which the Willochra Creek has its course, with its numerous branch creeks from the hills, and I obtained particulars, over a wide district, of the general position of the underground waters. From the depths at which the water stands in a large number of wells in the sloping country on the eastern face of the Flinders Range, I ascertained that on a line running about two miles below the top of the range the water in the wells was pretty uniformly at a depth of from ninety to one hundred feet from the surface of the creek level, and the water generally free from salt, and useful for domestic purposes and for irrigation; and on a line about three miles lower down, and parallel to the main road from Quorn to Wilmington, the wells were found to be one hundred and fifty feet in depth and generally slightly brackish. I found, also, these depths prevailed generally along this slope of the Flinders Range. From these data, and from levels taken with the Aneroid barometer, I laid down last year a hydrogeological section of the country from the Coonatto Range, past the township of Bruce, across the Willochra Valley and the Flinders Range referred to, as far as the next valley of the Capowie Creek. On this section I showed the line of surface, and underneath, and nearly parallel to it, the line of saturation or underground waterline on the slope of the hills, and projected this latter line under the plain at the township of Bruce at a depth of one hundred and ninety feet. I notice whilst writing that a boring party, under the Conservator of Water (Mr. J. W. Jones), have just struck water near Bruce at about that depth, which is artesian, and, rising to the surface, flows over at the rate of 10,000 gallons per day.

The conclusion I am inclined to draw from these and other data are the following, namely :—

1. The underground waters of that district, coming from the hills, are flowing below in the same general direction as the fall on the surface of the country, and on a line nearly parallel to it. The general course of the underground water on one side of the Willochra Creek basin is shown in a section which I have prepared; it is most probable that the same conditions prevail generally throughout the Flinders Range, of which this is a part. The underground waters from the Mount Lofty Range seem also to pass under the plain in a similar position.

2. The sources of these underground waters is percolation from the surface. This percolation takes place chiefly under the beds of rivers and creeks, and other water courses in the hills and on the plains, in a vertical direction, and also laterally on each side of the stream.

In South Australia that portion of the rainfall is much the larger which never reaches the rivers and creeks, but enters the ground on or near the spot where it falls, and goes to swell the volume of subterranean streams. This proportion varies much in different countries. In England the rainfall is sometimes roughly divided as follows, viz. :—One-third for evaporation and absorption ; one-third for percolation into the ground to form springs ; and the remaining one-third drained into the rivers. In warmer and drier climates the proportions for percolation and absorption are very much greater. On the Buffalo River, Africa, four-fifths of the rainfall is lost by evaporation and percolation underground. In most countries gaugings of the flow of water in the various streams have been taken during a course of years and those compared with the rainfall records, so that in any particular district the available quantity of water that can be conserved may be estimated with sufficient accuracy ; in this colony we have only very slight data of this kind ; rainfall guagings have been taken for several years, but for practical purposes they are of very little value without guagings of the flow of water in our rivers and creeks. And I wish here, in passing, to point out the great need, for scientific as well as for practical purposes, of this information, which can only be obtained by a systematic guaging of the flow of water in our principal streams.

The question of the proportion of our rainfall, lost by percolation and other causes, is a very difficult one, and yet of the greatest practical importance. From guagings taken by me of the flow of the River Wakefield, and other streams, I find the following are the approximate results:—At Barossa, in 1884, $16\frac{1}{2}$ inches loss out of a total rainfall of $21\frac{1}{2}$ inches; at Beetaloo, gauged in 1885, 24 7-10th inches loss out of a total rainfall of $25\frac{1}{3}$ inches; and at the River Wakefield, gauged in 1886, $21\frac{1}{2}$ inches loss out of a total rainfall of $21\frac{3}{4}$ inches per annum. Assuming the loss by evaporation and absorption to be half the above quantities, the loss due alone to percolation under ground will be as follows, viz.:—At the Barossa catchment area annually, a loss of $8\frac{1}{4}$ inches in 1884, and five inches flowing in the river in the hills; at Beetaloo in 1885, loss by percolation 12 3-10ths inches, and flowing in the river 6-10ths inches; at the River Wakefield in 1886, loss by percolation $10\frac{3}{4}$ inches, and flowing in the river 18-100th inches.

II. THEIR UTILISATION IN OTHER COUNTRIES.

Such underground water supplies in many other countries have been turned to practical account; for instance, in California, where tunnelling has been carried out under some of the rivers; at Seville, in Spain, where water supply is obtained by a tunnel into water-bearing strata, consisting of permeable calcareous rocks resting on impermeable clay. The springs rise and flow away through the tunnel to the city, and some parts of these tunneling works are said to have been carried out by the ancient Romans. Explorations also were made by tunnels into the hills in the neighbourhood of Lisbon, resulting in the obtaining of a supply of about 120 million gallons per annum; also the city of Florence has obtained water by similar means; a tunnel has been driven into the valley of the River Arno, and the supply of water, which is of an extra pure quality, for domestic purposes, is 1,734 million gallons per annum, or about twice the supply for the city of Adelaide, and the total cost of these works is only £268,000.

Another instance is that of the Naples water works which draw their supplies from springs in the northern slope of Monte Somma. The waters of these springs are collected by means of infiltration galleries; the floors of these galleries are not paved, and openings are left in the side walls and arch for the water to flow in. The water-bearing strata are in the hills and situated fifty-two miles from the city, and 1,050 feet above the sea. The whole of the supply thus collected in tunnels is about 38,000,000 gallons per day.

As however, our conditions are different to those of the countries just named, it appears to me necessary to examine the question entirely from the standpoint of our own conditions; in some of these countries the rainfall is much larger than here, and in others, though the rainfall is no greater, yet the rivers are fed by the melting snow on the mountains; notwithstanding these climatic differences, I have no reason to doubt the conclusion that the underground supply of water is of such a great extent as to make the question of utilization one of the most important questions for this and the various countries of Australia.

III.—A SCHEME FOR EXTENTION OF THE ADELAIDE WATERWORKS.

The urgent need of an addition to the water supply is a question which has not yet been sufficiently realized by the citizens of Adelaide, Port Adelaide, and other suburban towns.

As to the present source of the supply for the Adelaide waterworks, leaving out of account the small supply from other sources, the water is all taken from the River Torrens in the winter months, viz., from May to November inclusive, and in these months reservoirs are all filled for storage for the summer season; from December to May the supply is drawn from the storage in the reservoirs alone. This, then, is the key question to the whole position, how to augment the supply during the summer months, December to May? It is evident that if permanent springs can be found with a sufficient supply to supplement the present storage of the reservoirs through these months, the problem can be solved in a simple and inexpensive manner, and it is to this problem I have been devoting my attention for some years, as already stated. In the course of my investigations I have examined the River Torrens at various points from near its source to the Reedbeds, and endeavoured to obtain a general knowledge of the river as a whole. The catchment area is about one hundred and thirty square miles, and assuming the average rainfall at twenty-five inches per annum, the total quantity of water falling upon the area is about 47,000 million gallons; twenty-two per cent. of this flowing in the river as estimated for Barossa, this would amount to about 10,000 million gallons, leaving the enormous quantity of 37,000 million gallons as waste water. Assuming that one-third of this waste is due to evaporation and absorption, then we have no less than about 24,000 million gallons passing underground annually, or about twenty-three times the present capacity of the Adelaide Waterworks.

With respect to the underground waters near the river, so far as the evidence goes, it appears to me they lie much nearer the level of the river bed than is the case in some of our northern streams, which I have examined. At Athelstone, the first place examined above the plains, the well at Mr. Abner's section is about a quarter of a mile from the river and where the surface of the country is higher, and water is obtained in the gravel at river level; this water rises and falls with the river, showing a laternal percolation from the latter river of the distance named. Proceeding up the river to a point near Highercombe I found there is a remarkable abundance of water in the country and springs exist a considerable height above the river, which issue from the surface in a large number of gullies; in fact, so prevalent is the water at the surface in the form of permanent springs that few wells are to be found at the river after you pass through the gorge into the hills. At one place, in a small radius of a mile or two from Section No. 5,494, Hundred of Yatala, there are about fifty springs of considerable volume, I am informed, some of which I examined, and I made a rough estimate of the quantity of water thus issuing from the ground in these springs in the gullies branching off from the valley of the Torrens, in a distance of say about eight miles, and I think it will not be less than about one million gallons per day, or about one half the supply of the Adelaide Waterworks.

I conclude from the data I have obtained so far that the line of saturation or main underground water line of the valley of the Torrens is in summer near the level of the river bed, and that it rises a little above this in winter. This is independent of the artesian springs at a higher level. If this conclusion is correct, then it is evident that by going in with a level or drive under the river in suitable localities, where there are good water-bearing strata, a permanent supply of water could be obtained, and that supply would probably be of an extra good quality by natural filtration through the permeable rocks of the locality.

The mode of carrying out the works for tapping these underground waters would be to proceed alongside the river for a short distance in an open cutting on one of the flats, and then drive the rest of the distance under the level and follow the course of the river as nearly as possible, and gather the water in the main drive and also in cross country levels, sinking shafts at intervals for facility of working.

The following are the chief advantages in my opinion of a scheme of this kind:—

1. Extra purity of water and a lower temperature. There is every probability of this.

2. Economy of cost as no storage reservoirs are required.

3. Facility of extension at any time in a gradual way by continuing the drives and levels.

As the estimate of cost of the former scheme at Barossa for increasing the Adelaide suppy was not less than £700,000, and I hope by this scheme to show that it can be done for under £200,000. I think the importance of the matter will be readily seen.

This subiect is of the greatest consequence, not only to South Australia, but also to the other colonies of Australia, in all of which the question of how to obtain water for domestic and stock supply, as well as for irrigation purposes in good quantity and at a moderate cost, is now generally acknowledged to be of the most vital importance.

FRIDAY, AUGUST 31.

The President, Professor W. C. Kernot, M.A., C.E., in the Chair.

The following papers were read :—

1.—THE FIREPROOFING OF CITY BUILDINGS.*

By JOHN SULMAN, F.R.I.B.A.

AUSTRALIAN cities have hitherto been remarkably free from great all destroying conflagrations. This immunity may be accounted for in many ways. The buildings are not very lofty or closely packed, artificial heating is less used than in colder climates, manufactures are not fully developed, the fire-brigades are well organised and the water supply is sufficient. But some of the conditions are rapidly changing and the risks are increasing. The causes of the changes are the simultaneous introduction of a great amount of English capital and the adoption of safe and speedy lifts. The former has caused a boom in city land, and the latter has rendered the top floors of lofty buildings easily accessible. When land becomes abnormally dear an adequate return on the capital invested can only be obtained by "taking it out of the sky." This movement is now in full swing in Melbourne and ere long the heart of each of the chief cities of Australia will be packed with eight, ten, or twelve story structures. If these are constructed on the same principle as ordinary buildings of three or four stories and a great fire should take place, the destruction would rival that of Chicago. Our present mode of building is to run up brick or stone walls as thin as the Building Act will permit, fill the openings with wooden frames, form the floors of inflammable Oregon joists, cover them with boards, ceil with thin wooden linings, cut them through from top to bottom for lifts, cased in with wood, if cased at all, divide the rooms with wooden partitions, erect a wooden staircase, and finally cover

* Since this paper was read it has been revised and amplified by the author.—ED.

all in with a wooden roof—what is this but a magnified match box? Should a fire get a start at the bottom of a lofty building so constructed, nothing could save the occupants of the upper stories, the danger of spreading would be increased ten-fold and the risk of a general conflagration greatly augmented. On the ground of humanity alone this danger ought to be faced at once, to say nothing of the immense loss of property that is inevitable should such a fire occur.

The problem, though practically new to Australia, has been met both in Europe and America. In the cities of France, Germany and Italy a non-inflammable building is the almost universal rule, in England and America it is becoming the rule, at any rate for buildings of importance where the occupants are many or the contents valuable. Let us therefore glean what hints we may from these countries and apply them to our own needs. England and America will naturally afford us the best information on this system of building construction, as the modes in use on the Continent of Europe are foreign to our customs and ideas, though did time permit some useful hints might be gained therefrom.

But first let me qualifiy the title of my paper. Such a thing as an absolutely *fireproof* building does not exist. Given a sufficient quantity of highly inflammable fuel and in time all materials would fail under intense and long continued heat. The object is therefore to render a building *fire-resisting*, and this may be effected in many ways and to different degrees to suit different requirements. For instance, a factory or warehouse would not require the same treatment as a Bank Strong Room ; or a private dwelling, that of a large Hotel or Theatre. The Americans divide their buildings into classes, viz.: ordinary, slow burning, and fireproof (so called). The division is simple and suited to my purpose, I will therefore adopt it though I shall make the terms embrace more than they do in America.

The ordinary building I have described—let us now see how we may make it less combustible, or, in fact, slow burning. For the sake of clearness I will number each suggestion.

1. In a warehouse or factory, with naked floors, the mere substitution of an Australian hardwood, such as well-seasoned ironbark, in place of Oregon joists, girders, and posts, is a distinct gain, especially if the timber be thickly coated with limewash or a fire-resisting paint, such as that prepared from asbestos.

2. In ceiled buildings, plastering is much more fire-resisting than wooden linings, especially if hardwood, or, better still, wire lathing be used instead of sawn American laths. For plastered ceilings Oregon joists are preferable to hardwood, because they do not shrink or twist so much and cause fewer cracks in the plaster. Asbestos mortar may also be used instead of ordinary lime mortar.

3. To make up for the use of the inflammable timber the joists may be pugged with hair mortar, (Pl. XXXIX., fig. 1). When the plastering gives way the pugging prevents the flames getting round all three sides of the joists.

4. Instead of using plastering or pugging, the ceiling may be formed of sheets of galvanised iron, kept three inches away from the joists and coated on the top with two inches of hair mortar, (Pl. XXXIX., fig. 2), as at the *Courier* building in Brisbane.

5. A still better mode is to line the ceilings with light porous terra-cotta tiles, hung up to the joists by iron screws and clips, or hoop or angle iron, but kept one inch away from the wood, (Pl. XXXIX., fig. 3). They may be left bare or plastered. This system is a good one, but adds somewhat to the weight of the floor. It is used in the United States.

6. Instead of ordinary deep joists at eighteen inches centres, timbers almost square, set at three to six feet centres may be used. These are covered with three inch planking, with grooved and tongued joints. (Pl. XXXIX., fig. 4.) This mode is occasionally adopted for warehouses, both in England and the States, but is common in bridge work. It is quite slow burning in comparison with a floor composed of the ordinary joists and boards. If the underside be limewashed, plastered, or cased with galvanised iron or tin plates, its resistance is materially increased.

7. Ordinary deep joists may be set close together and spiked, screwed, or bolted to one another. (Pl. XXXIX., fig. 5.) The joints are filled with fine plaster or cement. The ceiling may be coated with plaster (large flat-headed nails forming the key), and the floor with cement or tiles. It is well to lay an inch of loam under the cement or tiles to prevent cracking. This system is known as Evans and Swain's,* and is useful when timber is cheap and the risk of failure from dry rot and white ants is not great.

8. Timber posts and beams of large size have been found more fire-resisting than unprotected cast iron columns and rolled iron girders. The timber chars to the depth of an inch or so and will then stand for a considerable time. This was especially noticeable at the *Evening News* office fire. A coat of limewash, fireproof paint or solution, or a lining of galvanised iron or tin is very desirable where the risk is considerable, as for instance, where there is much oil in use, which would soak into the wood. Oily cotton waste in conjunction with an oily floor is especially dangerous, being very liable to spontaneous combustion. A coat of hair mortar mixed with chloride of lime, with large headed nails for a key, also stands well when not subject to hard wear, and is still more fire resisting than the protecting coatings just mentioned. Unprotected cast iron columns melt if the heat is fierce, or crack, if the hose is turned on them while red hot, and rolled iron joists or

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* See Appendix A.

wrought iron girders twist, sag, fail, and drag the floors down (and walls too in some cases), more quickly than timber beams of the same strength. This is the experience of Captain Shaw, of the London Fire Brigade and of many others.

9. Staircases and lifts cutting through the floors render the foregoing precautions of little service, because they act as vertical flues for fire and smoke. They should therefore be placed outside the main walls, or if they must be kept inside should be enclosed by brick walls, or at least light terra cotta partitions, and shut off by fire resisting doors. An ordinary wooden staircase may be rendered partially fire resisting by filling in the soffit with concrete. The fire can then only get at one side of the wood and hence it burns slowly.

10. The roof is of much importance. A fire may be started there by careless plumbers employed on repairs, by sparks from adjoining buildings, or in other ways—while the roof remains intact over a fire there is still a chance of subduing it, when it goes all hope vanishes. If the roof be open, viz. without a ceiling under it, many of the expedients suggested for floors may be adopted to increase its resistance to fire. In some American factories the roof is formed of three inch planks (Pl. XXXIX., fig,4) on beams laid almost flat, and covered with several thicknesses of roofing felt and then a layer of asphalte, finished off with fine gravel rolled into the asphalte. Asphalte though bituminous, as mixed and laid with grit is fire resisting. With an ordinary roof the best precaution is a thoroughly fireproof ceiling. In Sweden where fires are frequent this is compulsory; for two story dwellings with attics, a three inch thickness of brick or stone laid in mortar is enforced. One of the floors suggested in the next section might also be introduced in this position with the greatest advantage. A good fire resisting ceiling may, however, be made of timber joists cut feather edged and filled in solid with concrete, or by nailing fillets on the side and then filling in with concrete. The lower edges of the joists only being exposed, they would resist for a long time, and, not being intended to carry any other load, the weight of the concrete is not so objectionable as it would be in ordinary floors.

11. The size of an undivided building should be restricted. In London the Building Act limits this to 216,000 cubic feet which would allow an area of say 100′ 0″ × 43′ 0″ × 50′ 0″ in height. The greater the subdivision, the greater the security, hence some authorities hold that this is the chief point to attend to, as no floors are absolutely fire proof, but brick walls of sufficient thickness are. In all cases the division walls should rise well above the roof. In London and Sydney the minimum is fifteen inches and in Melbourne twelve inches. A greater height might be enforced with advantage in exceptional cases. Of course no combustible material should penetrate through the division walls.

12. Communication between subdivided buildings is frequently essential, and the doorways so made are too often the cause of the destruction of large blocks of buildings. Hence, even in slow burning construction they should be as fireproof as possible, and will be described in the next section.

By the adoption of one or other of the foregoing suggestions best suited to the needs of any particular building, it might be made much less combustible than the ordinary structures which fill our cities, and in most cases a fire could easily be confined to the particular section of the building in which it commenced, pending the arrival of the Fire Brigade. This alone would be a great gain, as a large amount of property would be annually saved, and the distressing loss of life which frequently occurs would be entirely obviated, as sufficient time would be allowed for escape. The cost of either of these improvements is only moderate, and would not add very appreciably to the outlay on most buildings.*

The more perfect systems of fire-proofing are of course more expensive than those first described, but are well worth the outlay in buildings of any importance. I will deal with them in the same order as in the slow burning system.

a. Cast iron girders and brick arches, (Pl. XXXIX, fig. 6), were used for many years in all kinds of buildings, and are still, I believe, in the cotton mills of Lancashire, being in that locality the cheapest form of solid floor suitable for machinery. Cast iron, however, is very liable to blow holes and various other defects, and snaps sudddenly if cold water is thrown on it when heated. This kind of floor is also very heavy and needs to be tied in with rods to resist the thrust of the arches. The serious failure of a floor of this kind at King's College, London, from a defective casting proved the death-blow of this system, so far as its general adoption was concerned.

b. Fox and Barrett's system, (Pl. XXXIX., fig. 7), was also much used at one time. It consists of rolled iron joists supporting small intermediate joists or T irons about 1′ 6″ apart which carry fillets of wood about $1\frac{1}{2}'' \times 1\frac{1}{2}''$ covered with lime-concrete. The wood fillets are a defect, but enable a cheap concrete to be used, and also afford fixing for the ceiling laths. This has lately been obviated by the use of specially made bricks in lieu of the wood fillets, and so far is an improvement, but nevertheless the system lacks simplicity.

c. Where a flat ceiling was not required Dennet's arching of plaster concrete, (Pl. XXXIX., fig. 8), was frequently adopted, and in Her Majesty's Theatre, London, I have seen this material spanning 8ft. or 10ft. without intermediate support. It has the advantage of largely reducing the quantity of iron in the floor, but the

* See Appendices B, and C.

material itself has not the fire-resisting qualities of cement concrete. Wooden ceiling joists and plaster are adopted if a flat ceiling is required, thus reducing the value of the system as a fire proof one.

d. Rolled iron joists filled in with Portland cement concrete formed the next step in advance, and this mode is still much used owing to its simplicity and economy. For wide spans and light loads the concrete may be arched, for heavy loads where the rolled iron joists must be closer a flat ceiling is preferable, (Pl. XXXIX., fig. 9.) If the boarded centering be kept 1″ to 2″ below the lower flanges of the joists, the concrete partially or wholly covers them. Then the ceiling may be formed by cementing direct on the concrete, thus completely covering the iron joists. This is a great gain, as in case of fire, the lower flanges are slightly protected, and do not so readily heat, stretch, and fail. If there are any iron girders carrying the joists they can be protected by binding galvanized wire netting around them, tied to strips of hoop iron and then filling in with fine cement concrete between boards, giving a thickness of at least 2″ over the iron in every part. I am adopting this system in several works at the present time, and find it simple and comparatively inexpensive. For obvious reasons, the lighter the concrete the better, hence, coke breeze is much used both for casing the girders and for filling in between the joists. It was, I believe, first introduced in some of Allen's Workmen's dwellings in London, is incombustible when mixed with cement, and is, moreover, less likely to fly to pieces from heat than gravel or broken stone concrete. The addition of a small proportion of sand varying with the fineness of the breeze is advantageous.

e. For small rooms and light floors, Mr. Allen used plain bars of iron as joists, crossed by $\frac{1}{2}$″ rods laid the other way. The breeze concrete 6″ in depth, was then filled in on boarded centering making a very thin, but fairly strong fire-proof floor. The iron is entirely protected and the cross rods hold up the concrete. A preferable alternative is to use deeper plates, punch them and thread the rods through the centre on the neutral axis of the plates, (Pl. XXXIX., fig. 10), the rods have a greater depth of concrete above them, and hence there is less chance of fracture.

f. Another form of floor, much used in Melbourne at the present time, is a German development of the corrugated iron type, called "Traegerwellblech," (Pl. XXXIX., fig. 11.) It consists simply of sheets of tough iron rolled into deep corrugations or channels, and filled in above with concrete. It is not so fire-proof as the floor described in clause *d*, as the lower flanges of all the iron joists are exposed ; but it will carry a considerable weight. When the load is light, a much cheaper floor may be made by substituting ordinary twenty-four guage corrugated iron, cambered from joist to joist, and then filled in with concrete. Another form of corrugated flooring is "Lindsay's patent steel decking" which consists of splayed steel channels rivetted together. It is covered with concrete, and will span from twenty to fifty feet, without girders. The metal is, however, exposed on the underside, unless a false ceiling of wood and plaster, or concrete is formed underneath. The only example of this construction in the colonies, so far as I am aware, is in Mr. Paling's new buildings, near the Post Office, Sydney.

g. The honour of inventing the most perfect fire-proof floor as yet introduced, must, I think, be accorded to the Americans. It consists of straight keyed arches of hollow terra-cotta blocks, which fill in between the rolled iron joists. The girders, and the lower flanges of the joists are protected by linings of the same material (Pl. XXXIX., fig. 12), kept an inch or so away from the surface of the metal. This floor is very light, strong, and practically fire-proof, the air-space between the terra-cotta and the iron preventing the transmission of heat. In 1870, a girder for the National Safe Deposit Company, of London, protected as just described, was tested by fire with the most satisfactory results, and since then this system has grown rapidly in favour.* This was the first example of the construction in England, but whether borrowed from the Americans or not, I cannot say. A great improvement which the Americans have undoubtedly introduced is the material known as porous terra cotta. It is simply clay mixed with saw-dust, or other vegetable matter, which is consumed in the burning of the blocks. They are thus honeycombed, and are muchlighter and more heat-resisting than ordinary terra cotta. The best known American systems are those of the Wight Fire-proofing Company, and "Henry Maurer and Co.," who both adopt porous terra-cotta. In England, the Doulton-Peto system is precisely similar to the American, but is carried out in ordinary terra-cotta. The Ameri can systems are represented by a company in Melbourne, and the Doulton-Peto by an agent in Sydney. During my last visit to Melbourne, I noticed that porous terra-cotta of local manufacture, or terra-cotta "lumber," as it is called, is being used in one or two buildings, though as yet it leaves something to be desired on the score of accuracy and finish. As in the coke concrete flooring, so with this, there is no need for a false ceiling, because the plaster or cement can be laid straight on to the terra-cotta, which, if porous, affords an excellent hold. A further precaution is to prepare the blocks with dove-tailed grooves, and so increase the key. Although the most expensive of any floor, it is, in my opinion, the most fireproof, and therefore should be adopted when the greatest safety from fire is desired.

h. All the systems I have just described can be finished with a wooden floor, when desired, by laying ordinary wooden joists on

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* See Appendix D.

the iron, when the weight to be carried is heavy, the iron joists are far apart, or the filling in is weak. These, however, occupy space, and afford fuel for a fire, so that is better to fix rebated fillets under the top flange of each joist, (Pl. XXXIX., fig. 9), well wedged, and bed intermediate bearers on the filling. A more fire-proof mode is to fill up to the top of the iron joists with concrete, float the same with cement, and lay solid wooden blocks or parquetry in one of the many forms in which they are now prepared and used in England. There being no interstices, the chances of ignition are much modified, and the quantity of inflammable material is greatly reduced. A perfectly incombustible floor, laid directly on the concrete, such as cement, asphalte, slate, tiles or marble, is, of course, the best from a fire-resisting point of view, and is especially desirable in the passages of public buildings.

i. The supports of the floors are equal in importance to the floors themselves, and if insufficiently fire-resisting, the building is but little better than one of ordinary construction. Cast iron is notoriously treacherous, giving way altogether if suddenly cooled. Wrought iron and steel columns have lately been introduced, but these are liable to buckle under heat. They may be partially protected by plaster or wire-lathing, or, better still, by porous terra-cotta blocks, (Pl. XXXIX., figs. 13*a* and 13*b*.), which may be secured either by grooved joints and bonding, or by clips and bolts. In all cases, an air space should be allowed between the blocks and the metal, and with these precautions metal columns may be considered practically fire-proof. Another mode of rendering columns fire-proof without casing, is to keep them charged with water. The oxidation is a fatal objection with wrought iron columns, but in cast is not so serious.

j. As in slow burning buildings, staircases and lifts should be enclosd by brick walls, and kept outside the main walls of the buildings, and in addition the material of the staircase itself should be incombustible, as iron, stone, or marble, or, better still, of a fire-proof material, as concrete or terra-cotta. The form of the staircase is also of importance, especially if placed within the building, the most perfect being that enclosed by walls on both sides of each flight. An open well in the centre becomes, during a fire, a vertical flue, and enormously increases combustion.

k. Instead of using wood for the internal divisions of a building, the Americans now largely adopt partitions of hollow porous terra-cotta (Pl. XXXIX., fig. 14), three, four, or six inches in thickness. They are very light, strong, sound proof and fire-resisting, and can be built on any of the floors just described. These reduce the risk of fire very materially.

l. By the use of flat tiles of the same material and light ⊥ or L iron, roofs may also be rendered entirely incombustible, as the slates or other covering can be nailed or secured directly to the porous terra-cotta, which can be sawn with a saw, and will hold cut nails. The importance of this development is very great, as hitherto roofs have been confessedly the most difficult portion of a building to deal with.

m. In a thoroughly fire-proof structure, the material of the walls is of much importance. A stone containing much carbonate of lime or magnesia, is turned by fire into quick lime, and crumbles. Granite if heated and drenched with water, disintegrates. A sandstone, free from lime, will usually stand fire, but well burnt bricks, especially if they are not too dense, and are laid in lime mortar, are, about the best material available. Their only superior are firebricks laid in fireclay cement, but for any ordinary purposes the latter are unnecessary.

n. Where a large quantity of highly inflamable material such as oil, turps, varnish, spirit, &c., is stored, the only safe plan in addition to the foregoing is to rigidly limit the size of the structure and subdivide by brick walls into sections. The doors of communication then become an important feature. In London $\frac{1}{4}$ inch plate iron is the minimum thickness allowed and there must be a door on each side of the wall. The frames also have to be of iron and fit closely. Iron, however, buckles under great heat, and various alternatives have been suggested as iron frames filled in with concrete or wire lathing, or better still, with porous terra-cotta panels. The closing of the doors is however the great difficulty, at the critical time they are never shut, hence the Americans have devised sliding tracks and bolts, stays or fastenings with a link fusible at a low temperature. For slow burning construction doors of two $1\frac{1}{2}''$ thicknesses of wood cased with galvanized or tinned iron may be adopted. They are much cheaper than iron andwould last quite as long as the floors.

o. In addition to any of the foregoing suggestions for fireproofing buildings, such accessories as fire hydrants, sprinklers and fireproof paints and coatings are always of much value. With the former an adequate supply of water devoted solely to this purpose is of the utmost importance; also the periodical testing of the hose and valves. Sprinklers are another American notion, consisting of lines of water-pipes throughout a building fitted with numbers of valves closed by a fusible plug or link. Undue heat releases the link and the water is discharged in a shower. One serious objection, however, is raised against automatic sprinklers—viz., that more property is destroyed by water, than is saved from fire. Another mode, where iron columns form the supports is to charge them with water, from an overhead tank, and apply circular jets, operated by fusible plugs as just described. If automatic sprinklers are adopted, an escape for water should be provided, and more especially if the goods consist of inflammable liquids.* Of fireproof paints and coatings I can only say their

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* See Appendix E.

name is legion, but those containing asbestos as a basis appear to be the best. Most, if not all, require frequent renewal to maintain their efficiency.

But I must draw my paper to a close. There is much more that might be said even from the practical point of view of the materials and processes at present available, as well as on the further development and cheapening of fireproof construction, especially with a view to the elimination of ironwork. I had intended to deal also with the relative cost of the systems I have described, their especial applicability to various classes of structures, and the desirability of bye-laws defining and enforcing some system of fire-resisting or fire-proof construction in the more crowded portions of our cities; but time and space forbid. I must therefore content myself with offering this short and imperfect *resumé* of what is known on the subject to building owners and fellow-workers, who will ere long be called upon to deal practically with the question of "Fireproofing City Buildings."

Appendix A.

(From the London Building News of April 27th, 1887.)

"We are glad to see that our opinion of the merits of Messrs. Evans and Swain's new method of fireproof construction has been confirmed by the result of a test experiment conducted last week on the site of the old city gas works, near Blackfriars Bridge. The following details are taken from the *Times*:—A room was built in 14 inch brickwork, and measuring 14 ft. square inside, with a height of 7 ft. from ground to ceiling Over this room was laid the flooring, which consisted of deal battens 7 in. deep by $2\frac{1}{2}$ in. thick, placed side by side edgeways, and spiked together. One-third of the ceiling thus formed to the room was plastered, the key for the plaster being nails partially driven in. A second third was also plastered, the key for the plastering in this case being dovetails cut on the wood; the remaining third was left unprotected. The cracks between the battens were grouted with fine plaster. On one side of the room was a doorway 4 ft. wide, whilst two of the walls were pierced each with two holes 9 in. by 6 in., fitted with iron air gratings for draught.

In this building about four loads of timber were placed on Monday morning last, the fuel reaching nearly to the roof. Just above the fuel, and with its ends resting on ledges cut in the walls, was an ordinary rolled iron joist 7 in. deep, which was placed there in order to test and compare the action of the fire on the iron and the wood. A weight of about 3 cwt. was placed on the centre of the joist. At 10 o'clock the fire was started, and in a very short time a roaring furnace was going within the building, for tar barrels and other combustibles were used in making the fire. In about an hour the iron joist bent and twisted, and toppled over into the fire; the floor, however, remained cool on the top. At 12.30 the fire showed itself through a defective joint in the unprotected portion of the flooring, end some loose earth was thrown on the leakage. About 1 o'clock, slight ascapes of smoke took place through some of the joints in those portions of the floor which were protected by plaster, the leakages being attributed to the defective grouting of the joints. About this time, too, the wall adjoining the unprotected portion ot the floor showed signs of giving way. At 2 o'clock, after four hours exposure to intense heat, the unprotected portion of the floor began to show signs of yielding, but it did not give way for another hour, when a portion fell in. The flames then readily laid hold of the battens on their exposed sides, burning them off one after the other. It was then determined to extinguish the fire so as to save a portion of the floor, to ascertain what weight it would carry after its exposure to the flames. A fire engine was therefore called into requisition, and in about an hour the fire was subdued. About 6 ft. of the flooring was thus saved, the greater portion of which was that to which the plaster was held up by means of nails. Although the underside of the flooring was charred to a depth of about 4 inches, it sustained a weight of about 3½ tons before giving way. The weight consisted of a pile of granite pitching stones, which were gradually loaded on to the remnant of the floor until it broke down. These results show that timber flooring, thus constructed, presents an extraordinary amount of resistance to fire, and the experiments may be pronounced as most satisfactory. The brickwork was still green at starting, and the giving out of one of the walls readily admitted the fire to the first series of battens, otherwise it is a questien if they would have yielded to the flames so soon. The experiments demonstrated that after 4½ hours exposure to an intense fire—and about three hours after the rolled joist had been crippled—the plaster-protected portion of the floor was still sufficiently safe for firemen to walk upon. In no case in the event of a fire, would a floor be subjected to such a crucial test as was this, for efforts would quickly be made for the extinction of the fire. But should such a remote contingency happen with one of Messrs. Evans and Swain's floors, it will be seen that other things being equal, a remarkable margin of safety will be left. We may observe that the floor was the lightest form recommended by the patentees for ordinary buildings."

Appendix B.

(From the Sydney Morning Herald, December 3rd, 1888).

THE LATE FIRE.

TO THE EDITOR OF THE HERALD.

Sir,—The recent destructive fire has called especial attention to the system of building generally adopted in this city, and Superintendent Bear in his letter in your issue of Tuesday also refers to the inflammable character of a large amount of city property, and the necessity of revised building laws to regulate the new and lofty buildings now being erected. Being much interested in this subject, I had the pleasure last August of reading a paper before the Australian Association for the Advancement of Science on the "Fireproofing of Buildings," and in one of my opening paragraphs described the ordinary city structure as follows :—

"Our present mode of building is to run up brick or stone walls as thin as the Building Act will permit, fill the openings with wooden frames, form the floors of inflammable Oregon joists, cover them with boards and ceil with thin wooden linings, cut them through from top to bottom for lifts, cased in with wood (if cased at all), divide the rooms with wooden partitions, erect a wooden staircase, and finally cover all with a wooden roof What is this but a magnified matchbox ?" These remarks have been forcibly illustrated by the recent fire. For instance, unprotected floors of Oregon are about the most inflammable that can be devised. Lifts cut right through these floors from top to bottom act as a vertical flue for the rapid extension of the fire, and would doom any building, notwithstanding the most vigorous attempts of the most perfect fire brigade, in confirmation of this eye witnesses noticed that the fire rushed up the lift-shaft and so set the upper stories of the front ablaze. One gentleman who was in Roberts's Hotel at the time also informed me that the flaming debris as it fell from the upper story set the floors below alight, and that if only one of these had been fire-proof, the conflagration might have been more readily stayed The wooden staircase also burnt rapidly, and formed another channel of communication between the different stories.

The means of obviating such disasters are, primarily, the placing of vertical communications as lifts and stairs outside the walls of a building, or at any rate enclosing them within walls through which there are only small openings shut by self-closing doors; and secondarily, by the adoption of more or less fire-resisting or fireproof floor and supports. The first is a matter of planning, to which I would most earnestly draw the attention of property owners, and my fellow-architects, for although it may at times involve a little inconvenience, and possibly waste of space, the resulting safety would more than compensate. The second is a matter of cost, which in the more simple forms recommended in my paper, is so moderate that the total outlay on a building is not appreciably increased, and in the more perfect would not increase the cost of an ordinary warehouse or store by more than 10 per cent. to 15 per cent.; while in more extensive structures, such as the new principal office of the Mutual Life Association in George-street, now erecting, the additional outlay amounts to about 5 per cent. When it is remembered that this secures practical immunity from fire, or at any rate rigid localisation, and hence easy extinguishing in a city with a well-organised fire brigade and good supply of water, it will, I think, be seen that such a system of construction would pay for itself in the reduction of insurance premiums and the increased rent obtainable for the security given.

In the late fire there was fortunately no loss of life, but should one occur during the hours of occupation in a building of similar construction used for work, amusement, or residence a calamity would be inevitable,. If people choose to store their goods in inflammable buildings and insure heavily, it is to a great extent their own lookout, but when it comes to a question of human life the building laws of the city should define the limits of safety. This subject, I am glad to hear, is being considered by the City Council, and the sooner the new rules come into force the better, for all round us we see lofty buildings being erected in the matchbox style I have described, which would be nothing less than death traps to their unfortunate occupants should a fire get a hold before discovery. Broadly and generally, these rules should divide buildings into classes, according to risk involved and the number of people likely to be gathered therein. The most dangerous, such as theatres, should be completely fireproofed. Halls and churches should have at least fireproof stairs and passages as required in London; and hotels or buildings in separate occupation on each floor should not only have fireproof stairs, and passages, but fireproof floors as well. A few rules as to ample exits are also essential, and stairs and lifts should be especially dealt with. A good hint might also be taken from the Swedish building laws, which compel the insertion of a fireproof floor or ceiling under every roof, and I have no doubt Superintendant Bear will confirm me when I say that so long as the roof is intact there is a chance of preservation, but when once alight the building is doomed.

I am, &c.,

November 30. JOHN SULMAN.

Appendix C.

(From the Sydney Morning Herald, December 4th, 1888.)

'Before the impression created by the recent fire in Market-street fades away, the questions which the disaster has raised should be seriously considered. The chief thought in the public mind at first was one of surprise. A large building, full of valuable property, situated almost within a stone's throw of the headquarters of the fire brigades, was as completely destroyed as though the city had been without any machinery for the extinction of fire. Natually enough, astonishment was expressed at the fact, and it was supposed that either the water supply or the management of the brigades was at fault. But we have since been assured by the Superintendent that there was an ample supply of water, that the firemen did their best, and that the public, so far from having grounds for dissatisfaction, should be thankful that the fire was confined to the premises in which it broke out. Whether Mr. Bear's statement is a complete answer to the complaints which have been made is a matter upon which there may be some difference of opinion, but there can be no question as to the gravity of the issues which he has raised. He tells us that "scores of buildings in the city have been constructed in a dangerous manner, and that if some of these places were once to catch fire, losses to the amount of millions, instead of thousands, would probably be caused. His views are shared by a correspondent, one of the architects of the city, who calls attention, in a letter which we published yesterday, to the perils which exist in consequence of the methods of building which have been adopted. These gentlemen do not write as alarmists, but as men having knowledge, and their statements demand attentive consideration. Sydney has never yet been devasted by a great fire, and it is to be hoped never will; but, remembering what has happened in Chicago and Boston, and looking at the facts testified to by our correspondents, it would be folly to shut our eyes to the danger which menaces the city.

According to our correspondents, a large number of the buildings which have been erected in the business parts of Sydney have been constructed without the least regard to safety so far as fire is concerned ; economy and convenience have been considered, but scarcely a thought has been given to the risks which are so apparent to the professional eye. Mr. Sulman graphically describes the style of building which seems to be in vogue :—"Our present mode of building is to run up brick or stone walls as thin as the Building Act will permit, fill the openings with wooden frames ; form the floors of inflammable Oregon joists, cover them with boards, and ceil with wooden linings ; cut them through from top to bottom for lifts, cased in wood (if cased at all) ; divide the rooms with wooden partitions, erect a wooden staircase, and finally cover all with a wooden roof." Our correspondent goes on to say that unprotected floors of Oregon pine are about the most inflammable that can be devised, and the "lifts cut through these floors from top to bottom act as a vertical flue for the rapid extension of the fire, and would doom any building, notwithstanding the most vigorous attempts of the most perfect fire brigade." Buildings constructed in this fashion are likened by our correspondent to "magnified matchboxes," and he is right. When a structure of this sort takes fire the whole place is in flame in a few minutes, and unless assistance is at hand almost immediately, there is little hope of saving anything. The external walls, together with the efforts of the firemen, may prevent the flames extending to other buildings, but we are told that if these methods of building are allowed, we cannot expect that fires will always be kept within bounds. We are warned that some day we may have to deplore the loss of property worth millions of pounds.

How many buildings there are in Sydney which may be classed as dangerous we are not aware; and, even if they could be all discovered and pointed out, it is difficult to see how their defects could be amended without pulling down and rebuilding them. But the erection of any more dangerous structures ought at least to be prevented. Mr. Sulman points out a number of ways in which buildings might be made more secure. Lifts and staircases, he says, should be placed outside the walls of a building where practicable, but at any rate they should be enclosed within walls through which there are only small openings shut by self-closing doors. This is one thing; another is the adoption of fire-resisting or fireproof floors and supports. If these two conditions were observed there can be no doubt that the danger from fire would be greatly reduced. Lifts and staircases constructed in the ordinary way conduct the flames from place to place, and do much to hasten the destruction of a building. Inflammable floors and a roof easily burnt are also dangerous features. Under these conditions a building in which a fire gets a good start has little chance of being saved. The flames spread quickly from floor to floor, and the whole structure is speedily involved. But a building having well-protected lifts and staircases, and fireproof floors and roofs, would burn slowly, and the fire brigades would be at work before things had gone too far. One would think that people who erect buildings would have regard to these things, but the rule seems to be the other way. The "matchbox" style is preferred because it is cheap and convenient; danger from fire is not thought of at all, or is made a secondary consideration.

The question is one which the City Council should deal with at the earliest possible opportunity. The Superintendent urges that the building laws should be "revised and enforced." We infer from these words that the building laws do not go far enough, and that, such as they are they are not carried out. There are, therefore, two directions in which amendment should be made. The Council should see that the building regulations that have been framed are enforced, and it should at once set about strengthening them. The conditions of to-day are very different to those of a few years ago. As land in the city becomes scarcer and dearer, so does the height of the buildings increase. It is obvious that if buildings of many storeys are constructed on the "matchbox" plan, they are not only unsafe themselves, but are a danger to the edifices on either side. It is a good thing, no doubt, to insist that the walls should be of a given thickness, but this is not everything Our correspondents point to certain precautions without which no large building can be regarded as reasonably safe, and it is a question for the Council to consider whether these precautions should not be insisted upon. If it is necessary for the safety of the city that lifts and staircases should be guarded, or that floors and roofs should be fireproof, the observance of these rules should be made compulsory. Human nature is human nature; and if people are left to their own devices, we may be sure that insecure and dangerous buildings will multiply, with the result probably that the city will be involved some day in a great disaster."

Appendix D.

(From the Transactions of the R.I.B.A., 1875-6.)

"Two experiments were made, the first being to test the effectiveness of the construction, when the action of flame during a fire, would be continuous for two hours and a half. A furnace was built, 4 feet wide, and 14 feet 9 inches long internally, the top of which was made to resemble the brick arched floor of a building. The two segmental arches were 9 inches thick, and had a bearing throughout the length of the furnace upon a rolled iron joist 10 inches deep and 6 inches wide with a span of 14 feet 9 inches. This girder was protected by fire-clay lining, so that no part of the metal could be attacked by the flames. Fire bricks were used for the arches so as the better to test the efficiency of the fire-clay linings, but ordinary stock bricks were to be employed in the actual building. Plastering was but on the underside of the lining, as in the case of a ceiling, and the spandrils and crown of the arches were filled in with concrete, having a finished surface of portland cement on the top equivalent to the flooring.

When the furnace had stood sufficiently long for the plastering and mortar to set, the girder, being then loaded to one-fourth of its breaking weight deflected 3-16ths. of an inch. The fire was lighted and kept up for two hours and a half with dry pattern wood as fuel. After one hour the deflection of the girder was $\frac{5}{16}$ths. of an inch in the centre, and at the end of the two and a half hours it had increased to 1 $\frac{3}{16}$ths. of an inch. Water was then applied through a hose, and when shortly afterwards the upper part of the furnace was removed, the girder appeared uninjured, although the intense heat had calcined the lower surface of the fire-clay, The deflection disappeared as the iron gradually cooled.

The second experiment was for the purpose of testing the same girder under conditions still more severe, being equal to the largest fire which could exist in any one part of a building. The furnace was rebuilt as at the first and was similarly loaded. The fire was kept up as fiercely as possible for one hour and a half, the flames being continuous. It was then slackened and kept as nearly as possible to a smouldering heat for twenty-four hours, but as the fire had to be renewed from time to time, the heat was periodically increased, and the test thereby made more severe than had been contemplated. The deflection of the girder, which was $\frac{3}{16}$ths. of an inch before the fire commenced, became $\frac{19}{32}$nds. at the end of an hour and a half. It increased to a maximum of 1 $\frac{7}{32}$nds. of an inch, but diminished as the heat subsided. About an hour after the fire was lighted the plastering began to drop off and four hours later, the fireclay was observed to be red hot. One end of the girder which projected slightly through the brickwork of the furnace was throughout quite cool and no appreciable expansion was observed. At the end of the twenty-four hours the fire was put out as before, large quantities of water being thrown upon the beam and its surroundings by means of a force pump and hose. The top and side of the furnace was then partially removed, when all the fireclay was found upon the girder precisely as when first put on. The girder which was quite uninjured was subsequently fixed to form part of the flooring of the building to which the experiments had reference."

Appendix E.

At the Spirit Room in the Natural History Museum at South Kensington, London, the floor is pierced with iron gratings, and the basement below is laid several feet deep with clean gravel, and the hydrants are placed *outside* the windows. The flaming spirit and water sinking into the gravel would be extinguished.

2.—THE HISTORY OF CIVIL ENGINEERING IN NEW SOUTH WALES.

By W. H. Warren, M.I.C.E., Wh. Sc., Professor of Civil and Mechanical Engineering, University of Sydney.

ROADS AND RAILWAYS IN THIS COLONY.

It is proposed in the following paper to describe the most important works in connection with Civil Engineering which have been executed in the colony during the first hundred years of its existence.

ROADS.

Roadmaking, so far as establishing a line of communication between places where settlement had commenced, would be one of the first engineering works which the early colonists would find it necessary to undertake. The Great Dividing Range trending, roughly speaking, almost parallel with the coast, with the spurs which run out from its eastern and western slopes, gives rise to obstacles which have to be surmounted in establishing a line of communication between the coastal districts and the interior. One of the earliest works of this nature is the western road over the Blue Mountains to Bathurst, first surveyed by Mr. Evans and opened by Mr. Cox in 1815, the descent being made by a pass down Mount York, and road *via* Fish River to Bathurst Plains. The direction of this road was afterwards changed by Sir Thomas Mitchell, to *route via* Mount Victoria, and was carried through Bowenfells and across the Dividing Range at the Cox River, where large cuttings were made. Another line of communication to the western interior was soon after opened up along the Dividing Range between Windsor and the Vale of Clwydd, traversing the main ridge between the Grose and the Colo Rivers, *via* Mount Tomah, much after the same fashion in which the Main Western Road, which was just opened, passes along the ridge between the Grose and the Cox Rivers. Extensive improvements have recently been made on this line, and it is now practicable for vehicular traffic. Further improvements at the Kurrajong and in the neighbourhood of Mount Tomah are contemplated to render this road safer and easier to travel.

The main north road from Sydney originally passed *via* Gladesville punt and Dural to Wiseman's Ferry on the Hawkesbury River; but the direction of this road has been altered so as to pass over the Iron Cove and Gladesville bridges, and the punt has been abolished. At Wiseman's Ferry, some of the heaviest and most costly roadwork of the colony was executed by means of convict labour, under the supervision of Mr. Larmer, one of Sir Thomas Mitchell's officers. Leaving Wiseman's Ferry, the road continues, with a good deal of side-cutting, to Wollombi township, a distance of fifty miles from the ferry. This sterile *route*, however, has, during the past fifteen years, been abandoned in favour of a pass down Shepherd's Gully up the McDonald River, now crossed by a fine timber bridge at St. Albans, and thence *via* the Wollombine Common up Mount Manning Pass, rejoining the old road seventeen miles south of Wollombi. This *route* continued northerly to the crossing of Cockfighter's Creek, and from that point gave access to the northern districts of the Hunter and Liverpool Plains. An alternative *route* for travelling stock only was afterwards travelled by way of Howe's Valley and the Colo Valley, along the western ridges of the Macdonald and Hawkesbury Rivers, crossing at Richmond. This track has, within the last ten years, been much improved, and it is expected by the end of this year to be completely opened for vehicular traffic.

ROADS FROM THE SOUTH COAST TO THE TABLELAND.

The first road from the Clyde River (Nelligen), ascending the tableland to Braidwood, was undertaken about 1854 and completed about 1852, under the direction of Sir Thomas Mitchell. It is about seventeen miles long, the mountain pass inside cuttings being three miles long at a gradient of 1 in 12. The work was done by day labour, under the supervision of Mr. Adalbert Weber, the labourers, who were thoroughly good men, content with their lot, and anxious to retain their employment, being paid at the rate of £35 a year and rations. This road abounds, as do all the coast roads, in great local beauties. The road from Eden, Twofold Bay, was a mere track up the mountains, until the roads instituted by the Roads Department were made up the Big Jack and Tanawangala Mountains, which gives access to the Manero Tableland, Bombala, and Cooma, from Eden and Bega. A new pass has lately been made to connect the latter place via Brown's Mountain and Nimitybelle with Cooma, the centre of Manero. From Moruya, situated sixty miles north, a road on very rough sidelings has been made by the Roads Department, giving access to Braidwood via Araluen, formerly the seat of a large gold industry. The old road before mentioned, about thirty miles north of Moruya, reaches the same centre from the Clyde.

From Ulladulla (Milton) thirty miles further north, two roads have been made accessible for vehicular traffic, also a road to Braidwood; and from Nowra (Shoalhaven), forty-five miles further north, an old road, *via* Nerriga and the Sassafras Range, now not much used, but kept in passable condition, completes the tale of three *routes* converging on Braidwood. From this point going northerly the traffic naturally goes to

Mossvale, the nearest and most southerly point at which the Great Southern Railway can be tapped from the coast. There is, therefore, from Nowra, the centre of Shoalhaven, the chief road over Cambewarra Range, crossing the Kangaroo Valley and ascending the Barrengarry Mountain to the tableland at Mossvale. The work on this road was of the heaviest character, the mountain passes being some eight miles in length, crossing a fertile country which, twenty years ago, a horseman could hardly cross with safety in wet weather. Eleven miles north and thirteen miles north of Cowra two more passes have been made, giving access from Berry to the above road in the Kangaroo Valley, both similar in character and grade to that of the principal road from Nowra. Some thirty miles north of Nowra from Jamberoo, the Kiama district has a mail coach road up the mountain to Mossvale, which is thus connected with the coast by four good vehicular roads, easily graded and well maintained. Northerly, a few miles from Albion Park, is a good horse track, and it is in contemplation to improve it for vehicular traffic.

From near Wollongong there are other mountain passes, giving an access to fertile settlements behind Mount Cordeaux, Mounts Kembla and Kiera, that have not yet been properly improved by the Roads Department, although some work has been done to ameliorate the worst parts. At Bulli Pass, in 1867, work was undertaken by the department to establish the most important road of communication between the Illawarra district at its northern end and the Great Southern Railway at Campbelltown. This pass, remarkable for its natural beauty, has not only been for years the favourite drive of tourists on account of its wonderful vegetation, but has been the main artery of communication with the Illawarra district until the opening of the Illawarra railway. The grades are somewhat severe, being as sharp as 1 in $7\frac{1}{2}$ in places; but as the road was laid out in straight reaches, no complaint has ever been made. The average mountain grade is about 1 in 8. (See Plates XLVII., XLIX.) A very romantic, but somewhat dangerous, road has been made round the Coal Cliff, overhanging the sea, giving access directly by way of steam ferry at George's River to Sydney. This road, though little used at the time of its formation, proved of essential service during the construction of the Illawarra railway, which could not well have been carried out without it. The whole of the South Coast road is now trafficable by vehicles from Sydney to Twofold Bay. All rivers intervening are either bridged or provided with suitable ferry accommodation to carry over heavy loads. Communications with the tableland have been established at every point where it is deemed necessary. At Burragorang, some twenty-five miles west of Picton on the Southern line, a very heavy work has just been completed to render the fertile valley of that name, situate at the junction of the Cox and Wollondilly Rivers, accessible for interchange of traffic. This is one of the heaviest and most romantic mountain passes executed by the Roads Department, and requires some further works for its completion. Its utility extends for some miles up and down the valley of the Wollondilly, and possibly, at some future date, communication may be established higher up the Cox to effect a junction with the Western line.

ROADS FROM THE NORTHERN COAST TO NEW ENGLAND.

The earliest lines of communication in this portion of the colony consisted of the road from Port Macquarie to Walcha, and the A. A. Company's road from Gloucester up Hungry Hill, the former of which ascends an extraordinarily long spur in the ascent to the tableland, keeping it for thirty-five miles, the track being waterless from the foot to near the summit. This road has been, until recent times, in use by New England settlers sending down wool to port, and also by the coast settlers returning the produce of their warmer climate. The road was difficult and dangerous, and the port was always very hazardous, consequently little or nothing has been done to improve it. The railway being now open, all traffic from New England takes advantage of it, and the road is now hardly ever travelled. The latter road referred to was opened roughly as a dray track to communicate between Hungry Hill, the A. A. Company's township and estate at Port Stephens, and their properties on the Liverpool Plains. It is now much used, as a pass having been made through Gawnie, partly supplanted it in general traffic years ago, and the opening of the Great Northern-road by a new pass over the Liverpool range and up Doughboy Hollow, executed by the present Roads Department in 1861, rendered both the former passes almost obsolete.

With a view to establishing a line of communication between the large rivers north of Port Macquarie and the tableland, the formation of the road from Grafton to Glen Innes, was commenced about 1863. This road, commonly known as the Newton Boyd, is one of the largest works undertaken by the Roads Department, and was under the immediate supervision of Mr. Howison as resident engineer. It consists generally of a series of heavy, long, mountain cuttings, and one of the bluffs was so severe that the usual expedient of tunnelling on a common road had to be resorted to. This road was followed subsequently by similar roads from Grafton to Armidale, and from Kempsy to the Macleay River to Armidale, the work on the latter being particularly heavy, and gradients very even and easy throughout. From the head of the Manning a vehicular pass also exists via Cooplacurrapa, joining the old A. A. Company's road at Nowendoc, the summit of the Hungry Hill. The three principal main roads of the colony, viz., the Southern (from Sydney to Albury), the Western (from Sydney to Warren), and the Northern (from Morpeth to Maryland), are metalled throughout nearly the whole of their lengths; and with the exception of one interval—viz., that of the Hunter, at Aberdeen—are fully bridged.

THE ROADS AND BRIDGES DEPARTMENT.

The Roads and Bridges Department was established in January, 1861, just after the departure of Captain Martindale to England. Captain Martindale, prior to that date, in addition to the office of Chief Commissioner for Railways, performed the duties of Commistioner for Roads and Superintendent of Electric Telegraphs, under the title of Commissioner for Internal Communication, under the direction of the Honorable the Minister for Lands and Works, until the 1st October, 1859, when, in pursuauce of a resolution of the Legislative Assembly of 21st September, the Department of Lands and Works was divided, and the Department of Secretary for Works was created. The most important duty devolving upon the Department of Roads is the selection of the works to be executed, and the appropriation of the expenditure of the annual vote. Nearly the same obvious principles have always guided the department, and the means at its disposal have been devoted :—

1. To the removal of all complete interruptions to traffic, more particularly to mail transit, by bridging the rivers and creeks.

2. The improvement of all the most difficult mountain passes and swamps.

3. The final determination of the direction of the roads and the clearing of the same, followed by drainage and culverting where most required.

4. The forming and metalling of roads, excepting where municipalities exist.

DETAILS OF CONSTRUCTION.

It being impossible to insist on any one uniform mode of construction, the character of the work has been adapted, as far as possible, to the locality, the nature and quantity of available material, and the requirements of the traffic. Of the 27,000 miles of road in charge of the department, it is estimated that about 7,000 miles are metalled, 2,000 are graded mountain passes, and the remainder, for the most part, are cleared and provided with culverts. The total length of iron and timber bridges up to the 30th June, 1888, was as follows :—Timber bridges, 32·54 miles; iron bridges, 3 miles; timber, masonry, brick and concrete culverts, 21·20 miles. During the last sixteen years fifty-three miles of earthenware culverts have been constructed. Iron culverts constructed with rolled girders and buckled plates from four feet to thirty-five feet clear span are now largely used, and the floor over the buckled plates is filled in with tarred metal The abutments are constructed either of masonry or concrete.

BRIDGES.

The bridges constructed by the department up to 1865 were found to be too narrow in the roadway; from that time up to the present a minimum width of eighteen feet has been adopted for bridges near towns, and from fourteen feet to sixteen feet in more remote localities. Spans of simple timber beams with corbels have been used up to forty feet spans, and trussed timber bridges with iron suspension rods up to ninety feet spans. Laminated timber arched bridges, continuous, and others hinged at the centre, have also been constructed. The Bathurst Bridge, designed in 1868, consists of three wrought-iron spans with vertical struts and diagonal ties. The upper boom and inclined end struts are constructed of girder section formed of wrought-iron plates and angle irons, the tension cord being formed of wrought iron bars only. The spans are one hundred and eleven feet six inches, one hundred and thirteen feet, and one hundred and eleven feet six inches respectively between centres, fixed at one end and expanding over the other on cast-iron rollers. The trusses, which are one hundred and ten feet centres of bearing pins, eleven feet centres of pannels, and twenty-four feet eight inches apart centre to centre, carry wrought-iron cross girders which can be prolonged beyond the main girders to form cantilever supports for the footways when required. The roadway is formed of timber, twenty-one feet clear, between kerbs. The substructure consists of cast-iron cylinders six feet diameter, with wrought-iron bracing girders. The bridge was open for traffic in 1870.

The Parramatta Bridge, designed in 1877, consists of five wrought iron non-continuous lattice girders, one hundred and fifty and a-half feet centres of piers, and a swing span revolving on a central pier, and having an opening upon one side of sixty feet clear, and on the other of fifty-seven feet. The main girders, which are trough-shaped, braced with wrought-iron flat tie-bars, and wrought-iron channel struts, stiffened with ladder bracing, are one hundred and fifty feet in length, thirteen feet two inches between boom plates, and twenty-seven feet four inches betwen centres. Expansion is provided for by gun-metal plates sliding on cast iron plates. The deck consists of hardwood, resting upon wrought-iron cross-girders. The swing span consists of four wrought-iron lattice girders, seven feet deep, stiffened with plates for twenty feet from centre, and strongly braced together. The span revolves on a central pivot and on conical wheels, rolling on a cast-iron roller-path nineteen feet in diameter. The ordinary piers are constructed of cast-iron and wrought-iron cylinders six feet diameter braced with wrought and cast-iron. The cylinders comprising the swing-pier are of wrought and cast iron six feet in diameter, five in number, braced together with wrought and cast iron. The abutments at each end are of sandstone masonry. This bridge was completed ready for traffic on January 31st., 1881. Iron Cove Bridge, drawings of which were completed in 1887, is of the same general design, but without swing, and consists of nine spans of one hundred and twenty-six feet three inches, on four feet six inches diameter cylinders. Opened for traffic in 1882.

Nowra Bridge, designed in 1879, consists of eight American (double intersection Murphy-Whipple) truss spans; one, one hundred and eighty-three feet nine and a-half inches; one, one hundred and twenty-six feet ten and a-half inches; four, one hundred and twenty-six feet four inches; and one, one hundred and twenty-five feet two and a-half inches, also one span of fifty feet ordinary plate girders. The piers are formed of cast-iron cylinders seven feet and five feet diameter, braced with horizontal and diagonal bracing. Depth between centres of top and bottom members of trusses, twenty-five feet; width between centres of trusses, twenty-two feet six inches; clear width of roadway between curbs, nineteen feet eleven and a-half inches. The bridge rests at its northern end upon an abutment of freestone masonry, and was opened for traffic on August 1, 1881.

The Manilla Bridge, over the Namoi River was designed in 1881. The main spans consist of five non-continuous wrought-iron lattice girders one hundred and twenty-six feet ten inches in length, eleven feet four and three-quarter inches in depth, and twenty-one feet between centres, formed of the ordinary trough section, braced with wrought-iron tie bars and channel struts, stiffened with ladder bracing. The roadway is eighteen feet in the clear throughout the bridge, and is formed of tarred metal, upon wrought-iron buckled plates. The north end of main bridge rests on a concrete abutment, the other approach being formed of six non-continuous wrought-iron lattice girders, sixty feet nine inches long, five feet four and a-quarter inches deep, and nineteen feet centres, with the cross girders resting upon the top booms. The abutment at this end is also formed of concrete. The piers for main spans are formed of cast-iron bottom lengths six feet diameter, with top lengths consisting of five feet diameter wrought-iron cylinders, braced with wrought-iron diaphragm bracing, connected to bottom lengths by cast-iron conical lengths connected with transverse bracing. The piers for approach spans consist of cast-iron screw cylinders two feet six inches diameter, with four feet six inches diameter of screw. Owing to difficulty experienced in screwing, pits were sunk and screw ends of cylinders stepped in concrete Traffic commenced over the bridge on March 17, 1886.

The following bridges of the same type have also been constructed:—Namoi River Bridge, at Gunnedah, two spans, one hundred and twenty-seven feet three inches; designed in 1881. Namoi River Bridge, at Yellow Bank, one span, one hundred and twenty-six feet; designed in 1882. Namoi River Bridge, at

Bingera, two spans, one hundred and twenty-seven feet three inches, four spans one hundred and twenty-six feet ten inches; designed in 1882. Bingera Creek Bridge, Bingera, two spans, ninety feet six inches; designed in 1881. Taemas Bridge, over Murrumbidgee River; designed in 1884. The main bridge consists of two wrought-iron lattice girders four hundred and sixty-four feet long and ten inches deep, forming three spans of one hundred and forty feet, one hundred and eighty-two feet, and one hundred and forty feet respectively, bearing on two abutments and two cylinder piers. The main girders consist of horizontal plates and T-irons in booms, the webs being formed of flat wrought-iron tie bars and ladder-braced channel-struts, with plate webs and angle-iron framing over piers and abutments. Wind bracing, formed of T-irons and flat plates, is conneeted to the bottom booms. The deck consists of timber bearing upon wrought-iron cross girders and timber longitudinals. The main girders are fixed over one abutment, bearing over the piers and remaining abutment upon M'Donald's expansion rollers. The piers are formed of cast-iron cylinders, six feet diameter in bottom lengths, connected to wrought-iron top lengths, five feet diameter, with cast-iron conical cylinders, and braced with wrought-iron diaphragm bracing. The abutments are ashlar masonry, built of limestone, backed with hand-packed rubble. The bridge was opened for traffic on the 14th April, 1888. At the official testing of this bridge the following results were recorded by automatic testing apparatus:—With end span loaded with fifty tons, maximum deflection of end span, 0·5 inches; maximum upward deflection of centre span, 0·12 inches; permanent set, 0·04 inches. With centre span loaded with seventy tons, maximum of deflection of centre span, 0·79 inches; maximum upward deflection of end spans, 0·21 inches; permanent set, 0·05 inches. The vibration, considering the length of spans and lightness of construction, was inconsiderable.

The Snowy River Bridge, at Buckley's Crossing, designed in 1884, is similar to the above; but the central span of one hundred and eighty-two feet is omitted. The Barwon Bridge, at Brewarrina consists of one steel lift span, fifty-five feet between centres of cylinders, and seven timber approach spans. The main girders are fifty-one feet one and a-quarter inches long, four feet six inches deep and sixteen feet between centres, composed of horizontal steel plates and angle-iron bars, with bracing formed of steel channel-struts, and flat steel bars. The deck, formed of timber, rests on steel frames fitted between steel cross girders. A wrought-iron chain attached to each end of top boom and main girders, passes over a bevel chain wheel at top of each tower, and is attached to a cast-iron balance box weighted with lead. Another chain connected to bottom of balance weight passes over chain wheel and machinery shaft, and connects to bottom of main girders. Two winches, resting on platforms secured to each pier convey the power necessary to raise the bridge. The towers, formed of angle irons and plates braced with T-irons and flat bars, are connected longitudinally with overhead girders. Bevel gearing to ensure uniformity of motion connects chain wheels at top of towers. Two men can lift the main span through nineteen feet in three minutes. The piers are formed of wrought and cast-iron cylinders, four feet six inches diameter, sixteen feet centres, based with wrought-iron diaphragm bracing. The bridge was designed in 1885. Lift bridges of the same type, with iron approach spans, were constructed at Bourke in 1877, and Balranald in 1878, whilst a contract for a modified design, working wire rope in place of chains, has recently been let for the Murray River and Mulwala.

PUNTS AND FERRIES.

The total number of ferries provided for by the Roads Department is one hundred and thirty-seven; eighty-five of these are worked by punts, with hand gearing and wire rope of a total length of eleven and a half miles; six punts are worked by steam and wire rope; fifty-two crossings are supplied with passenger boats only, eighteen of them being of iron, for occasional use during flood time, as it was found that in the hot months the timber boats were useless when most required. All the punts are built of timber, except seven, which are of iron. The old system of chain and gearing has been replaced by galvanised crucible steel wire rope of a strength of eighty tons per square inch. These steel ropes last from nine to twelve months, working constantly fifteen hours a day for seven days a week. The commonest kind of indiarubber is found to be the best lining for the driving wheels, and gives quite sufficient grip on the rope. The sizes of ropes used are two and a-quarter inches circumference for hand-worked ferries, and two and a-half inches circumference for steam ferries. In most cases the ferries are leased for a term of years, but all the steam ferries are worked by the Department.

CARRIAGE WAYS.

The older streets of Sydney were originally roughly formed over the routes of the bullock drays, and as buildings sprang up these tracks were first ballasted with sandstone, and ultimately metalled with broken ballast, but they remained very convex in shape and difficult to maintain. As the traffic developed with the growth of the city, increasing renewals and reconstructions became necessary, in spite of which the cost of maintenance in the principal thoroughfares rapidly increased. The streets with light traffic were reconstructed with satisfactory results in the following manner:—A solid foundation, consisting of hand-packed hammer-dressed sandstone pitchers, ten inches deep, was laid and covered with a layer of broken basalt two and a-half inch gauge, which was rolled to a smooth surface with a steam roller; the rise in the road was made one in forty. On steep grades, in which Sydney roads abounds, frequently ranging from one in nine to one in twenty-two, dry Macadam stone stacked on a platform is covered with well-boiled tar and left for about five weeks before using on the road. It is spread and rolled to a smooth surface, and finished by sprinkling over the surface fine screenings or sand. In 1880 Mr. A. C. Mountain, M. Inst. C.E., then City Surveyor, recommended the adoption of Australian hardwood blocks for paving the principal streets of the city, which was adopted by the City Council, and up to the end of 1866, when Mr. Richards was appointed City Surveyor, 200,000 square yards had been constructed, of which 40,000 square yards were laid by the engineer for tramways. The blocks were laid upon a concrete foundation, six inches thick, which was rendered with cement mortar. The spaces between the blocks were originally one inch wide, which were filled with well-boiled tar and pitch and basalt screenings. The joints have, however, been reduced to three-eights of an inch, with satisfactory results, A considerable amount of timber-paving with narrow joints is in progress under Mr. Richards.

RAILWAYS.

RISE AND PROGRESS OF RAILWAYS IN NEW SOUTH WALES.

The first combined movement on the subject of introducing railways into New South Wales took place as far back as January, 1846. On the 29th of that month a public meeting was held in Sydney for the purpose of considering the expediency and practicability of establishing railways in this colony. Subsequently Mr. Woore was appointed to make a survey from Sydney to Goulburn, which he completed and reported upon in January, 1848. A petition was presented to the Legislative Council, April 4, 1848, in favour of establishing railways, and stating that the first cost would be reasonable and the undertaking profitable. This resulted in an address to his Excellency the Governor-General embodying certain resolutions passed by the select committee of the Council, which were transmitted to the Secretary of State. On the 11th September, 1848, a provisional committee was appointed to make arrangements for the establishment of a company, and in November of the same year "The Sydney Railway Company" was floated with a capital of £100,000, in shares of £5 each. On the 9th of January, 1849, Mr. Shields was appointed engineer to the company (which was incorporated by Act 13 Victoria), and entered upon his duties under the management of a directorate elected by the shareholders. It was not until the 3rd of July, 1850, that the first turf of the first railway in the Australian colonies was turned by the Hon. Mrs. Keith Stuart in the presence of his Excellency the Governor Sir Charles Augustus Fitzroy and a large and representative assembly. The company in the first stage of its existence had many difficulties to encounter. The decision of the Home Government in matters of vital importance, for the success of the enterprise, was withheld for a long time, and in spite of the support and encouragement given by the local Government, the position of the directors was a most trying one. In January, 1857, Mr. Shields resigned and Mr. Mais temporarily succeeded him. On March 12th the tender of Mr. Wallis for the construction of four and a-half miles of lines from Haslem Creek towards Redfern was accepted for £10,000, and all went well until the discovery of gold in the Bathurst country, which increased enormously the cost of labour and materials, embarrassing the directors and threatening the contractor with ruin. On June 30th Mr. Mais resigned, and Mr. Wallace succeeded him as Engineer-in-Chief. Mr. Wallace recommended a double line from Sydney to Parramatta. Mr. Wallis, the contractor, was released from his contract, and Mr. Randle accepted one for works between Cleveland Paddocks and Ashfield. The difficulties of the labour market resulted in the importation of five hundred railway labourers from England. The financial difficulties of the company induced them to apply to the Government for a loan of £150,000 —two-fifths to be subscribed by capitalists and three-fifths from the public money. The request was complied with, and it was agreed that, in future, the directors should be partly elected by the shareholders and partly nominated by Government. The total cost of the line to Parramatta and the Darling Harbour branch and station was £389,000. The capital of the company was only £250,000, thus leaving a deficiency of £139,000 which was provided for by means of another loan of £150,000 from the Government and £100,000 more of subscribed capital.

HUNTER RIVER RAILWAY COMPANY.

While the Sydney company was struggling with the unprecedented difficulties of the times, a movement took place in 1853 for the construction of a line between Newcastle and Maitland, and an Act was passed incorporating the company on the 10th of October the same year. It was anticipated by the shareholders that this undertaking would be very successful, as the country around Maitland was productive and populous. The agricultural, pastoral, and mineral wealth was also considerable, and there was plenty of fine timber for railway purposes. Mr. Wallace was appointed consulting engineer, and Mr. Gall resident engineer. Arrangements were made for bringing over five hundred labourers, and a tender for the construction of a line from Honeysuckle Point to Hexham was accepted. The company lasted a little more than a year, and only succeeded in making the preliminary arrangements for carrying out the works. The continued advance in the price of labour convinced the shareholders of both companies of the hopelessness of carrying out the works so as to yield a fair return for the capital invested, and they ultimately agreed to transfer their property to the Government.

Three Railway Commissioners were appointed, with Captain Ward as chief, and the railways became the property of the Government from the 3rd September, 1855, from which time up to the present they have been carried on by Government officers. On the 15th June, 1857, Mr. John Whitton, M. Inst. C.E., was appointed Engineer-in-Chief for Railways, which position he still holds.

The railways of New South Wales (Pl. XLI.), though essentially one entire concern as the property of the Government, consist of the following:—Southern Line: Main Southern line, Sydney to Albury, three hundred and eighty-eight miles; South-Western line, Junee to Hay and Jerilderie, two hundred and thirty-two miles; Cootamundra to Gundagai, thirty-three miles; Goulburn to Cooma, one hundred and thirty miles; Darling Harbour branch, one mile; Illawarra branch, Sydney to Kiama, seventy-one miles. Western Line: Main Western line, Granville to Bourke, four hundred and eighty-nine miles; Richmond branch, Blacktown to Richmond, sixteen miles; Mudgee branch, Wallerawang to Mudgee, eighty-five miles; Blaney to Murrumburrah, ninety-five miles; Orange to Molong, twenty-two miles. Northern Line: Strathfield to Waratah, ninety-two and a-half miles; Newcastle to Tenterfield, three hundred and eighty-two miles; Werris Creek branch to Narrabri, ninety-seven miles. Grand total: 2,133½ miles.

All the railways in the colony are constructed for a single line, except the following which are double:—1. Darling Harbour branch. 2. Sydney to Penrith. 3. Sydney to Hurstville. 4. Newcastle to Maitland. 5. Bottom Points of Great Zig-zag to Bowenfells.

LINES CONTEMPLATED.

Southern Line: Wagga Wagga to Tumberumba, Gundagai to Tumut, Tarago to Braidwood, Goulburn to Cookwell, Eden-Bega. Western Line: Orange to Wilcannia, Nyngan to Cobar, Bathurst to Lockley, Dubbo to Young through Forbes and Parkes. Northern Line: Narrabri to Walgett, Muswellbrook to Cassilis, Glen Innes to Inverell and Grafton, Maitland to Cudgen through Grafton. See map prepared by Mr. John Whitton, M. Inst. C.E., Engineer-in-Chief. (Pl. XLI.)

The English gauge of four feet eight and a-half inches is used throughout the New South Wales Railways (Mr. Shields recommended the Irish gauge, five feet three inches, and an Act was passed in 1852 fixing this gauge for the colonies) the reason of its adoption is to be found in Mr, Wallace's letter to the directors, 8th of September, 1853, in which he says:—"The narrow gauge has been found to combine in a higher degree than any other the great commercial requisites for a railway—namely, speed, safety, convenience, and economy. For these reasons it has been adopted with little exception throughout Europe and America. In India and in Egypt, where the highest engineering talent has been employed, had a wider gauge been considered necessary or an improvement, it would, no doubt, have been adopted, but such has not been the case, in both these countries the narrow gauge has been determined upon. I feel it my duty to represent these facts to you, and at the same time to obtain a revision of the Act which fixes the gauge of railways in Australia at five feet three inches." Mr. Whitton, however, immediately after his appointment recommended the adoption of the five feet three inch gauge. Captain Ward and Captain Martindale also recommended this gauge, and it is to be very much regretted that this advice was not followed. The line was then open to Liverpool only, and the alteration might have been made at a comparatively trifling cost. In Victoria the gauge is five feet three inches, in South Australia five feet three inches and three feet six inches, and in Queensland it is three feet six inches.

EXCAVATIONS AND EMBANKMENTS.

The formation width for a double line of way is thirty feet, and for a single line of way either fifteen or eighteen feet. The slopes of the cuttings in ordinary earthworks are one in one; but through rock the sides are left perpendicular, or with a very slight batter of from one-eighth to a-quarter to one. The slopes of embankments throughout are one and a-half to one. In the construction of the Illawarra and Mudgee Railways, considerable modifications in these slopes have been rendered necessary on account of the treacherous nature of the material excavated, and the formation of the country. Several slips of considerable magnitude have occurred in the embankments and cuttings. The total quantity of excavation, principally in rock, on the line between Penrith and Bathurst, a distance of one hundred and eleven miles, is five and a-half millions of cubic yards.

GRADIENTS AND CURVES.

On the Southern line, the steepest incline from Sydney to Picton, fifty-three miles, is one in sixty-six. From Picton to Mittagong, twenty-four miles, there is one continuous incline of one in thirty-three for sixty-seven chains in length, and one in thirty for a length of two miles and two chains. There are also inclines of one in thirty-three for seventeen chains, forty-five chains, forty-two chains, and nine chains, and one in thirty for seventy chains. From Mittagong to Goulburn, fifty-seven miles, there is no incline steeper than one in forty. The steepest incline on the length from Goulburn to Wagga, one hundred and seventy-four miles, is one in forty for a distance of one mile fifty-eight chains.

On the Western line, from Parramatta to Penrith, the steepest gradient is one in sixty-six for a length of seventy-four chains; from Penrith to Bathurst the total lengths of the steepest inclines are as follows:—One in thirty for one mile sixty-three chains, one in thirty-three for sixteen miles fifty-three chains, one in forty for six miles twenty chains, one in forty-two for four miles two chains, one in forty-six for thirty-one chains, one in forty-seven and eighty-nine for seventy chains, one in forty-eight for forty-eight chains, one in fifty for seventy-seven chains; making thirty-five and a-half miles of inclines ranging from one in thirty to one in fifty. The longest continuous incline of one in thirty.three is one mile and sixty-six chains. From Bathurst to Orange, forty-seven miles, the steepest incline is one in forty, and the longest continuous incline two miles and seventy chains. From Orange to Dubbo there are a few short inclines of one in forty, and from Dubbo to Bourke very few steep inclines occur, the greater portion of the line is either level, or on gradients of small inclination.

On the Northern line, between Strathfield and Newcastle, the steepest gradient is one in forty, the longest length of which occurs in the descent to the Hawkesbury Bridge at Peat's Ferry, where it is three miles long (See Pl. XLIV.). On the line between Newcastle and Singleton the steepest gradient for a short distance is one in sixty-three. From Singleton to Muswellbrook there are four short inclines of one in thirty-three, and from Muswellbrook to Murrurundi the steepest gradient is one in fifty. Between Murrurundi and Tamworth the steepest gradient is one in forty. From Tamworth to Tenterfield there is a gradient commencing at two hundred and eight and three-quarter miles from Newcastle of one in forty-eight for a distance of three and a-quarter miles; the steepest gradient is one in forty for a length of three miles, in the descent from Ben Lomond. From Wallerawang to Mudgee the steepest gradient is one in forty, which occurs in a few short lengths, the longest of which is about one and a-quarter miles. From Sydney to Kiama, on the Illawarra Railway, there is no gradient between Sydney and George's River steeper than one in sixty; the steepest gradient between this point and Kiama is one in forty, which occurs in three lengths, the sum of which is three miles. From Sydney to Goulburn the sharpest curves occur at entering and leaving Picton Station, where they are sixteen chains radius. From Picton to Goulburn, one hundred and thirty-four miles, there is no curve less than thirty chains radius. From Goulburn to Wagga Wagga, one hundred and seventy-four miles, in descending the Cullerin Range, twenty-two miles from Goulburn, there is one curve of nineteen chains radius. With this exception, the smallest radius of a curve is twenty chains. From Wagga Wagga to Albury, seventy-five miles, the smallest radius of a curve is thirty chains. The smallest radius of a curve on the portion of the line from

Parramatta Junction to Penrith, twenty-one miles, is thirty chains. Between Penrith and Bathurst, a distance of one hundred and eleven miles, the smallest radius of a curve is five hundred and twenty-eight feet, the total length of such curves being five miles, including those upon the two zig-zags. There are also on this length twenty miles of curves, ranging from eight to twelve chains radius. Between Bathurst and Orange the smallest radius of a curve is twelve chains. From Orange to Bourke the smallest radius of a curve is twenty chains. On the line from Newcastle to Murrurundi, with the exception of one curve of twenty chains radius through the town of Muswellbrook, there is no curve of a smaller radius than thirty chains. From Murrurundi to Tamworth the smallest radius of a curve is twelve chains on ascending and descending the Liverpool Range. From Tamworth to Tenterfield the sharpest curve occurs three hundred and fifty-seven miles from Newcastle. It is 27.14 chains long and ten chains radius. There are 89.95 chains in four lengths of twelve chains radius, and 63.20 chains in two lengths of eleven chains radius. On the line from Strathfield to Waratah there are four curves of eleven chains radius of a total length of 62.50 chains, and two curves of twelve chains radius of a total-length of 33.65 chains. From Wallerawang to Mudgee the two sharpest curves are twelve chains radius of a total length of 65.79 chains. There are also curves of fourteen, fifteen, sixteen, seventeen, and twenty chains radius. On the Illawarra line the three sharpest curves are ten chains radius of a total length 53.37 chains. The remaining sharp curves on this line are eleven, twelve, and fourteen chains radius.

WORKS.

From Sydney to Parramatta the first work of importance is the Redfern tunnel, under the intersection of Cleveland and Regent streets. It was originally built of stone and brick for a double line of way, but it has recently been reconstructed for four lines of way, with plate-web girders and buckled plates. There are several minor bridges formed with plate-web girders varying in span from thirty feet to fifty feet, and there are foot-bridges or subways at the various suburban stations. The most important structure occurs between Petersham and Summer Hill stations, where a stone viaduct of nine spans has been replaced by an iron bridge of three spans of ninety feet, each consisting of four main girders, somewhat resembling a Pratt truss in design, with eye-bars and pin connections where the members are in tension. The main girders are spaced about eight feet centre to centre, and are braced together in a vertical plane with diagonal bracing; the height of the viaduct in the deepest place is sixty feet. The deck of this bridge is constructed on the American principle, which consists of cross-sleeper timber bearers fixed on the top of main girders. They are ten by ten in section, and are spaced twenty inches apart from centre to centre. There are two longitudinal beams which act as guard rails fixed on the top of the cross beams; these serve to distribute the concentrated weight of the driving wheels of the engine over two or more cross-sleeper beams. The testing of this bridge showed that the lateral bracing of the main girders in a vertical plain caused the outer girders to deflect more than the inner girders, which would not have occured if the two main girders under each line of way had been braced independently. The deflections of the main girders when tested with engines which produced a load equivalent to 1·4 ton per foot, run on each line of way, was from three-eighths to five-eighths of an inch. The links which form the bottom flange have an eye at each end and one in the centre, which may cause the tensile stresses in the links to be unequally distributed when the bridge is traversed by engines having unequal loads on the wheels.

From Parramatta Junction to Albury the first important work met with is the bridge over the River Nepean ,at Menangle, about forty miles from Sydney, which is designed to carry a double line of railway. It consists of two main box-girders, continuous over three openings, having each a clear span of one hundred and fifty feet. The main girders are twenty-five feet six inches apart in the clear, each forming a continuous girder four hundred and eighty-six feet long, extending over two intermediate piers. Between these girders transverse or roadway girders are placed at a distance of three feet from centre to centre. The piers are built of masonry spaced one hundred and sixty-two feet from centre to centre, over three of which expansion rollers are placed. The height of the bridge from the level of the water in the river to underside of the girders is sixty-five feet. The approach on the Sydney or northern side is nine hundred and seventy-eight feet long in spans of twenty-six feet each of timber, constructed for a single line. The approach on the southern side is of timber four hundred and thirty-two feet in length in spans of twenty-six feet. This bridge was completed in 1863. With a load of 1·4 ton per foot run on each line of way the maximum stress developed in the top boom of the box girders is 4·32 tons per square inch, and in the bottom boom 5·3 tons per square inch. The maximum live load only slightly exceeds the deadweight of the structure. With one ton per foot run on one of the main girders the greatest deflection observed was half an inch. The Menangle Bridge was the first large railway bridge erected in New South Wales. Since its erection in 1863 the design has only been reproduced in the Penrith Bridge.

The viaduct at Picton over the Stonequarry Creek, fifty-three miles from Sydney, is built of masonry, and consists of five openings, of forty feet each. The arches are semi-circular, and on an incline of one in forty, and in consequence of the proximity to the Picton Station, it has been built for a double line of way.

Its entire length is two hundred and seventy six-feet and its extreme height from foundations to rail level is seventy-eight feet. The Picton tunnel through Redbank Range (fifty-four miles from Sydney) is one hundred and ninety-eight yards in length, lined with brickwork set in cement throughout, and constructed for a single line of way. In form it is eliptical, fifteen feet wide in the widest part, and seventeen feet high from rail level to soffit of arch. The Gibraltar tunnel, seventy-nine miles from Sydney, the excavation of which was through hard shale and sandstone, is five hundred and seventy-two yards in length. It has been lined throughout in brickwork and masonry in cement, and is of the same form and dimensions as the tunnel through the Redbank Range at Picton. The bridge over the street just beyond Moss Vale station consists of two main girders of the Schwedler type, ninety-eight feet span on a skew, spaced fifteen feet nine inches centre to centre, the cross girders are fourteen feet apart, centre to centre and there are longitudinal rail-bearers.

The viaduct over Barber's Creek, one hundred and eleven miles from Sydney, is three hundred and forty feet in length, and consists of five spans of sixty feet each, having two wrought-iron plate web girders, thirteen feet apart, and four feet seven inches deep, resting on stone piers set in Portland cement, the railway being carried on cross girders thirteen inches deep and three feet apart. The viaduct over the first crossing of the Wallondilly River, one hundred and twenty-two miles from Sydney, is six hundred and sixteen feet long, and consists of eight spans, in the following order, counting from Sydney :—Two spans of sixty feet, one span of one hundred and thirty feet, and five spans of sixty feet. The sixty feet spans are similar to those over Barber's Creek, but the one hundred and thirty feet spans consist of two box girders, thirteen feet six inches apart and ten feet deep; cross girders as in the sixty feet spans. The piers aud abutments are built of brick, set in Portland cement. The viaduct over the second crossing of the Wollondilly River, one hundred and twenty-seven miles from Sydney, is six hundred and sixteen feet long, and consists of one span of sixty feet, one of one hundred and thirty feet, and five of sixty feet, precisely similar in construction to the first crossing. The height of the rails above ordinary water level is forty-six feet.

Boxer's Creek viaduct, one hundred and thirty-three miles from Sydney, consists of two spans of sixty feet, resting on brick piers set in Portland cement. The height of the rails above ordinary water level is forty-six feet. Mulwarree Creek viaduct, which is close to the town of Goulburn, and one hundred and thirty-three miles from Sydney, is eight hundred and fifty-eight feet in length, and consists of twelve spans of sixty feet, each of wrought-iron plate web girders, similar in construction to those at Barber's Creek, and resting upon brick piers set in Portland cement. The Wagga Wagga timber viaducts, which have been erected over the low ground liable to flood, near the Murrumbidgee River, form the approaches to the Wagga Wagga iron bridge. These extensive timber structures comprise six viaducts, the details of which are given in the following table :—

No. of Viaducts, Bowen to Wagga	No. of Spans in each Viaduct.	No. of Beams 29ft 6in. long.	No. of Timber Piers.	No of Piles in the Piers.
1	113	904	114	456
2	528	528	67	268
3	32	32	5	20
4	576	576	73	290
5	448	448	57	228
6	40	40	6	44
	316	2528	322	1306

The superstructure is of ironbark. All the spans are twenty-eight feet six inches in the clear, formed of beams twenty-nine feet six inches long bolted to corbels fixed to the timber piers. The piers are constructed of round timber piles. In fifty-eight piers the piles are driven into the ground to depths varying from fourteen to fifty-seven feet, and in two hundred and sixty-four piers the piles are tenoned into sills bedded in concrete at depths varying from six feet to eight feet below the surface of the ground. The difficulty of obtaining ironbark timber for the whole structure in the short space of time allowed for its erection necessitated the use of other kinds of timber for the piers, such as stringy bark, ash, messmate, apple, box, spotted and white gum, &c., of which a large proportion had to be cut when the sap was up instead of during the winter months. In consequence of this the dry rot soon appeared in a certain proportion of the piles, and this decay, together with the cavity or pipe in some of them, has reduced their sectional area. White ants, which have been found in some of the piles, have been successfully eradicated by the use of kerosene and a mixture of arsenic and tallow.

These viaducts were tested by the Bridges Commission, and the maximum deflection observed with two engines, each weighing sixty-three tons sixteen hundredweight three quarters, was ·59 inches. The bridge consists of two lattice main girders continuous over four openings, each having a clear span of one hundred and fifty feet. The main girders are fourteen feet apart in the clear, each forming a continuous girder six hundred and thirty-nine feet long, extending over three intermediate piers. Between the lattice girders transverse or roadway girders are placed at a distance of three feet from centre to centre. The piers are one hundred and fifty-nine feet from centre to centre, and, together with the abutments, consist of cast-iron cylinders nine feet in diameter, filled with cement concrete. The top cylinders of each pier are braced together with wrought-iron diagonals and ties. Each lattice girder is twelve feet one inch deep over all. The booms are trough-shaped, connected with a double lattice web. A light lattice overhead bracing girder, is rivetted to the top table of the main girders over the piers and at mid-span. The lattice girders rest on cast-iron bed plates fixed on piers. Bessemer steel rollers are provided for expansion over four piers. The calculations show that, with a live load of 1.4 tons per foot run on the bridge, the booms are subjected to a stress of 3.82 tons per square inch in compression, and 4.7 tons per square inch in tension. The stresses in lattice bars in compression vary from two tons per square inch at abutment to .5 tons per square inch at mid-span, while the stresses in tension vary from 3.4 tons per square inch at abutments, decreasing to about one ton per square inch at midspan. The cross girders are to some extent relieved by the longitudinal bearers; but if these were not considered, the stresses produced by the driving wheels of the heaviest engines, added to the dead load, would be 5.12 tons in compression and 5.79 tons in tension.

Just beyond Albury there is a lattice-girder bridge for a double line of railway to carry the New South Wales and Victorian Railways over the River Murray. The bridge consists of two main openings of one hundred and fifty feet in the clear, with timber approaches on each side. The two main girders, which are three hundred and eighteen feet over all and seventeen feet four inches deep, are continuous over the central pier. There are four systems of triangulation in this bridge instead of seven, as in the case of the Wagga Wagga Bridge, which, with the greater depth of the girder, gives it a much lighter appearance. The details of the girders are also better than those of the Wagga Wagga Bridge. The piers consist of cast and wrought iron cylinders, braced together, and sunk to an average depth of one hundred and twenty feet. The cross girders are three feet deep and spaced five feet eight inches centre to centre, and there are longitudinal rolled iron girders eight inches deep, arranged one under each rail. The clear headway under the bridge is nineteen feet above summer level. The unit stresses developed in this bridge, with a live load of 1.4 ton per foot run on each pair of rails, are about the same as those of the Wagga Wagga Bridge, and the deflections under the test load showed that the Albury Bridge was slightly stiffer.

On the Western line, from Parramatta to Penrith, all the bridges are constructed to carry a double line of railway. There are four heavy plate web girder bridges over streets of sixty feet and sixty-six feet span, each consisting of two plate web girders, with cross girders, and a longitudinal girder for distributing the loads from driving wheels over two or more cross girders. There are thirteen bridges or viaducts, consisting of from one to fifteen spans, each forty feet in the clear; and three bridges, consisting of spans each thirty feet in the clear; there is one viaduct consisting of five spans each forty feet in the clear, and eight spans each thirty feet in the clear. The forty feet spans consist each of four Warren girders under the railway, each forty-four feet long over all and five feet three inches deep, resting on piers and abutments built of brick in cement. The four girders are braced together, both in the horizontal and vertical plane, and the deck is somewhat similar to that described for the Petersham Viaduct. The thirty feet spans consist each of four main plate web girders under the railway, resting on brick piers and abutments.

The bridge over the Nepean River at Penrith is constructed for a double line of way, and carries the main Western road and a single line of railway. It consists of three openings, each one hundred and eighty-six feet in the clear, and one opening of one hundred and twenty-seven feet in the clear. The larger openings have two main box girders, spaced twenty-five feet six inches apart in the clear, and twenty-eight feet six inches from centre to centre, each forming a continuous girder five hundred and ninety-four feet long and thirteen feet deep, extending over two intermediate piers. The roadway is carried on cross girders nineteen and a-half inches deep and spaced three feet centre to centre, over which are laid longitudinal timbers fourteen by nine, and three inch planking throughout. The approach span of one hundred and twenty-seven feet is also constructed with two main box girders, each one hundred and thirty-five feet over all and ten feet deep. The piers are built of masonry, and are twelve feet wide at the top, and spaced one hundred and ninety-eight feet centre to centre. The main girders are supported upon timber platforms, each twelve feet long by four feet eight inches in width, and the expansion rollers are similar to those of the Menangle Bridge. With a live load of 1·25 ton per foot run on each line of way, the maximum stresses in the booms would be 5·82 tons per square inch in tension, and 4·64 tons per square inch in compression. The maximum stress in the rivets over piers is 9·3 tons per square inch. With one ton per foot run on the main girder, the deflection observed was ·93 inches. There are also three spans of twenty-six feet of timber framing on the eastern side of the bridge, three similar spans on the western side, and a timber viaduct between the Penrith Station and the river Nepean, consisting of sixty-four spans of twenty six feet each.

The Knapsack Valley Viaduct is built of masonry on an incline of one in thirty, and consists of five spans of fifty feet each, and two of twenty feet each. Mount Clarence Tunnel, eighty-eight and a-quarter miles from Sydney, is five hundred and thirty-nine yards in length, and lined throughout in masonry set in cement. Between this point and Wallerawang Station there are seven viaducts, all built of masonry set in Portland cement. These viaducts are of an aggregate length of two thousand two two hundred and twenty-five feet, varying in height from ten feet to seventy feet, and in spans from ten feet to fifty-four feet. There are also three tunnels, one on the Lithgow Valley Zigzag, seventy-seven yards in length, one at Morangaroo, two hundred and sixty-seven yards in length, and one under the Mudgee-road forty-seven yards in length. Beyond Wallerawang the line passes through Rydal and down the valley of the Solitary Creek, over which stream seventeen plate web girder bridges have been erected in a distance of nine miles ; they consist of thirty feet, fifty feet, sixty feet, and sixty-six feet spans, and the abutments and piers are of brick, set in Portland cement.

The bridge over the River Macquarie at Bathurst, one hundred and forty-four miles from Sydney, is constructed for a single line of railway, with two continuous wrought-iron lattice girders, four hundred and eighty feet each in total length, twelve feet six inches deep, and placed fourteen feet apart. It is divided into three spans of one hundred and fifty feet, each span being supported on two cast-iron cylinders nine feet in diameter, sunk to a solid foundation of an average depth of fourteen feet below the ordinary level of the water in the river. The cylinders are filled with concrete, composed of gravel and cement in the proportion of six to one. The details of this bridge are similar to those of the Wagga Wagga iron bridge. The maximum deflections observed with a live load equivalent to 1·4 tons per foot run were ·82 inches in the side spans, and ·75 inches in the middle spans.

The bridge over the River Macquarie at Wellington is similar in design to the Bathurst Bridge; there is, however, an approach span on each side, consisting of two main plate web girders, sixty-one feet span in the clear, and six feet deep, with a deck similar to that on the main bridge. The maximum deflections obtained with a live load equivalent to 1·4 per foot run on the main spans were ·92 inches on side spans, and ·52 inches on the middle spans. The maximum deflections observed on the approach span with a live load of 1·5 ton per foot run was ·36 inches.

The bridge over the River Macquarie at Dubbo is similar in general design to the bridges at Bathurst and Wellington. It consists of three main openings of one hundred and fifty feet in the clear, and two of sixty feet, one on each side of the main openings. The two main lattice girders are each continuous over two piers ; they are four hundred and seventy-seven feet long over all, and fifteen feet deep. There are four systems of triangulation, and the details of the main girders are similar to those of the Albury Bridge. The piers consist of cast and wrought iron cylinders braced together (the average depth of the cylinder piers is seventy-six feet), and the clear headway under the bridge is forty-seven feet six inches above the summer level. The cross girders are two feet two inches deep, spaced seven feet four inches centre to centre, with longicudinal rolled iron girders under rails eight inches deep. The unit stresses developed in this bridge with a live load of 1·4 ton per foot run are similar to those of the Bathurst Bridge, but the deflections prove the bridge to be somewhat stiffer.

On the Northern line from Strathfield the first important work is the bridge over the Parramatta River, which is constructed for a double line of railway: it consists of six spans, each one hundred and fifty feet in the clear. There are four main lattice girders, each continuous over two piers, the aggregate length of which is nine hundred and fifty-six feet eleven inches over all, and seventeen feet eight and three-quarter inches deep. The details of the main girders, the dimensions and arrangement of the cross girders, rail bearers, &c., are similar to those of the Albury Bridge. The piers consist of cast and wrought iron cylinders braced together and sunk to an average depth of eighty-five feet, giving a clear headway of thirty-five feet above high water. The unit stresses developed in this bridge with a live load of 1.4 ton per foot run are similar to the Albury Bridge, but the deflections observed under test loads proved it to be stiffer, The bridge was tested by Mr. Whitton in various ways, and the maximum deflection observed with three engines on each pair of rails, of a total weight of four hundred tons, or equivalent to 1.4 ton per foot run, was ·8 inches. Six tunnels occur in the descent to Peat's Ferry, the total length of which is one thousand seven hundred and sixty-two yards. They are twenty feet high from rail level to soffit of arch, and twenty-five feet wide at a height of seven feet six inches above the rail level, with a semicircular arch of twelve feet six inches radius. The sides of the tunnel consist of curves struck with arcs of circles of thirty feet radius, and where inverts occur the radius is one hundred feet. These tunnels, like all the railway tunnels on this line, are lined throughout with brickwork or concrete eighteen inches thick. At thirty-six miles 15.44 chains from Sydney occurs the most important bridge in Australia.

THE HAWKESBURY BRIDGE.

The bridge now in course of construction across the Hawkesbury River presents many features of interest. Instead of being designed by the Engineer-in-Chief, as in other cases, tenders and designs were invited by the Agent-General, Sir Saul Samuel, in England. In response to this invitation, fourteen offers to construct the bridge were received from the leading bridge constructors in the world, ranging in price from £296,350 to £702,384, which were submitted to a committee of eminent engineers, and to Sir John Fowler, for report. Both Sir John Fowler and the committee were unanimous in favour of the design and tender of the Union Bridge Company. The Engineer-in-Chief, Mr. Whitton, while in favour of the design, recommended certain modifications and additions which increased the cost of the work £13,000, the total cost being £340,000. The bridge is two thousand eight hundred and ninety-six feet between abutments and is constructed for a double line of way. In consists of seven spans, with a clear headway of forty feet above high-water level. The super-structure consists of two main trusses in each span, which are four hundred and ten feet from centre to centre of bearings, and fifty-eight feet six inches effective depth at the centre, spaced twenty-eight feet apart centre to centre. They are constructed with eye-bar tension members and pin connections on the system so largely used by American engineers for long-span bridges. The ratio of span to depth is about seven. There are thirteen panels in each truss, spaced thirty-one feet six inches centre to centre; the compression members are of rectangular box form, composed of plates and angle bars, accurately prepared at joints for butting without covering plates. The trusses are braced together with complete systems of lateral bracing, between both top and bottom chords, and there are light sway bracings at right angles to axis of bridge, in the plane of the vertical compression members, connecting the top cord to the ends of the cross beams between the vertical members. The end raking posts for forming the portals to each span are stiffened laterally by cross frames latticed with angle bars carried down as low as the traffic will allow. The floor of the bridge is constructed with cross girders attached to vertical compression posts spaced thirty-one feet six inches centre to centre, with four longitudinal girders or stringers. The ratio of depth to span in the cross girders at centre is one to five and a-quarter. A timber decking supporting the rails rests upon the longitudinal stringers of the ordinary American type similar to that adopted in the Petersham Viaduct.

The six piers which support this structure in the bed of the river consist of concrete from low water downwards, cased in metallic caissons. The cutting edges and lower lengths for about one-third of the height are of steel, the remainder of wrought iron. Above the concrete the pier is carried up in masonry in the form of two circular columns fourteen feet in diameter, and twenty-eight feet centres, with a connecting wall between them six feet thick. The body of the pier is forty-eight feet by twenty feet, with rounded ends. The piers, as originally designed and carried out, in three cases only, were splayed at the ends; the others have been modified so as to have vertical sides, which facilitates sinking in the true position. There are three internal cylinders or shafts to each caisson, eight feet in diameter, splayed out at botttom to meet the outer shell and the cutting edges of the cross walls. These shafts are used to excavate the materials from the inside by means of grab dredges, and the spaces between them and the outer shell are used to load the cutting edges. The depth of No. 1 pier is one hundred and fifty-one feet below base of rail; No. 2 pier, one hundred and ninety-nine feet six inches; No. 3 pier, one hundred and eighty-nine feet six inches; No. 4 pier, one hundred and ninety-four feet six inches; No. 5 pier, one hundred and ninety-six feet; No. 6 pier, two hundred and fifteen feet six inches.

This important bridge represents in its design the combined experience of the most eminent engineers both in England and America. The steel was manufactured by Messrs. William Arrol, of Glasgow, and the Steel Company of Scotland. All the riveted work has been manufactured in Scotland, the eye-bars only by the Union Bridge Company out of blanks prepared in Scotland. The steel is specified to stand a tensile strength between thirty and thirty-three tons per square inch, with an ultimate elongation of twenty per cent. in a length of eight inches. An eye-bar tested to destruction gave the following results:—66,445 pounds ultimate tensile strength per square inch; contraction of area at fracture, 51.05 per cent.; elastic limit, 36.063 pounds per square inch; elongation in 12 inches, 27½ per cent.; elongation in 8 feet 20.76 per cent.

There are three tunnels between the Hawkesbury Bridge and the junction with the line from Newcastle, the longest of which occurs at forty-one miles fifty chains from Sydney, and is one thousand eight hundred and forty-eight yards long. The remaining tunnels are one hundred and ten and one hundred and seventy-six yards long respectively. They are similar in design and construction to those already referred to in this line of railway.

There are five wrought-iron plate web girder bridges over the Orimbah, Wyong, Woy Woy, and Wallara Creeks and the Broadwater. Each bridge consists of three openings sixty feet in the clear, formed with two main girders one hundred and ninety-eight feet long over all and seven feet deep, spaced twenty-five feet six inches centre to centre; each girder continuous over two piers. The top flanges consist of horizontal plates eighteen inches wide by nine-sixteenths of an inch thick, with two angle-iron stiffeners each four inches by four inches by half an inch. The bottom flanges consist of horizontal plates eighteen inches wide by five-eighths of an inch thick. The angle irons uniting the flanges to the web are four inches by four inches by half an inch. The cross girders are two feet nine inches deep. The piers consist of cylinders six feet in diameter. The bridge over Cockle Creek consists of four openings sixty feet in the clear formed with two main girders two hundred and forty feet long over all and seven feet deep, each continuous over three piers, and in other respects similar to the bridges over Orimbah and other creeks referred to. The bridge over Dora Creek consists of seven openings, each sixty feet in the clear, formed with two main girders, each continuous over two piers, and also two main girders, each continuous over three piers; in other respects the bridge is similar to those last described. As only one pair of rails was laid over these bridges when they were tested by the Engineer-in-Chief, the maximum load which could be put upon one girder was .71 tons per foot run, and the maximum deflection observed with this load during the testing of all the bridges was .23 inches. A series of timber openings occur in this line, just beyond Gosford, twenty-six feet and ten feet in the clear, similar in construction to those on Southern and Western lines.

On the line from Newcastle to Tenterfield the first work of importance is the bridge over the Hunter, at Singleton, forty-nine and a-half miles from Newcastle, which consists of five timber-arched openings each eighty feet in the clear, and two masonry arches fifteen feet span. The piers and abutments are built in masonry set in Portland cement. Each eighty feet span consists of four laminated timber arches under the railway, having a rise of twelve feet three inches; they are formed of planks three inches inthickness and bent by steaming and fastened together by wrought-iron bolts. The main ribs are three feet deep at the springing, diminishing to two feet at the crown of the arch, and are fifteen inches thick. Resting on theop tof each arch is a longitudinal beam of ironbark timber, twelve inches by twelve inches, extending the full length of the bridge, supported over the spandrails by open timber-bracing. Joists ten inches by seven inches and thirty feet long are laid across the roadway three feet apart from centre to centre, and covered with three inch planking throughout the full length of the bridge. The width between the parapets is twenty-seven feet six inches.

A bridge over the River Hunter at Aberdeen, eighty-eight miles from Newcastle, erected in 1871, is of the same construction as the lattice-girder bridge over the River Macquarie at Bathurst and Wellington, with the exception of the depths of the cylinders, which for this bridge are sunk an average depth of twenty feet below the ordinary level of the water in the river. The testing of this bridge with a load equivalent to 1.37 ton per foot gave a maximum deflection of .92 inches in the side spans and .89 in the middle span. The tunnel through the Liverpool Range, one hundred and twenty-six miles from Sydney, is five hundred and twenty-eight yards in length, and is lined throughout with brickwork set in Portland cement. It is of the same dimensions and form as the tunnels previously described.

The bridge over the Peel River at Tamworth consists of two lattice main girders forming a clear span of one hundred and fifty feet. The main girders are each one hundred and sixty-one feet nine inches over all, and placed fourteen feet apart in the clear. Between them transverse or roadway girders are placed at a distance of three feet centre to centre. There are two piers, each of which consists of cast-iron cylinders nine feet in diameter, filled with cement concrete, and braced together with wrought-iron diagonals and ties. The calculations show that with a live load of 1.4 ton per foot run on the bridge, the booms are subjected to a stress of 3.72 tons per square inch in compression, and 4.37 tons per square inch in tension. The maximum deflection observed with a live load equivalent to 1.4 ton per foot run was ·9 inch. There are timber approaches on each side similar to those of the Wagga Wagga iron bridge. The bridge over Peel-street, at Tamworth, consists of one span sixty feet in the clear, formed of two plate web main girders, each sixty-five feet nine and a-half inches long over all, spaced fourteen feet eight inches apart in the clear, and fifteen feet ten and a-half inches centre to centre. The piers are built of brickwork, with stone caps. The maximum stresses developed with a live load of 1.5 tons per foot run are 3.5 tons per square inch in tension and 4.42 tons per square inch in compression. The maximum deflection observed with this load was .29 inch.

The bridge over the Macdonald River is similar in design to the bridge over the Peel River at Tamworth, except the piers are of brick in cement. The maximum stresses and deflections observed are about the same as those obtained in the Peel River Bridge.

From Sydney to Kiama, on the Illawarra Railway, the first important work occurs four and a-half miles from Sydney, viz., the bridge over Cook's River, which is constructed for a double line of railway. It consists of three openings, each sixty feet in the clear, formed with two plate web girders, each continuous over two piers. The piers and abutments consist of cast-iron cylinders six feet in diameter. The details of this bridge are similar to those erected over Orimbah and other creeks on the Strathfield to Waratah line already referred to, and the deflections under the test load showed similar stiffness. There are ten tunnels, the first of which occurs about five and a-quarter miles from Sydney, constructed for a double line of railway. The remaining nine tunnels are constructed for a single line. The form and dimensions of the double line tunnel are similar to those constructed on the Strathfield and Waratah line. The single line tunnels are elliptical in section, seventeen feet high from rail level to soffit of arch, and fifteen feet wide. At a height of five feet above the rails the curve of the tunnel is struck with four centres, with the following radii: seven feet six inches, thirteen feet six inches, nineteen feet three inches respectively. The tunnels are lined throughout with eighteen inches of brickwork. Where the foundations are of good rock the curved walls rest upon footings two feet two and a-half inches wide, at other places an invert arch is built fourteen inch thick with a fall of twelve inches. A central drain twelve inches by twelve inches. runs throughout the length of the tunnel, the bottom of which is two feet nine inches below the level of the rails. A series of eight tunnels, constructed as described above, occur in a distance of ten miles, the aggregate length of which is two and a-half miles, the longest is under the Bulga Range, and is nearly a mile in length. The George's River Bridge. twelve and a-quarter miles from Sydney, is constructed for a single line of railway, and consists of six openings, each one hundred and fifty feet in the clear, formed with four main lattice girders, each continuous over two piers, the aggregate length of the main girders over all being nine hundred and fifty-six feet eleven inches, and fifteen feet deep. The cross girders are two feet two inches deep, spaced seven feet four inches centre to centre. The longitudinal rail-bearers are eight inches deep. The piers and one abutment consist of cast-iron cylinders braced together. The other abutment is built of masonry. The cylinders are sunk to an average depth of one hundred and twenty-one feet, giving a clear headway of thirty-five feet above summer level. The details of this bridge are similar to the bridge over the River Macquarie at Dubbo, which has been already referred to. The unit stresses and the deflections developed under test load prove this bridge to be similar in strength and stiffness to that of the Dubbo Bridge.

There is a large number of timber openings on this railway, varying from ten feet to forty-two feet in the clear. They extend over the following creeks, rivers, and low-lying country: Port Hacking Creek, consisting of seven openings, each forty feet in the clear; Stanwell Creek, consisting of an arch thirty feet in the span; M'Anny's Creek, consisting of four openings, twenty-six feet in the clear; Stack Creek, consisting of five openings, twenty-six feet in the clear; Towradge Creek, consisting of six openings, twenty-six feet in the clear; American Creek, consisting of eight openings, twenty-six feet in the clear; Mullet Creek, consisting of twenty-four openings, twenty-six feet in the clear; Macquarie Rivulet, consisting of nine openings, twenty-six feet in the clear; Lake Illawarra, consisting of six openings, twenty-six feet in the clear; also of ten openings, fifteen feet in the clear; and of one opening, ten feet in the clear. Flat adjoining Minumurra River, thirteen openings, fifteen feet in the clear; flat adjoining Minumurra River, one hundred and twenty openings, ten feet in the clear; Minumurra River, nineteen openings, twenty-six feet in the clear; Minumurra River, two openings, fifteen feet in the clear;

approach to Kiama, twelve openings, twenty-six feet in the clear; approach to Kiama, two openings, fifteen feet in the clear.

On the railway between Blayney and Murrumburrah a bridge has recently been built across the River Lachlan, at Cowra. It consists of three openings, each of one hundred and fifty feet in the clear, and four openings each sixty feet in the clear, arranged two on each side of the larger openings. The dimensions and details of the one hundred and fifty feet openings are similar in every respect to the bridge over the River Macquarie at Dubbo, and the dimensions and details of the sixty feet openings which consist of plate web girders continuous over one pier, are similar in every respect to the bridges on the Northern Line, such as the one over Orimbah Creek. The cylinder piers are sunk to an average depth of sixty-eight feet, and the clear headway above summer level is sixty-seven feet. The testing of this bridge with three engines on each of the one hundred and fifty feet span, weighing two hundred and three-quarter tons, which is equivalent to a uniformily-distributed load of 1·33 tons per foot run, showed a maximum deflection (when the engines were running at full speed) of ·64in. The sixty foot spans were tested with one engine only, and the maximum deflection observed was ·25in.

PERMANENT WAY.

The rails on the length from Sydney to Goulburn, from Parramatta Junction to Bathurst, and from Newcastle to Murrurundi, were originally laid with wrought iron double-headed rails weighing seventy-five pound per yard, fish-jointed throughout, on chairs weighing twenty-five pounds each. From Goulburn to Wagga Wagga, Bathurst to Orange, and from Murrurundi to Tamworth, lighter iron rails were used, with single heads of the Vignoles pattern without chairs, weighing seventy-one pounds per yard and fish-jointed throughout. These iron rails are being replaced by steel rails and re-rolled iron rails, the worn-out iron rails being re-rolled at the Eskbank Iron Works, Lithgow. All the lines which have been constructed since these above referred to have been laid with steel rails. The author has thoroughly investigated the re-rolling of worn-out iron rails at the Eskbank Works, and considers that the re-rolled rails must necessarily be inferior to the original iron rail. The economy of steel as a material of construction is nowhere better exemplified than in the case of rails, and its low cost should prevent contracts being let by the Government in the future for the re-rolling of iron rails. The worn-out rails may be manufactured into good round bar, angle, and T-irons, whereas they will only make very inferior rails.

ENGINES.

The engines used on the New South Wales Railways are extremely varied in design, which is to a great extent rendered necessary by the natuie of the loads to be drawn, and the character of the railways over which they are required to travel. The type which is largely used for working the section from Penrith over the Blue Mountains to Bathurst is known as the "Consolidation" Goods Class, No. 131, made by the Baldwin Locomotive Company. Its characteristic features are large outside cylinders, and four pairs of coupled driving wheels, four feet in diameter, over which is distributed equally a weight of thirty-seven tons by means of compensating levers. There is a single bogie in front, and a double bogie tender. The total weight of this engine and tender, in steam, is over seventy-five tons. In order to minimise the resistance to traction in passing round sharp corners, some of the driving wheels are without flanges. Another type which is used on the Great Southern, Western, and Northern Railways is known as the "Mogul Goods," No. 205 Class. It is made by Messrs. Beyer and Peacock, of Manchester, and it has outside cylinders, with three pairs of coupled driving-wheels, four feet in diameter, over which is distributed a weight of about thirty-five tons. The maximum load on a pair of wheels is thirteen and a half tons. There is a single bogie in front, and the total weight of the engine and tender is about sixty-six and a half tons. The express passenger engine, made by Messrs. Dubbs and Co., of Glasgow, consists of a double bogie in front, with inside cylinders, and two pairs of coupled driving-wheels, six feet in diameter, over which is distributed almost equally about twenty-four and a half tons. The total weight of the engine and tender, in steam, is about sixty-three tons. Extensive workshops have been erected at Eveleigh, which are fitted with the most modern appliances for the repairs of the locomotive engines and rolling stock used on the New South Wales Railways.

The following Tables show the various engines, carriages, and trucks used :—

Table I.—Shows the classification and numeration of engine.

Table II.—The carrying capacity and weight of the various trucks and wagons.

Table III.—Gives similar particulars of the carriages.

NEW SOUTH WALES GOVERNMENT RAILWAYS.

CLASSIFICATION AND NUMERATION OF ENGINES.

TABLE I.

Class No.	Description of Engine.	Position of Cylinders.	Total No. in Class.	How Numbered.	Size of Cylinders.	Diameter of Wheels.	Wheel Base. Engine.	Wheel Base. Coupld.	Wheel Base. Tender.	Wheel Base. Total.	Weight Empty. Engine.	Weight Empty. Tender.	Weight in Steam. Tender.	Weight in Steam. Engine.	Comparative Tractive Coefficient.
					″ ″	′ ″	′ ″	′ ″	′ ″	′ ″	T. C. Q.	T. C. Q.	T. C. Q.	T. C. Q.	
1^N	tender	in	3	1^N to 3^N	16×24	5-7½	14-6	7-0	11-0	31-2	22 12 0	10 17 0	25 10 0	20 8 0	91.
5	tender	in	2	4^N	14×22	4-7	13-6	7-6	8-0	29-7½	16 7 0	7 4 0	19 15 0	12 18 2	78.4
				5	14×24	4-7	13-0	6-9	8-0	27-9	16 11 0	7 4 1	17 13 0	12 18 2	78.4
6^N	tank	out	2	6^N, 7^N	16×24	4-6½	17-7	8-3		17-7	30 12 0		35 0 0		112.73
10	tender	in	1	10	17×24	5-7	13-3	6-9	11-0	36-9	28 8 3	12 5 0	33 14 0	22 10 0	103.52
13	tender	out	2	10^N	16×22	5-0¾	13-6	7-0	8-6	29-5	22 16 2	8 13 0	26 6 2	14 10 3	92.7
				13	16×22	5-0¾	13-9	7-0	8-6	29-9	22 16 2	8 13 0	26 6 2	14 10 3	92.7
14	tender	in	3	14 to 16	16×20	6-1	14-6	0-0	11-0	32-9	23 6 1	10 13 0	26 5 0	19 8 0	70.14
17	tender	in	23	11^N to 13^N, 18^N, 19^N, 21^N, 22^N, 17 to 22, 40 to 47, 52, 103	18×24	4-0½	11-6	11-6	11-0	34-9	26 11 2	11 10 1	30 5 0	20 7 0	160.33
20^N	tank	in	1	20^N	16×24	4-1	14-6	14-6		14-6	30 0 0		35 0 0		125.39
23	tender	out	13	14^N to 16^N, 23 to 28	18×24	5-9½	18-0	8-4	11-0	37-1	28 19 1	11 5 0	31 12 3	19 6 0	111.88
				32 to 35	18×24	5-6½	18-0	8-4	11-0	37-1	29 5 3	11 5 0	32 16 1	21 16 0	116.93
23^N	tender	in	4	23^N to 26^N	18×24	3-10	11-6	11-6	11-0	33-3	28 8 0	11 8 0	31 1 0	20 4 0	169.
29	tank	in	4	9^N	12×17	3-1½	10-3	10-3		10-3	13 4 2		16 18 0		65.28
				29 to 31	11×17	3-1½	10-9	10-9		10-9	14 18 2		19 12 0		54.85
36	tender	in	8	36 to 38	16×24	5-7¼	14-6	7-0	11-6	32-0	24 17 1	12 7 0	28 0 0	24 0 0	91.36
				39	17×24	5-7¼	14-6	7-0	11-6	32-0	24 17 1	12 7 0	28 0 0	24 0 0	103.14
				75, 76	16×24	5-7¼	14-6	7-0	11-0	32-6	25 14 1	11 7 0	29 13 0	22 6 0	91.36
				77, 78	17×24	5-7¼	14-6	7-0	11-0	32-6	25 14 1	11 7 0	29 13 0	22 6 0	103.14
48	tender	in	11	48 to 51, 53 to 59	19×26	4-0½	11-6	11-6	11-0	34-11	32 2 3	13 1 1	35 18 1	24 11 2	193.53
60	tender	in	6	60 to 65	19×28	5-0½	11-6	11-6	11-0	34-11	33 16 3	12 17 0	37 5 3	25 18 3	167.07
67	tank	in	8	67 to 74	13×20	4-0	12-0	12-0		12-0	21 16 2		28 0 0		70.42
79	tender	out	68	27^N to 30^N, 37^N, to 39^N, 47^N to 51^N, 79 to 92 118 to 126, 143 to 157, 165 to 182	18×24	5-6½	19-6	8-0	11-0	38-6	34 18 2	11 14 2	37 11 3	21 13 3	116.93
93	tender	in	70	1 to 4, 31^N to 36^N, 40^N to 46^N, 93 to 102, 104, 106 to 117, 142, 164, 183 to 204, 291^N 369 to 372, 385, 386	18×24	4-0	11-3	11-3	11-0	33-11	30 14 0	11 12 0	33 16 0	22 11 0	162.
105	tender	out	2	105	18×24	5-3½	21-6	8-6	9-3	39-1	30 0 0	10 9 2	33 17 0	20 8 0	122.46
	tender			130	18×24	5-3½	21-6	8-6	14-4	43-6	30 7 1		34 4 1	25 6 0	122.46
127	tank	in	6	66	12×17	3-3	10-9	10-9		10-9	14 9 1		19 5 2		62.77
				127 to 129	12×17	3-0¾	10-9	10-9		10-9			22 16 0		66.61
				292, 293	12×17	3-1½	10-9	10-9		10-9	14 13 1		17 18 2		65.28
131	tender	out	11	131 to 141	20×24	4-1	22-10	14-9	14-4	46-0	40 14 0	10 3 1	46 4 2	25 15 3	195.92
158	tank	in	6	158 to 163	16×24	5-0½	18-8½	7-4		18-8½	32 15 0		40 1 1		101.55
205	tender	out	70	205 to 220 221^N to 224^N, 225 to 230, 231^N to 238^N, 239 to 254, 314 to 328, 329^N to 333^N	18×26	4-0	19-0	11-0	11-0	39-4	39 7 0	12 13 3	42 8 1	24 6 1	175.5
255	tender	in	41	255 to 260	17×26	6-1	19-9	8-0	11-0	38-10	34 13 2	13 2 2	37 11 0	24 11 0	102.93
				261^N to 264,^{N} 265 to 284	18×26	6-1	19-9	8-0	11-0	38-10	36 3 1	13 5 3	38 19 0	24 17 3	115.4
				334^N to 340^N, 341 to 350	18×26	6-1	20-9	8-0	11-0	39-9	37 8 3	12 17 1	40 1 2	25 3 1	115.4
285	tank	in	6	285 to 290	15×22	4-0	13-9	13-9		13-9	28 1 3		33 19 0		103.12
294	tender	out	10	294 to 303	19×24	4-0	22-9	14-9	14-4	44-9	37 14 1	10 4 3	41 18 0	26 19 3	180.5
304	tender	out	10	304 to 313	18×26	5-1	23-2	15 0	14-6	46-2	39 11 3	13 10 3	42 11 0	26 15 3	138.1
351	tank	in	18	351 to 368	15×22	5-1	13-9	7-0		13-9	31 17 0		39 4 0		81.15
373	tender	out	12	373 to 384	19×26	5-6½	22-0	8-3	11-0	41-2	41 15 1	14 5 1	45 7 0	30 7 2	141.14

TABLE II.

Description of Vehicle.	Carrying Capacity.	Weight. Tons.	Cwt.	Qrs.
A. Low-sided Wagon..........	6 tons	4	3	...
B. High-sided Wagon..........	6 ,, ...	4	6	...
	6½ ,, ...	4	17	3
	8 ,, ...	5	5	2
C. Covered Vans................	6 ,, ...	5	10	...
	7 ,, ...	5	14	3
	8 ,, ...	5	15	3
D. Medium-sided Wagon......	5½ ,, ...	4	13	...
	6 ,, ...	4	13	...
	6½ ,, ...	4	13	...
	8 ,, ...	5	4	2
E. Timber Trucks...............	6 ,, ...	4	6	...
	8 ,, ...	4	7	...
F. Wagon	10 ,, ...	7	10	3
	18 ,, ...	12	1	...
G. Wagon..........................	10 ,, ...	8	9	...
	15 ,, ...	12	12	...
Powder Vans...............	5 ,, ...	5	2	...
	6 ,, ...	6	2	1
	8 ,, ...	6	4	3
Sheep Vans..................	100 sheep	5	15	...
Cattle Wagon...............	10 cattle	5	16	...
	12 ,, ...	6	3	1
Meat Vans......	6 tons	6	12	...
Ballast Wagons............	6 ,, ...	3	2	...
	7 ,, ...	4	18	...
Dump Cars..................	20 ,, ...	9	16	2
	18 ,, ...	9	10	1

TABLE III.

CLASSIFICATION OF PASSENGER ROLLING STOCK.

NEW SOUTH WALES GOVERNMENT RAILWAYS.

Designation of Vehicle.	Numbers of Vehicles as per Register.	No. of Compartment. 1st Class.	No. of Compartment. 2nd Class.	Carrying capacity. Persons.	Carrying capacity. Tons	Carrying capacity. Cwt.	Wt. Empty Tons	Wt. Empty Cwt.	Av. Wt. Loaded. Tons.	Av. Wt. Loaded. Cwt.	Remarks.
Ashbury Carriages ...	40 to 45	3	4	64	4	...	24	12	28	...	Comprises sleeping cars, known as Lady Parkes and Lady Robertson.
Lady Parkes Sleeper ...	8, 9	...	...	20 Sleepers.	1	5	26	8	28	...	
Dining Car	1	...	...	38	2	7	25	11	28	...	
Redfern Type Bogie Carriages	70 to 81, 84 First Class	6	...	48	3	...	13	17			
	70 to 81 Compo.	2	4	56	3	10	13	9	17	...	
	188 to 190, 194 Second Class	...	7	70	4	7	15	...			
English Bogie Carriages	17 to 20	Saloon and 2 Comp.	...	38	2	7	15	13	18	...	
Eight-wheeled Radial Carriages	10 to 15	Saloon and 2 Comp.	..	38	2	7	15	3	17	10	
Redfern Four-wheeled Carriages	85 to 90	3	...	18	1	2	9	...	10	...	
Six-wheeled Radial Carriages	16, 21, 29 to 36 First Class	4	...	32	2	...	11	5			
	45 to 53 Compo.	2	4	52	3	5	11	16	14	10	Includes all six-wheeled stock.
	39, 180 to 185 Second Class	...	6	60	3	15	12	...			
Ordinary Four-wheeled Vehicles	1 to 9, 22 to 27, 91 First Class	...	...	15 to 28	1	5	6	2			From this Class are omitted second-class carriages which commenced to run before 1861.
	1 to 7, 9 to 32, 39 Compo.	...	...	24 to 32	1	15	7	...	8	...	
	61 to 91, 92, 93, 126 to 179 Second Class ...	...	...	40	2	10	7	...			
	1 to 6, 9 Mail Vans, 1 to 6, 21 to 26 Brake Vans	...	...	...	2	...	6	6			
American Type ...	49 to 59, 63 to 69, 82, 83, 92 to 94 First Class	...	...	60	3	15	16	10			
	54 to 58, 60 to 69, 82, 83 Compo.	...	...	60	3	15	16	10	20	...	
	94 to 125, 186, 187, 191 to 193 Second Class ...	...	...	60	3	15	16	2			
	1 to 7, 10 Sleepers	...	...	20	1	5	17	16			
Horse Boxes	1 to 73...	...	...	...	...	...	6	8	7	10	Includes all the different types of horse boxes.
Carriage Trucks ...	2, 3, 5 to 25, 27 to 42	...	...	...	...	...	4	5	5	...	
Prison Vans	2 to 5	...	...	...	...	...	6	16	7	10	
Goods Brake Vans, Six-wheeled... ...	3 to 5, 11 to 15, 20 to 22, 27 to 39, 41 to 124, 125 126, 129, 130, 135 to 144	...	...	...	...	...	11	14	12	...	
Clemminson's	60 to 62 First Class	6	...	36	2	5	20	...	22	...	
	7 to 9 Second Class	...	7	70	4	7	19	...			
Eight-wheeled Radial Brake Vans	7 to 18, 27 to 32	...	...	...	...	...	15	...	18	...	
Passenger Bogie Brake Vans	47 to 55 Brake Vans	...	...	...	...	...	16	...	19	...	
	6, 7 Mail Vans (Express)	...	...	...	...	...	15	13			

BLOCK SYSTEM AND BRAKES.

The block system which ensures that no two trains shall be on the same section of the line at the same time, is partially in force on a considerable length of the New South Wales Railways; and on all single lines the staff and ticket system is strictly carried out. Between Sydney and Parramatta, and at many of the important station-yards throughout the colony, the absolute block system is in force in conjunction with the interlocking system, which consists of the mutual interlocking of the levers which actuate the points, signals, and gates of level crossings. and collecting them altogether in a signal-box placed in a prominent position. Special arrangements exist to minimise the danger of facing points where they cannot be avoided altogether, as at the entrances of terminal stations, so that the points cannot be moved while a train is passing over them, and they are held closed, or fully open, as the case may be, the operations being completed by the movement of a bolt by means of a lever in the signal-box, which is interlocked with those actuating the points and signals. This system is so arranged that the signal for a particular train to pass cannot be given until the points are moved in the proper position for that train to pass in safety; and it is further provided that the consent of the signalman in both the home and distant signal-boxes shall be given before the signal is given allowing the train to pass into the section. The movement of the levers which ensures this result locks all other levers, whether for points or signals which might allow a train to pass at the same time as the train in question and produce a collision.

Brakes: The passenger trains are all fitted with the automatic continuous air-brake, the merits of which are generally admitted, and it is also proposed to fit up goods trains with a suitable automatic continuous brake, which will ensure the stopping of the train under all conditions of ordinary work and emergency, as well as the complete control of its speed down the long and steep inclines which have already been referred to.

The author is indebted to Mr. John Whitton, M. Inst. C.E., Engineer-in-Chief for Railways, for complete sections of the railways, and for various particulars on bridges, tunnels, &c.; and to Mr. J. Middleton, Locomotive Superintendent, for the list of particulars of locomotive engines and rolling stock; Mr. W. C. Bennett, M. Inst., C.E., Commissioner and Engineer-in-Chief for Roads; Colonel Wells, and Mr. J. A. McDonald, M Inst. C.E.

TRAMWAYS.

The first public tramway established in Australia was constructed from Redfern along Pitt-street to Circular Quay, and opened for traffic in December, 1861. The undertaking was by no means successful, and in 1865, the rails were taken up. The necessity of connecting the railway terminus at Redfern with the city was fully recognised at that time as it is to-day, but the public mind had become prejudiced against tramways, partly in consequence of their failure in the past, and it was not until 1880 that a bill was passed authorising the construction of Government tramways. The Redfern line was completed first as it was anticipated that the traffic would be considerably augmented during the time of the exhibition, which expectation was fully realized. Tramways were at the same time rapidly pushed forward to the various suburbs from the city, and at the present time twenty-seven and a-half miles have been constructed, in addition to which there is a tramway from Campbelltown to Camden a distance of seven and a-half miles, and also between Kogarah and Sandringham and Sans Souci, and from Newcastle to Plattsburg.

All the tramways are worked with steam engines, which, for the most part, have been manufactured by the Baldwin Locomotive Company. They are all provided with a non-automatic vacuum brake. Similar tramways have been constructed at other parts of the colony by private enterprise. The lines are generally constructed in the following manner:—A trench eight feet three inches wide, by one foot two inches deep, for the straight portions of the line, and one foot four and three-quarter inches deep for the curved portions, which is filled with a layer of ballast four inches deep, consisting of sandstone broken to three inch gauge. On the ballast the cross-sleepers are laid, which are eight feet long by eight inches wide by four inches deep, excepting where joints occur in the rails, when sleepers are twelve inches wide. The sleepers are spaced two feet eleven and a-half inches centre to centre, and are packed up to the proper levels, after which the rails are securely fixed. The space between them up to the level of the underside of the paving sets or timber blocks, as the case may be, is filled with cement concrete, mixed in the proportion of eight to one. Where the tramways are laid in the streets a continuous guard-rail is used. In consequence of the great wear of the rails between Redfern, Liverpool-street, and Circular Quay, due to the concentration of the traffic of all the city and suburban lines on this section, it is now being relaid with rails of a much heavier section, with guard-rails, breaking joints between the joints of the main rails, and the foundations are also stronger. The tramways are still in an experimental state, and the results are not altogether satisfactory, however, the system may be thoroughly revised at no distant date. On the North Shore a cable tramway was opened on the 22nd May, 1886, and is still in operation.

HYDRAULIC ENGINEERING.

SYDNEY WATER SUPPLY.

The early settlers in Sydney depended for their water supply upon tanks excavated along the line of a creek known as the Tank Stream, which formed the dividing line between East and West Sydney, and followed a line parallel to, and close to George-street, widening out where Macquarie-place now stands. As the population increased—especially along the banks of the stream—the supply became polluted and insufficient for the rising city. The next attempt to obtain a supply of water for the city was due to Mr. Busby, who drove a tunnel from the Lachlan Swamp (under the ridge dividing the drainage of Port Jackson from that of Botany) to Hyde Park, which tunnel, known as the Busby bore, supplied the lower parts of Woolloomooloo and Darling Harbour by gravitation. A further examination of the site of the swamp led to what is known as the Botany scheme, which up to last year supplied Sydney with water. The Botany scheme consisted of a catchment area of barely seven square miles in extent, composed entirely of sand, which retained the water falling upon it, like a sponge. A small portion of the drainage area supplied the upper part of the Lachlan Swamp, and was distributed in the manner already referred to; the remainder of the drainage collected into a stream known as the Lachlan or Botany Stream, which was intercepted before falling into Botany Bay in the first instance by means of a puddle dam built across the stream, and afterwards by means of sand dams built along its course with timber bye-washes, the objects being to hold back the water and keep the sand thoroughly saturated. Three pumping engines of the overhead beam construction were erected in 1858 to pump the water from the Botany dams to a brick service reservoir built in Crown-street, along a line of pipes six miles long. From the Crown-street reservoir the water was pumped to similar reservoirs at Paddington and Waverley for the supply of the higher parts of the city. The maximum quantity supplied by pumping from Botany was probably about six and a-half million gallons per day, which was supplemented by about three hundred thousand gallons from the Busby bore. The Botany scheme has supplied Sydney up to the end of last year, and has never been exhausted, although the city has frequently been put on a limited allowance. During the year 1885, a pair of horizontal compound pumping engines designed by Mr. Norman Selfe, M. Inst. C.E., were put down to assist the old beam engines when necessary, but they have not often been required.

The necessity of securing an adequate supply of water for Sydney and suburbs, caused the Government on September 24, 1867, to appoint a Commission consisting of the following gentlemen :—Messrs. John Smith, M.D., C.M.G., Professor of Physics, University of Sydney; Edward Orpen Moriarty, M. Inst., C.E., Engineer-in-Chief for Harbours and River Navigation; Philip Francis Adams, Surveyor-General; Francis Henry Grundy, Civil Engineer; Thomas Woore, and William Christopher Bennett, M. Inst., C.E., Commissioner and Engineer-in-Chief for Roads and Bridges, to make a diligent and full inquiry into the present provision for a supply of pure water to Sydney and suburbs, and to institute all necessary inquiries to ascertain by what measures a plentiful supply might be best obtained. The Commissioners made four progress reports, and submitted their final report in February, 1869. The labours of the commission were devoted to the following considerations :—1. The population to be supplied with water. 2. The condition and prospects of the supply from Botany. 3. The new sources of supply. The commissioners reported that the Botany supply was inadequate and uncertain, and not to be relied upon in all seasons. They fully inquired into the following proposals for the supply of Sydney with water :—1. The Grose River, drainage two hundred and sixty-eight square miles of the Blue Mountain range. The Warragamba, draining three thousand two hundred and forty-seven square miles. 3. The George's River, draining three hundred and seventy-five square miles. 4. The Upper Nepean and Cataract, draining three hundred and fifty-four square miles. The latter gave rise to a high-level and a low-level scheme; the high-level scheme from Pheasant's Nest, with a storage reservoir at Bull's Hill, proposed by Mr. Grundy; the low-level scheme from Pheasant's Nest, with a storage reservoir at Prospect, proposed by Mr. Moriarty. The Commission adopted Mr. Moriarty's scheme.

Since the date of the report of the Commission other proposals were brought forward, including—5. The Loddon River and Madden's Plains, with extensions to the Wingecarribee Swamps. 6. The Erskine Valley, a tributary of the Nepean River. 7. A system of wells on the Botany reserve. The engineering advisers of the Government as members of the Commission having recommended the Upper Nepean scheme, it appeared to have been considered necessary by the promotors of the others which had not been adopted that an impartial opinion was not to be expected from them on any scheme that might be considered as a rival to their own, and an independent opinion was desirable. Accordingly Mr. W. Clark, M. Inst. C.E., was appointed by the Government to report on the various schemes, and also to advise them on the drainage of Sydney. Mr. Clark arrived in Sydney on November 29th, 1877, and in May of the same year reported in favour of Mr. Moriarty's scheme, which has since been proceeded with, and although the present water supply is derived from this scheme the works are not quite completed.

Since the publication of Mr. Clarke's report an amended scheme has been brought forward prominently by Mr. F. Gipps, C.E., the merits of which have been warmly discussed in the daily papers. Mr. Gipps proposed to construct a storage reservoir at Kenny Hill, instead of Prospect, and to lead the water into Sydney from the Kenny Hill Reservoir by means of a double line of pipes. The advantages claimed by the advocates of this scheme are somewhat as follows:—1. That the proposed site at Kenny Hill, being nearer to the source of supply, would shorten the length of the canals and aqueducts, &c., of sufficient capacity to convey the water to the storage reservoir. 2. That, in consequence of the greater elevation of Kenny Hill, a double line of pipes could be laid to a reservoir situated at Waverley, having such a steep mean hydraulic gradient that considerable economy would have resulted. 3. That the scheme is purely a gravitation scheme, and that consequently the pumping engines at Crown-street would not be required. 4. That the extra head of water would be valuable for the extinction of fires, and the working of hydraulic lifts and machinery.

DESCRIPTION OF THE SYDNEY WATER SUPPLY.

The present water supply of Sydney is derived from the Upper Nepean, the Cordeaux, and the Cataract Rivers, at a level sufficiently high to supply Sydney by gravitation.

The drainage area comprises three hundred and fifty-four square miles entirely in a sandstone country, which is at present practically unoccupied, and likely to remain so, since the country is sterile and consequently unsuitable for agricultural and pastoral pursuits.

The rivers above referred to rise in the mountain country running parallel to the coast, between the Bulli Pass and the Mittagong Range, and which attains an elevation of one thousand feet and upwards. The mountains present a very precipitous face towards the sea, with a more gentle slope landwards, they thus form a barrier to intercept the rain clouds coming from the sea, which condensing discharge their water on the extended area of these landward slopes.

A comparison of the records of rainfall near the coast, with that more inland, will show the larger rainfall is deposited soon after the clouds pass the summit of the range. The quality of the water from such a source as the one above referred to is unquestionable. There are, moreover, numerous swamps in the upper portion of the catchment area which retain the water falling upon it, preventing its rapid discharge by the rivers, and rendering their flow more equable.

These rivers, like all those in the sandstone country, have cut their way into narrow gorges of a very rugged character, till their waters reach, in a comparatively short distance, a level very little above that of the sea. The sides of these gorges are thickly covered with timber.

From Pheasant's Nest, which is a gorge of the character above described, just below the junction of the Cordeaux with the Nepean, the waters of the united streams are held back and raised to a height of 439.5 feet above the sea level by means of a dam about ten feet high, which is constructed across the Nepean.

The Nepean Tunnel which unites the waters of the rivers referred to with those of the Cataract River, commences at the dam, with an invert level of four hundred and thirty feet above the sea. It is 23,507.25 feet long, nine and a-half feet wide and seven and a-half feet high, driven through the sandstone rock and inclined on a gradient of two and a-half feet per mile, having a discharging capacity of ninety-seven millions of gallons daily.

At Broughton's Pass another similar dam is constructed, about twelve feet in height, across the Cataract River, by means of which the combined waters of the Nepean, Cordeaux, and Cataract are raised to a level of four hundred and twenty-six feet above the sea, and are then conveyed by the Cataract Tunnel, which commences with an invert level of four hundred and sixteen feet above the sea, being a drop of about two feet below the invert level of the Nepean Tunnel at this point; it is 9,724.33 feet long, ten and a-half feet wide, and eight and a-half feet high, driven through the sandstone rock on a grade of three and a-half feet per mile, and having a discharging capacity of one hundred and fifty-five millions of gallons per day.

On leaving the Cataract Tunnel, the outlet of which is a little over six and a-quarter miles from the Pheasant's Nest, the water is conveyed for several miles through very rugged country, intersected by deep creeks.

From the mouth of the tunnel, and for a lengths of 1,133 feet, the three and a-half feet per mile gradient is continued, the canal being cut out of the rock and having a width of nine feet, it then gradually widens to twelve and a-half feet, with vertical sides, and a fall of twenty-one inches per mile, the depth of water being eight feet when running full.

In excavating the canal over this portion and for some distance on, where the formation is sandstone, every endeavour was made to save the rock in places where it appeared that lining could be dispensed with. When it became necessary to protect the sides the lining is composed for the most part of dry rubble masonry, in places where the cutting was shallow, or the ground very bad, walls of concrete or of rubble in cement were built.

The creeks are spanned by large wrought-iron pipes or syphons, on stone piers or bearers, with concrete abutments.

The following are the particulars of the aqueducts:—

Simpson's Creek at the seventh mile.—Diameter of pipe, eight feet. Spans—two, twelve-feet; two, thirty-three-feet; and one, sixty-feet, making a total length of one hundred and fifty feet between abutments; gradient, one in 524.445; height of pipe above flood level in creek, twenty feet.

Elladale Creek at seven and three-quarter miles.—Diameter, eight feet. Spans, two twelve-feet; two twenty-three and a-half-feet, four, thirty-three-feet; six, thirty-five and a-third-feet; and four, sixty-feet; total length, six hundred and fifty-five-feet. The form of this flume is an inverted syphon lowering the centre portion to thirty-one feet below the bed level, and thirty-nine feet above flood level. This arrangement avoids unnecessary height of piers. The gradient is one in 699.786.

Ousedale Creek at a little beyond nine and a-quarter miles.—Diameter, seven and a-half feet. Spans—two, twelve and a-quarter-feet; two, thirty-one-feet; three, thirty-three and two thirds-feet; three, thirty-seven and a-half-feet; and two, sixty-feet. Total length, four hundred and twenty feet. The form is an inverted syphon, the centre portion being twenty-nine feet below bed level, and forty-one feet above flood level. The gradient is one in 433.884.

Mullaly Creek at a little over nine and three-quarter miles.—Diameter, seven and a-half feet. Total length, one hundred and seventy feet. Gradient, one in four hundred and twenty-five feet.

Leafs Creek at eleven miles.—Diameter, seven and a-half feet. Spans—two, seven and a-half-feet; one, thirty-seven feet; one, thirty-eight-feet; and three, sixty-feet. Total length, two hundred and seventy feet. Form inverted syphon, centre portion being thirty-four feet below bed level, and forty-two feet above flood level, Gradient, one in 459.965.

Nepean Creek at eleven and three-quarter miles.—Diameter, seven and a-half feet. Spans—two, twelve-feet; two, twenty-eight-feet; and one sixty-feet. Total length, one hundred and sixty feet, Height above flood level, twelve feet; gradient, one in 489.296.

Waudhausen Creek at twelve and three-quarter miles.—Diameter, seven and a-half feet. Spans—two, twelve-feet; two forty-eight-feet; and two, sixty-feet. Total length, two hundred and forty feet. Height above flood level, forty-seven feet; gradient, one in 382.155.

Menangle Creek at fourteen and a-quarter miles. Diameter, seven and a-half feet. Spans—two, twelve-feet; one thirty and a-half-feet; two, sixty-feet; and five, thirty-one and a-half-feet. Total length, three hundred and thirty-two feet. Height above flood level is fifteen feet; gradient, one in 431.729.

The smaller creeks and watercourses are carried either under the canal by brick syphon culverts or over it by wrought-iron or timber flumes. At a little beyond the tenth mile the water passes into Devine's Tunnels, six hundred feet and two thousand six hundred and eighty feet in length respectively, driven through the sandstone rock, and being of the same dimensions and gradient as the Cataract Tunnel. This is the last of the unlined tunnels, all other tunnels below this are in shale formation and are bricked throughout with three rings, in exceptionally bad places with four rings. At a little over fourteen and a-half miles the water discharges into the Sugarloaf Tunnel, 3907.52 feet in length, nine and a-half feet wide and seven and a-half feet high, the gradient being six feet per mile.

The canal up to this point has a gradient of twenty-one inches per mile and is twelve and a-half feet in width with vertical sides, except in a few places, for instance between Woodhouse's and Menangle Creek, where the ground was bad, with a steep cross slope, the walls were battered and otherwise made stronger.

At about three hundred and fifty feet beyond the outlet of the Sugarloaf Tunnel, there is a vertical drop in the canal of eight feet. Here there are sluice gates by shutting which the entire supply can be stopped if required or in case of accident. The water in such a case would pass over a large waste weir, and discharge into a natural watercourse leading to the Nepean about a mile distant.

After leaving the drop the gradient of the canal changes to two feet per mile with a width of twelve feet and a depth of eight feet. At about sixteen and three-quarter miles the section of the canal changes to one with sloping sides, the depth of water being seven feet, and width nineteen feet at that level, the gradient remains the same over this portion, viz., two feet per mile.

The Great Southern Railway is crossed at seventeen miles by means of a wrought-iron pipe on brick piers eight feet diameter, with spans two of eleven feet, one of fifty-one feet, one fifty-two feet, and one sixty feet, making the total length one hundred and eighty-five feet. The height above rail level is thirty-five feet, and the gradient 1 in 215.87. Over the sloping ground on each side of the railway, the canal is carried in embankment, the sides and invert being concreted.

At seventeen and a-half miles there is a substantial brick aqueduct over a deep depression, called the Kean's Creek aqueduct and four hundred feet beyond this the water enters the Mount Anna Tunnels, 2,248 feet and 366.6 feet in length separated by a piece of covered way two hundred and thirty-seven feet long. The smaller tunnel is curved on plan and both are similar in grade and cross section to the Sugarloaf; the covered way has a gradient of four feet per mile. The canal with sloping sides and gradient of two feet per mile continues to near the twenty-four and three-quarter mile mark, the sides and bottom protected with pitching nine inches in thickness.

The Badgelly Tnnnel occurs at a little beyond the twenty and a-quarter mile mark and is three thousand seven hundred and eighty-three and three-quarter feet in length with a piece of covered way four hundred and three feet long beyond the outlet.

The Mallesmain Tunnel at twenty-two and three-quarter miles is seven hundred and three and a-half feet in length also with covered way sixty-three feet and one hundred and forty-two feet in length at the inlet and outlet ends respectively.

The Box Tunnel at twenty-four and three-quarter miles is on a reverse curve, and is four hundred and five and one-third feet in length. These tunnels are lined and are similar in grade and cross section to the Sugarloaf and Mount Anna Tunnels. The water emerging from the Box Tunnel is conveyed by a canal with sloping sides giving a breadth of water at the surface of sixteen and three-quarter feet, and a depth of six feet, the gradient being four feet per mile, which continues to about the twenty-five and a quarter mile mark; after which it enters a semicircular canal, with a surface width of eleven and a-half feet and depth three and a quarter feet on a gradient of twenty-eight and a-half feet per mile, which extends to about the twenty-seven and a-half mile mark. It should be mentioned that there are sluice gates and a waste weir at the termination of the four feet per mile gradient near twenty-five and a-quarter miles. For the next half mile the gradient is reduced to nine feet per mile, with an increased section; it then passes into an ordinary canal with sloping sides on a grade of two feet per mile. The gradient is curved from the end of the twenty-eight and a-half feet per mile gradient to the commencement of the nine feet per mile gradient, and again from the end of this gradient to the commencement of the two feet per mile gradient. The semicircular section of the canal consists on the steep grade of six inch pitchers set in cement and grouted on four inches of concrete; the nine feet to the mile gradient consists of eight inch pitchers set in cement and grouted, and the whole is topped with a coping of concrete.

At thirty-four and a-half miles the water enters the Cecil Hills Tunnel, 10,608 feet in length, through two lengths of covered way, eight hundred and forty-five feet and four hundred and forty-five feet long respectively, to the Devil's Back and Calmsley Tunnels, the length of which are nine hundred and sixty-four and two thirds feet and 1,239 feet respectively, with a small piece of open canal intervening, then in canal on a gradient of two feet per mile for one and a-quarter miles, through Weston's Tunnel, four hundred and fifty and three-quarter feet in length; again in canal for a little over three-quarters of a mile and through the

Trafalgar Tunnel, six hundred and fifty-eight and two-thirds feet in length. The canal then terminates in a basin at a little beyond thirty-nine and three-quarter miles, with an overflow weir, sluice gate, and gauging weir, after which it flows into a concrete channel leading to Prospect Reservoir ; the inclination of this channel is one in 38.25, the level of the overflow weir at the end of the canal is 243.15 feet above the sea level, that is, 48.15 feet above the proposed high water of the reservoir. A thirty-inch main has been laid from the basin above the reservoir to the canal below it, for the purpose of supplying the latter independently of the reservoir, and also to give head for working valves, &c.

All the tunnels above described are similar to the Sugarloaf and Mount Anna in section and grade, and are lined throughout with three-brick rings.

The capacity of the works above Prospect is slightly over one hundred and and fifty millions of gallons per day.

The Prospect Reservoir when full will have a storage capacity of 10,812 million gallons, the area of the water surface will be 1,261 acres, the greatest depth will be seventy-five feet, and the depth from which water will be drawn twenty-five feet, giving an effective storage capacity of 7,110 million gallons. The reservoir is formed by the construction of an earthen dam, one hundred and ten chains long and eighty-five feet high in the deepest part, the width at the top will be thirty feet, the slopes are three to one inside and two and a-half to one on the outer side with fifteen feet berms at reduced levels, one seventy-five and one hundred and forty-seven. The reduced level at top of dam is two hundred and three feet, top water level, one hundred and ninety-five feet ; lowest level to which water can be drawn off, one hundred and seventy feet ; the maximum width of the base of the dam at the ground level is five hundred and twenty-five feet. The water slope is pitched with diorite blocks eighteen inches deep. The puddle-wall is carried down from a distance of about six feet below the top of the bank to the solid shale and is eight feet wide at the top, battering one in eight outwards to ground level, and inwards below the ground level to the shale foundation ; it is protected on each side with selected materials, consisting of red and white clay rammed in layers six inches deep sloping one in twelve downwards towards the puddle wall. The remainder of the dam consists of similar materials sloping in a similar manner towards the puddle wall but rammed in layers twelve inches deep.

The works for drawing water from the reservoir consist of a curved tunnel nine hundred and thirty-two feet long driven through the solid ground altogether clear of the embankment ; it is circular in form and twelve feet in diameter and is brick lined throughout. There is a stopping formed by building out the brickwork in stepped concentric rings, and filling up the space between them with concrete so as to prevent the water creeping along the outside of the tunnel. Two lines of cast-iron flanged pipes forty-eight inches in diameter are laid in the tunnel above referred to, which are continued through the inlet tower to the reservoir and into a basin at the outlet end, terminating in each case with a bell-shaped mouth, and having concentric rings cast on the lengths which pass through the brickwork of the tower. These pipes are also continued below the outlet tower to the scouring channel. The four feet pipes also extend to the bottom of the reservoir and can be used as syphons to empty the reservoir should it be necessary at any time to do so. In both the inlet and outlet towers are arranged the various stop valves and the machinery for raising and lowering them, which consists of screws driven by spur and bevel gearing. The valves in the inlet tower are arranged to draw the water from the reservoir at different levels. A lattice girder foot bridge of three spans on brick piers gives access to the inlet tower.

The canal below the Prospect Reservoir is four and three-quarter miles long, and the cross section is partly with vertical sides, and partly V shaped. The basin and part of the canal are lined with diorite ashlar masonry. The high water level of the reservoir end of the canal is 175.50 above sea level, the level of the top of the canal is the same throughout the entire length of this section, viz., 177.5 feet, this arrangement allows an increased head to be obtained for the works nearer Sydney. Owing to the nature of the ground nine hundred feet of this section had to be covered in and is virtually a culvert under pressure. The fall in the canal is at the rate of six inches per mile. The water is conveyed over a valley at forty-four miles by means of a brick aqueduct of twenty-two arches each thirty feet span. At the end of the canal there is a straining basin and pipe head reservoir from which the water is conveyed through wrought-iron pipes six feet in diameter three-eighths and seven-sixteenths of an inch in thickness for a distance of four and seven-eighths of a mile, terminating in a screening chamber at Pott's Hill. The capacity of the canal and six feet pipe from Prospect to Pott's Hill a distance of about nine and five-eighths of a mile is fifty millions of gallons per day. Near this point a large Balance or Service Reservoir is now being constructed. It will be one thousand three hundred feet in length and nine hundred feet in width having a capacity of one hundred million gallons. This reservoir will be constructed so as to admit of the water rising freely if necessary to the same height as the water at the commencement of the canal below Prospect, viz., 175.5 feet.

A branch pipe, fifteen inches in diameter, leads off the six feet pipe at the Dog-trap Road to supply Granville, Auburn, and South Parramatta.

From Pott's Hill screening tank two thirty-inch pipes will start and supply the Northern, Western, and Southern suburbs, one to be taken across the Parramatta River to Ryde, where there will be a pumping station to lift the water to a tank on the Lane Cove Road at Chatswood to supply the whole of North Shore. From the Reservoir on Ryde Hill the districts of Hunter's Hill and Gladesville will be supplied.

A forty-eight inch pipe carries the water from the screening chamber at Pott's Hill as far as the branch to Petersham a distance of seven and a-half miles, from which point to Crown Street, a distance of three miles and three-quarters, the pipes are forty-two inches in diameter.

The Petersham Reservoir holds two millions of gallons and is supplied by a forty-eight inch branch from the main one thousand two hundred yards long. The time required to fill the Reservoir is two and five-sixths of an hour.

The Crown Street Reservoir, into which the forty-two inch pipe discharges, is the one at present used for supplying Sydney. The top water level is one hundred and forty-one feet over H. W. Sydney and the bottom is one hundred and twenty-five feet. The capacity of this reservoir is about three and a-quarter million gallons; it is, however, contemplated to enlarge it to about four and a-half million gallons immediately. The pumps by which the upper levels of the town are supplied are at Crown-street.

The mean hydraulic gradient of the pipe from Pott's Hill is 1 in 2907.111, and the pipe will discharge a volume of water equal to seventeen and three-quarters of a million gallons daily.

About nine-tenths of the district of Sydney may be supplied by gravitation.

The following is a statement of the lengths of each description of work :—

Tunnels...	miles	$11\frac{5}{8}$
Canal	,,	$32\frac{3}{8}$
Across Prospect Reservoir	,,	$2\frac{1}{4}$
Wrought-iron flumes 8 feet and $7\frac{1}{2}$ feet diameter	,,	$\frac{1}{2}$
,, ,, pipe 6 feet diameter	,,	$4\frac{7}{8}$
Cast ,, ,, 4 feet ,, ...	,,	$7\frac{1}{2}$
,, ,, ,, $3\frac{1}{2}$ feet ,, ...	,,	$3\frac{3}{4}$
Total length of conduit in miles	...	$62\frac{7}{8}$

WATER SUPPLY OF THE TOWNS OF MAITLAND, MORPETH, NEWCASTLE, AND THE MINING DISTRICTS.

The scheme for the supply of the above-named towns was developed in a Report prepared by Mr. W. Clark, in 1877, and consists of pumping the water from the River Hunter at a point called Bolwarra, or Dickson's Falls, into a storage reservoir, situated between the river and the Walka Lagoon, from thence it flows into filter beds, and eventually, after passing through them, is received into a clear water tank. From this tank the engines take the water and force it up to a reservoir situated on the Butti Hill, a distance of five miles, containing one million gallons. On the passage a part of the water is diverted by a branch pipe two and three-quarter miles long to a reservoir at East Maitland, capable of holding five hundred thousand gallons, for the supply of East and West Maitland, and Morpeth, from which latter place the distance is two miles The level of the Butti Reservoir is two hundred and sixty-five feet above high water, and it commands the entire route of the pipe extending through the mining townships to Newcastle, where it is received in a reservoir at a level of one hundred and fifty-nine feet above high water, which commands all the levels below. Reservoirs are also provided for the supply of the various mining townships.

OTHER TOWNS SUPPLIED WITH WATER.

The system of supplying Bathurst, Goulburn, Wagga Wagga, Bourke, and Albury, consists of pumping the water from the river running near the town in question to a reservoir situated at a level sufficiently high to command the whole of the town. At Wagga Wagga and Albury the capacity of the reservoirs are being increased. The foregoing works on water supply have been constructed under the supervision of Mr. Moriarty, Engineer-in-Chief for Harbours and Rivers, &c. The author is indebted to Mr. T. Keil, M. Inst. C.E., for particulars of the Sydney Water Supply Works.

CONSERVATION OF WATER.

This paper, being a history of works executed in the colony, only a brief notice can be given of the various important works which have been proposed from time time, and which may be carried out in the future. The exhaustive report of the Royal Commission on the Conservation of Water will, therefore, be only briefly referred to. This Commission was appointed on May 10th, 1884, "to inquire into the best methods of conserving the rainfall, and for searching for, and developing the underground reservoirs supposed to exist in the interior of the colony; and also into the practicability, by a general system of water conservation and distribution, of averting the disastrous consequences of the periodical droughts to which the colony is, from time to time, subject." The Commission submitted three reports, the last of which was completed on the 9th of May, 1887. The reports were devoted to a statement of their investigations on the following subjects:—Physical features of the colony, rainfall evaporation, subterranean water, storage of water, tanks and dams, wells, irrigation, navigation, principal river basins and other drainage areas, riparian rights, and proposed legislation. The Commission indicated various surveys and explorations which they considered necessary in order that appropriate schemes might be devised for conserving and distributing water in the different river basins of the colony. Some complete investigations were undertaken by Mr. M'Kinney, M. Inst. C.E., Engineer to the Commission, regarding questions connected with the tract of country lying between the Murray and Murrumbidgee Rivers, dealing also with these rivers as sources for irrigation canals. The coastal rivers were investigated, and surveys were made of the Upper Darling with a view to irrigating the Riverina district. They arrived at the following conclusions:—1. That on water conservation mainly depends the prosperity and the development of the whole extent of the Central and Western divisions of this colony, and that though less required in the Eastern division it will add in many places there also in an important degree to the productiveness, and therefore to the value, of the land. 2. That, as the landowners, as a generl rule, are quite equal to the task of providing sufficient water for the stock which the land can carry under present conditions, Government works for supplying water to stock are required only on a limited scale, and generally only on travelling stock routes. 3. That the great object of water conservation in this colony, and particularly in the country west of the Dividing Range is for irrigation. 4. That the purposes for which irrigation is chiefly required are (*a*), to provide fodder and grain for horses, cattle and stud sheep; (*b*) to afford supplies to be kept in reserve for saving stock of all kinds in bad seasons; (*c*) to produce fruit, vegetables, and miscellaneous crops; and (*d*) to increase generally the productive powers of the land. 5. That any well-considered and properly-executed project for irrigation in the country west of the Darling Range would afford a good direct return on the capital invested, and would be a distinct benefit to the colony at large. 6. That legislation on the subject of water rights is a matter of pressing necessity, both to protect the rights of the State, and to foster and encourage local and private enterprise.

The Commission recommended:—1. That the maintenance of river-guage records as extended by them should be made still more complete, and the records kept continuously, and in a careful and systematic manner. 2. That the gauging of the rivers initiated by them should be continued in a systematic manner, so that the discharge of all rivers likely to be tapped for water supply purposes may be known for all readings of the gauges. This information is particularly necessary in the cases of the Murrumbidgee, the Darling, and the Murray. 3. That the subject of legislation on the lines suggested in their first report should receive early consideration.

The following special works were recommended :—1. That, as projects for the construction of irrigation canals from the Murray and Murrumbidgee have been submitted to us in a definite form by our engineer, and as information supplied with these projects has been carefully worked out, and is of a most favourable nature, the necessary funds for the required surveys should be sanctioned as estimated, and the surveys started forthwith. 2. That a sum of £5000 should be sanctioned for a more complete examination of the Lachlan, Macquarie, and Darling Rivers; and of Lake George, Lake Bathurst, and Lake Cudjellico. 3. That as great bodies of water from time to time flow down the Paroo, Bulloo, and Warrego, and run to waste in *Polygonum* swamps, and down fissures in the ground, a survey should be undertaken to ascertain whether it would be possible by the conservation or diversion of these waters to turn them to greater national advantage.

WATER SUPPLY FOR STOCK ROUTES.

The first works in connection with the water supply of stock routes were commenced in 1869, when a sum of £5000 was voted by Parliament for works on the Booligal and Wilcannia road, and handed over to the Roads Department for expenditure. In 1882 a sum of £50,000 was granted for tanks and wells, and arrangements were made for its expenditure on the different stock routes recommended by the Mines Department. By this time considerable experience had been gained as to the most suitable works for the purpose, and type drawings and specifications were prepared by Mr. A. P. Wood, under whose immediate supervision the works have been carried out. The works by which the stock routes have been supplied, or partially supplied, with water, may be divided into the following classes :—1. Wells; 2. Tanks; 3. Dams.

In the works constructed by the Government for reaching, lifting, storing, and distributing underground waters, the shafts are slabbed right through, and divided into two compartments, each two feet six inches square, by a brattice extending from the top to the bottom of the shaft. The lifting appliances consist of a whim and gearing, working two self-acting buckets, which discharge into a timber-framed, iron-lined service tank communicating with the troughing for watering the stock. In carrying out these works great care has to be taken to have the slabbing thoroughly fitted, and clay well puddled into all the spaces at the back of the same. The shaft must be carried down truly and have runners properly fixed, so as to ensure the buckets working smoothly.

Some of the water-bearing drifts are very troublesome and difficult to deal with, and in such cases, if the water has a considerable rise, with a strong supply, it is often found to be advisable not to sink to the drift, but to stop some few feet above it, and then put down a carefully tubed bore to tap the water. Boring is sometimes resorted to in order to avoid the necessity of puddling back water of bad quality. Framed timber lined with galvanised iron is generally adopted for tanks, although where timber is scarce and stone procurable close to the work, the latter is substituted. Iron-framed, buckled-plate tanks and steel troughing are now being used in preference to timber or masonry on all new works.

When tanks are constructed in watercourses an embankment is made below the excavation, and in cases where the channel is shallow, and the face of the bed considerable, this dam is carried above the level of the creek banks, and flanking embankments carried on the same level as the dam are continued up each side of the creek until they cut the natural surface of the ground. In other cases, where the face of the bed is inconsiderable, a dam is constructed both above and below the excavation, and these, if raised above the natural level of the creek banks, are joined by lateral embankments; an inlet pipe is laid under the upper dam, which allows water to gravitate into the excavation and enclosed space until it reaches the level of the water outside; a valve is then closed, and, if necessary, the outside water is pumped over the embankment into the reservoir. This plan gives a greater depth of water, and shuts off the tank supply from that in the shallow reach above it, and considerably reduces the loss from evaporation and soakage. In all works of this character great care must be taken to provide an adequate bye-wash, and wherever possible the work is so located as to allow of a natural channel being used for the purpose. The number of works completed up to date are as follows:—One hundred and five tanks, twenty-seven wells, and five dams.

SYDNEY SEWERAGE WORKS.

The high rate of mortality prevailing in the City of Sydney having attracted serious attention, the Government in the month of April, 1875, appointed a board called "The Sydney City and Suburban Sewage and Health Board," "to inquire into and report as to the best means of disposing of the sewage of the City of Sydney and its suburbs, as well as of protecting the health of the inhabitants thereof." The board consisted of fifteen members, viz.:—Messrs. M. B. Pell, B.A., Professor of Mathematics and Natural Philosophy, University of Sydney (Chairman); P. F. Adams, Surveyor-General; H. G. Alleyne, M.D., Health Officer;

Francis Bell, City Engineer; W. C. Bennett, Commissioner and Engineer-in-Chief for Roads and Bridges; Alderman M. Chapman; G. F. Dansey, M.R.C.S., City Health Officer; F. H. Grundy, C.E.; E. O. Moriarty, Engineer-in-Chief for Harbours and Rivers; Benjamin Palmer, Mayor of Sydney; R. B. Read, M.R.C.S.; Hon. John Smith, M.D., Professor of Chemistry and Experimental Physics, University of Sydney; John Whitton, Engineer-in-Chief for Railways; Hon. J. B. Wilson; and Charles Watt, Government Analyst. The chairman, with five other members of the board—Messrs. Alleyne, Bell, Bennett, Moriarty and Wilson were constituted a central board to carry on the general inquiry, and the services of the other members were utilised by the formation of committees to investigate subsidiary matters, and to report to the central board from time to time.

Within one year from the date of their appointment the board submitted nine progress reports and some matters of a most urgent nature as affecting the sanitary condition of the city were dealt with and remedied as far as practicable within that period. After a most exhaustive enquiry the board submitted their twelfth and final report in May, 1876, two years and one month from the date of their appointment. The city of Sydney is situated on the southern shore of Port Jackson, at about five miles distance from the Heads, or entrance to the Harbour from the South Pacific Ocean. From a point on the ocean cliffs, about three and three-quarters of a mile south of the South Head, and known as Ben Buckler Point, a high ridge extends in a westerly and south-westerly direction, having a mean elevation above sea-level at its eastern end of about two hundred feet and declining thence to about one hundred feet near Newtown. The district to the north of this ridge, on which the principal portion of the city is situated drains to Sydney Harbour, and the southern slopes drain to Botany Bay and Cook's River. It was decided that the sewage of those portions of Sydney and its suburbs which naturally drain into Port Jackson should be collected into an outfall sewer, and led away by the most direct course, and at as low a level as practicable, and discharged finally into the sea near Ben Buckler Point, while the sewage of the southern district should be collected into a separate system and taken to Botany and there be utilised as a sewage farm, there being an ample area of light sandy soil at a convenient level for irrigation by gravitation, available for the purpose. The area drained by the northern system is about five thousand three hundred acres, and the area drained by the southern system about one thousand one hundred acres. In 1879 the Government decided to proceed with the works on the general lines recommended by the board, and Mr. W. C. Bennett was appointed Engineer-in-Chief for Sewerage. The first contract was let in 1880. The northern and southern outfall sewers have been completed and brought into use, and most of the branches are either completed or in progress; but much yet remains to be done in the construction of minor sewers in connection with these systems.

THE NORTHERN SYSTEM.

The northern outfall sewer, commencing near the intersection of Newtown-road and Parramatta-street, and discharging into the ocean near Ben Buckler Point, as before described, is five and a-half miles in length, is oviform in section, varying in size from four feet six inches by three feet six inches at its upper end to eight feet six inches by seven feet six inches for a length of one mile at the outfall end, and has a fall of three feet six inches a mile. At a quarter of a mile from the head it is joined by the Prince Alfred Hospital connecting sewer, four feet six inches by three feet six inches in size, and by the Pyrmont branch, three feet three inches by two feet two inches. At the corner of Oxford and Liverpool-streets one mile and a-quarter from the head, it is joined by the King-street intercepting branch, and by the combined Bridge-street and Harrington-street intercepting branches, each four feet six inches by three feet six inches. A little further on it is joined by the Riley-street intercepting branch, and then by the Bourke-street intercepting branch, and at Barcom Glen, two miles from the head, it is joined by a branch sewer on the boundary line between the City and Paddington. Besides collecting the sewage from these various branches it intercepts a number of old sewers directly—one of these in the municipality of Paddington, being forty feet above the level of the outfall sewer at the intercepting point,—and a number of junctions are provided along the entire length to meet present and future requirements. Where the sewer crosses Deep Dene, a part of Rushcutter's Bay Valley, a storm-water overflow is provided, and from this point an overflow sewer was built to carry the storm-water into Rushcutter's Bay. It is half a mile in length, four feet six inches by three feet in size, has a fall of one in two hundred, and discharges above high-water level. A swamp one thousand feet in width had to be crossed by this overflow sewer, where the surface was some feet below the invert level of the sewer. The ground is of a spongy, peaty nature, to a depth varying from ten feet to over thirty feet. After digging trial pits and making borings, it was decided to carry this length of sewer on arches of twenty-five feet span and three feet six inches rise. To form the piers for these arches concrete cylinders of ten feet external diameter were sunk through the spongy ground into a stratum of clean sand below. These cylinders were then filled with concrete, and the arches turned, the thickness between the soffit of the arch at the crown and the invert of the sewer being twelve inches. The depths of the cylinders vary from ten feet to thirty-three feet. The whole of the work in the cylinders, arches, and sewer is concrete.

This work was completed some years ago, and was successful in every respect. It is covered by a large embankment, made of spoil from the outfall sewer works, on which a roadway has been formed. The sewage can also be diverted into this overflow sewer should it ever be found necessary to do so. Provision is also made at two other points on the sewer for storm-water relief and diversion of sewage when local conditions were favourable ; but as the admission of storm-water is carefully regulated, the overflow at Deep Dene will probably meet all possible requirements in this direction. The greatest quantity of rainfall admitted on any portion of the area drained by this system is at the rate of half an inch in twenty-four hours, and any rainfall in excess of this provision will find its way to the harbour by the old sewers, or by street gutters or natural watercourses. The northern system comprises the following new brick and concrete sewers :—Outfall sewer, five miles, two thousand seven hundred feet ; Prince Alfred Hospital intercepting sewer, one mile fourteen hundred feet ; Pyrmont branch, one mile two thousand one hundred feet ; Kent-street intercepting sewer, one mile three thousand nine hundred feet ; Bridge-street and Harrington-street intercepting sewer, one mile four thousand seven hundred feet ; Riley-street and Bourke-street intercepting sewer, two thousand feet ; Lacrozea Creek branch, fifteen hundred feet ; Rushcutter's Bay overflow sewer, two thousand five hundred feet ; proposed extensions to Glebe, Balmain, &c. (shown in dotted lines on sketch plan), five miles two thousand feet—total, eighteen miles six hundred and eighty feet. Some stoneware pipe sewers have also been laid up to twenty-four inches diameter, and a large amount of work remains to be done in laying pipe sewers or sub-mains. Concrete has been largely used in the construction of the sewers, as will be seen from cross sections of sewers on Plate XL., and all bricks used in the work are of very high quality The concrete (except that used for packing purposes) is composed of blue-stone, broken to a one and a-half inch guage, sand and Portland cement in the following proportions :—Four parts of stone, two parts of sand, and one part of cement. The bricks were nearly all supplied from two brickyards, and average samples taken from them were tested at the Sydney University Engineering Laboratory, with the following results :—Average crushing resistance per square inch, two thousand seven hundred and eighty-two pounds and two thousand two hundred and twenty-eight pounds. The crushing resistance of English Stourbridge fire-bricks is about one thousand seven hundred and seventeen pounds per square inch, and of London red brick about eight hundred and eight pounds per square inch. The tunnels are lined throughout, the minimum thickness of lining adopted being four and a half inches. In rock tunnels the lower part of the sewer up to a height of twelve inches above the springing level is lined with bluestone concrete, and the arch is closed with brickwork packed solid to the rock with sandstone concrete. In very wet rock a ring of brickwork (four and a-half inches) is laid inside an outer lining of concrete and sub-ducts, which were afterwards closed, were used during construction in order to secure water-tight work. The outfall sewer from Oxford-street to the ocean, a length of four and a-quarter miles, is rendered to three-fourths of its height, and the brick arch above that level is pointed. The remainder of the outfall sewer and the branch sewers are rendered all round with cement mortar, composed of one part Portland cement and two parts of sand. Every lot of cement brought on the work is tested at the head office, where complete testing apparatus is provided, and all cement which does not fulfil the specified conditions, or appears to be of inferior or doubtful quality, is rejected. The sewers are constructed chiefly in tunnels, and a great portion of the tunnelling is in sandstone rock. Numerous shafts were sunk for the driving of the tunnels, and to be used for ventilation afterwards, the deepest one being two hundred and forty feet. The rock tunnel excavation was done by blasting, and presented no difficulties. In some cases the drilling was done by percussive rock drills worked by compressed air, and where compressed air was used for this purpose it was also used to work the winding engines. In other cases the drilling was done by hand, and ventilation was provided by Root's blowers.

The outfall end of the sewer for a length of about four miles lies in more or less open country, and the blasting operations cause little or no inconvenience: but, having regard to the annoyance and inconvenience to the citizens, which must result from blasting operations within the city, inquiries were made as to the practicability of getting a rock-boring machine which would reduce to a minimum, or, if possible, altogether do away with, the necessity for blasting. In 1845 the first machine of this kind was invented for use in the Mont Cenis tunnel, but it was not perfected till 1849, and in the following year it was abandoned as being impracticable. Since that time many tunnel-boring machines have been invented and patented in England and America. Some were designed for cutting an angular groove round the periphery of the tunnel, and others were designed for making a cylindrical bore of the whole area. A machine of the former type was tried on the first section of the outfall sewers constructed, but it proved impracticable. One of the most promising of the latter type is the machine known as Brunton's, in which the boring is done by revolving cutters, and one of these machines to make a circular bore of seven feet diameter was specially made in London for this work, and imported, and it had a lengthened trial, extending over a period of about six months, during which time a length of sixty-six feet was bored, being at the rate of one mile of tunnel in forty years. The use of the machine was then abandoned, and the work proceeded in the ordinary way. The cause of the failure was attributed partly to the hardness of the rock, but principally to the occurrence in the rock of ironstone bands and nodules. In more favourable ground it is believed the machine would have been successful.

Mr. Bennett, in the prosecution of his inquiries as to tunnel-boring machines for small tunnels in the city, obtained, as far back as 1881, drawings and particulars of Doering's machine, but the rate of progress with them would have been so slow, or the number of machines required so great, that their adoption was not considered feasible.

The portions of the work which present most interest from an engineering point of view are on the outlet end of the outfall sewer. (See Pl. XL.) A length of one mile three thousand three hundred feet, commencing at the ocean outlet, was let in one contract. For one mile of this length the sewer is eight feet six inches by seven feet six inches, and for the remainder of the length it is eight feet two inches by seven feet two inches. It is constructed in tunnel on sandstone rock for three thousand nine hundred and sixty feet of this length, in tunnel in water-charged sand for one thousand six hundred and forty-three feet, and in open cutting in water-charged sand for two thousand nine hundred and seventy-seven feet, as shown on the longitudinal section. The construction of the sewer through the water-charged sand on this contract is interestiug, on account of the difficult nature of the work, and the outlet chamber is most interesting on account of the novelty of the design, there being nothing like it, as far as the author is aware, on any other works hitherto constructed. For draining the water-charged sand nine centrifugal pumps were used with six-inch to nine-inch pipes. Pumping wells were sunk to one side of the sewer trench, and close timbered to the foundation level; the sumps below this level, a few feet in depth, being steined with concrete to prevent any water entering except through a pipe built in the concrete and connected with the sub-duct laid along the centre of the sewer trench and tunnels. The sub-duct consisted of nine-inch earthenware pipes laid in hard wood boxes open at the top and packed with broken stone. These boxes were made watertight, and the sides were carried up about two inches above the foundation level, so as to prevent any water entering from below that level, except at the end of the duct, which was always kept some distance ahead of the concrete work. During the construction of the sewer, openings through the concrete were left over the sub-duct at intervals of two hundred feet, and lines with rakes attached were passed through from one to the other, and these lines were occasionally pulled backwards and forwards to keep the pipes clear of silt or other obstruction. Two travelling cranes with thirty feet jibs were used for raising the sand from the trenches, which were sunk with a batter of one in eight and close timbered at the sides.

The sand tunnels were close timbered at the tops and sides by poling boards or runners behind "sets" placed three feet to three and a-half feet apart, centre to centre, but it was not found necessary to timber the bottom either in tunnel or open cutting, The "sets" consisted of a cap piece and two props of round hardwood timber fourteen inches in diameter. The props were notched into the cap piece and rested on longitudinal foot plates and had spreaders between, at half the height, to take the side pressure, which was found to be great, being sometimes sufficient to force the ends of a nine-inch diameter spreader an inch or so into the props as if it had been morticed in. The caps were further supported by corner struts from the props butting unto a short spreader piece underneath the "cap." Cross-spreaders underneath the props were tried at first, but they had to be abandoned and the longitudinal foot-plates were substituted. The tunnel floor and roof were level in cross-section, and the span between the props of the cap piece was thirteen and a-half feet, and at the foot of the props seventeen feet, the height of cap above floor being fifteen and a-quarter feet. The "runners" were cut to nine feet lengths, and the tunnel face was advanced six feet or seven feet at a time, and only the most experienced and most careful miners procurable were allowed on this work. It took some days for the timber to get the full pressure it had to support, and during this time loud creaking noises were frequent, and were sometimes so great as to cause the miners to leave the face and retire back in the tunnel for a few minutes. On one occasion a cap piece fourteen inches in diameter at the smallest end was crushed where it rested on the prop; but whenever any indication of weakness was observed, additional timber was put in and the work was completed without any accident to those employed; and the only mishap as regards the work was a slight settlement, opposite a pumping well, on a short length of the sewer constructed in open cutting, amounting to one and a-quarter inch at the lowest point. For a short length on either side of this lowest point there was a longitudinal crack along the crown of the arch and the invert, and along the springing level at both sides. The cracks along the crown and invert were about one-eight of an inch in width, and the cracks along the springing level were very fine. It was thought that this accident must have been due to some defect in the sub-duct box allowing sand to enter below the foundation level. Levels were taken at intervals and the work carefully watched for a considerable time after the settlement was discovered, and it was found that no further settlement took place. It was not considered advisable to take up this short length of sewer lest further damage should be caused by pumping; but the trench was opened out again and the sewer was strengthened by widening the concrete to the two sides along the damaged length and turning a new concrete arch on the top of the old one. The cracks in the brick arch were then carefully filled and pointed from the inside, and the invert bricks were taken up and relaid to the correct level after grouting the crack in the concrete. Two courses of bricks were then taken out along the springing level and relaid in short lengths, and this portion of the sewer rendered afresh. No further settlement occurred, and the repairs carried out make this portion of the sewer as strong as any other.

One of the pumping engines employed was a twenty-five horse-power one, which also worked a stone-breaker and a saw-mill. Two ten horse-power and one sixteen horse-power winding engines were used at the rock tunnel shafts, and steam winches were used at the sand-tunnel mouths for hoisting purposes, and there were ten miles of tramline laid in connection with the work. At two hundred feet from the cliffs in the line of the sewer a shaft was sunk about thirteen feet by six feet in plan. The invert level of the sewer at this shaft is six feet above high water. From the eastern or sea end of the shaft a heading was driven out through the cliff in a direct line with the sewer, and the action of the waves watched for a considerable period before designing the outlet work. The conditions to be met as regards the action of the waves are indicated in the following extracts from the final report of the board before referred to:—"During southerly, south-easterly or easterly gales the waves on the coast attain enormous magnitude and strike the coast line and the cliffs with extra-ordinary force." . . . . . "No person who has not actually witnessed it can form an idea of the magnitude of the waves which roll on this coast, or of the overwhelming force with which they strike the cliffs in heavy storms." After that careful consideration of the subject which its importance demanded, the outlet work was designed and executed. A large chamber was excavated at the bottom of the shaft beforementioned, the finished inside dimensions of which are thirty-two feet in line of sewer, eighteen feet across line of sewer, and twenty-five feet in height. The floor of this chamber at the middle of its length is two feet three inches above high-water level. From the eastern or down-stream end of the chamber there are two circular outlet channels of four feet diameter, with a fall of one in thirty-nine. One of these outfall channels is in a direct line with the main sewer, and the other channel is driven in a straight line from the north-east corner of the chamber, making an angle of 31° with the former. Midway in the chamber and at right angles to the line of the sewer there is a massive weir curved in plan on the downstream face. and supported on the upstream face by the back of a massive tongue or cut-water, and at either end of the weir there is a four feet diameter circular opening, the bottom of which is at the floor level. The sewage from the main sewer enters the chamber on an ogee fall of three feet six inches, is diverted by the cut-water into two channels passing round the sides of the chamber in suitable curves through the circular openings at the ends of the weir wall, and thence it flows through the outlet channels to the sea. The lines of the outlet channels and general arrangements are such that waves rushing up either outlet, after crossing obliquely the lines of flow of the sewage, expend their force on the weir wall, and are deflected by it down the other outlet, or upwards in the chamber if a heavy sea happens to rush up both outlets at the same time, an event which seldom happens, as the northern outlet discharges in a recess in the cliff, sheltered from easterly and south-easterly winds. The ogee fall, the work in the chamber, to a height varying from eight feet to fourteen feet, and the lining of the outlet channels is constructed of blue-stone ashlar, packed solid to the rock with blue-stone concrete. The upper portion of the chamber is lined with blue-stone concrete, keyed in the arch with brickwork and the shaft from the top of the chamber arch to the surface is lined with brickwork packed solid to the rock with concrete. The voussoirs in the outlet channels are twelve inches in depth, except for a length of twelve feet at the outer ends, where the depth is eighteen inches; and this length of twelve feet is bolted together by longitudinal bolts, passing in grooves cut in the voussoirs, between a heavy annular casting, covering the outer end, and large washers at the other end, so as to bind the length into one solid mass, washers being used at the inner end so as to allow of a good bond being kept in the masonry. To guard against the contingency of the four feet openings in the weir wall becoming choked by any rubbish which might by any possibility get into the sewer, the height of the centre part of the weir is fixed so that the sewage would flow over it before any pressure would be brought on the main sewer. Any rubbish which may pass through the openings in the weir wall is certain to pass through the outlets, considering the action of the waves, so that no obstruction of the outlets from such cause is considered possible. Arrangements are made whereby workmen can descend the shaft and inspect the chamber, and do any raking or grappling, from a platform at a safe elevation, which might be necessary. Grooves are also provided for stop-boards by means of which either outlet or portions of the chamber can be shut off for examination or repair. In driving the northern outlet channel, a length of a few feet of rock was left in to keep out the sea during the lining of the channels and chamber, and the sea was kept out of the other channel by putting in a dam. When the work was thoroughly set, the channels were opened out. The height of the shaft from the chamber floor to the surface of the ground is one hundred and forty-five feet. The top of the shaft is protected by a stone wall enclosure with an iron door, and an open iron grating roof over the enclosure, not visible from the outside. The rush of air and spray caused by the dashing of the waves into the chamber is deflected by the weir wall of this shaft. The author has seen the outlet at work, and it seems to him to fully meet the requirements of the situation. It is simple, massive and effective. He had also frequent opportunities of examining the work at various stages when in progress, with the engineer, Mr. David M'Mordie, M.I.C.E., under whose supervision it was carried out.

MAIN SOUTHERN SECTION.

The main sewer drains the southern slope of the city, including boroughs of Redfern, Waterloo, Alexandra, and a portion of Paddington, the area being eleven hundred acres. It extends from Nobbs-street, Surry Hills, to the north bank of the Cook's River near its junction with Botany Bay. The sewer is designed to dischcharge four cubic feet per acre per minute, consisting of one cubic feet of sewage per minute, and half an inch of rain per acre per hour. It discharges into a screening-house, situated on the north bank of the river at a level of sixteen feet above high water, from whence it is conveyed by means of a syphon under the bed of the river to a sewage farm situated on the south bank of the river on a block of land known as Webb's grant.

For a distance of eighty-nine chains, commencing in Nobbs-street, the sewer is oviform in section three feet high by two feet wide; for the next thirty-two chains the section is increased to three feet three inches in height by two feet two inches wide, at the end of which a short length of sewer of the Hawkesly section, four feet six inches high by three feet six inches wide, connects it with the outfall sewer, which is two miles and forty chains long, of a circular section, five feet six inches in diameter, on a gradient of four feet to the mile. The first portion of the length of the sewer in Nobbs-street is in firm clay ground, but by far the greater portion consists of water-charged sand and old swamps.

The cuttings were in some places thirty feet deep, and considerable difficulties were encountered in keeping down the water, which was ultimately done by means of a sub-duct. A portion of the country traversed by the five feet six inch sewer consists of sand ridges, rendering necessary extensive excavations; the greater portion, however, consists of low-lying ground, over which the sewer is carried by means of an embankment.

Where the sewer passes over natural watercourses, concrete culverts have been constructed, through which the streams are carried under the sewer, so that the land drainage and the interests of market gardeners are not interfered with. The main sewer is constructed of blue-stone, lined with brickwork, and sandstone concrete for the lower portious; it is rendered on the inside with Portland cement mortar half an inch thick, in the proportion of one part of cement to two of sharp clean sand.

The sewer is provided throughout its length with ventilation manholes, and with gas check valves to prevent the sewer gas rising to the higher levels, also with flushing and penstock chambers. Three million bricks and thirty-five thousand casks of cement were used.

From the main sewer branches have been laid along Nobbs, Arthur, and Phillip-streets, and to these branches the City Council have connected a series of subsidary pipe sewers which are laid on the most approved system in straight lines, with lamp-holes, provided with dirt boxes and moveable gratings, the whole system being so constructed that it can be examined from time to time without disturbing the road. Complete arrangements have also been made for flushing by means of valve chambers and automatic syphons at the head of the pipe sewers; but, at present and until the city water is fully available, fresh water will be used from the adjacent water mains, conveyed to the lamp-holes or dead ends by means of a hose.

OUTLET-HOUSE AND STRAINING CHAMBER.

The inlet-house receives the sewage from the main outfall sewer, where it is made to pass through three sets of circular screens which can be revolved by means of gearing worked by hand. The screens intercept extraneous matter, such as heavy road detritus and sand, which it would not be advisable to admit into the syphon; it is therefore dredged out and conveyed to the sewage farm by means of trucks drawn by a six-ton locomotive over a timber bridge constructed (with a swing opening or lift) immediately over the syphon. The screening apparatus is in duplicate, so that one set is in operation while the material is being dredged from the other. The sewage, after passing through the screening chambers, flows into a chamber or sand-basin, where a further deposition of suspended matter, such as fine sand, takes place. This chamber is separated from the syphon well by means of a curved weir, over which the sewage falls into the well and from thence to the sewage farm. The sewage in the sand basin is raised when necessary by means of a small ejector, so that every drop of sewage is passed to the farm. The syphon is one thousand and ninety-two feet long, with grades of one in sixteen and one in eight hundred; the hydraulic grade is one in one thousand one hundred and two, and consists of cast-iron pipes three feet nine inches in diameter surrounded with concrete. The syphon delivers the sewage into an inlet-house, built on the south side of the river, from which the sewage passes along an open channel or main carrier, which is supported by means of concrete arches over the low-lying ground, and on a continuous concrete foundation on the higher ground. The main carrier is constructed with concrete six feet nine inches deep by four feet wide, with sides sloping one in eight on a gradient of three feet per mile. It is rendered inside with cement mortar of similar proportions to those used in the main sewer. The carrier is provided with stop-boards, grooves and valves on each side for regulating the supply of sewage over the areas prepared for its reception. The outlet well is provided with a twenty-four inch sluice valve for flushing out syphon, the available head being thirteen feet. The foundations of the inlet and outlet houses are constructed with bluestone and sandstone concrete rendered on the inside with cement mortar. The superstructure consists of red and white bricks with stone dressings. The roofs are formed with wrought-iron principals and purlins, wind-bracing bars, &c., covered with heavy corrugated iron. Provision is made in the inlet house for the discharge of storm water over weirs into channels leading directly into the river; and channels are provided for leading the sewage directly into the river should it ever be found necessary.

SEWAGE FARM.

For the purpose of filtering the sewage about three hundred acres of loose sandy ground were resumed, of which about twenty acres are in course of preparation in sections as required. A series of filter beds have been prepared for the disposal of the surplus water during heavy rainfall, the aggregate area of which is about six acres, and they are capable of filtering four hundred thousand gallons of sewage per acre in twenty-four hours. They are used in rotation, in order that the highest filtering power may be obtained. On the ground, sloping towards Cook's River, cultivation areas are laid out in terraces; each terrace is laid out on the ridge and furrow system, and connected to the main carrier by means of small timber distributing carriers with timber boxes and sluices, the whole system being so arranged that the plots can be flooded or watered as required. The terraces and banks of the main carrier are planted with *Mesembryanthemum tigrinum*; the prepared beds are planted with sorghum, barley, lucerne, Italian rye-grass, vegetables of various descriptions, orange and lemon trees. The area under cultivation is about three acres, which is found to be sufficient for the purification of the whole of the sewage at present delivered; but as the system becomes extended a larger area will be required. The cultivation is so far promising that good results may reasonably be expected in the future. The sanitary result is proved by the high degree of purity of the effluent water as shown by the results of an analysis made by Mr. W. M. Hamlet, the Government Analytical Chemist, which demonstrates the efficacy of atmospheric oxidation, sunlight, and filtration through sand.

STORM-WATER SEWERS.

Some extensive works have been carried out for the disposal of storm-waters for the protection of low-lying lands, among which may be mentioned the storm-water channel through Wentworth Park for carrying off the surplus water discharging into Blackwattle Bay. The sewer is constructed of concrete twelve feet wide and five feet six inches high. For a distance of eight chains the invert is constructed of sandstone concrete on a sand foundation, the extra foundation being required on account of the unstable condition of the natural bottom, consisting of soft yielding silt. The invert for this portion is covered with a bluestone concrete arch struck with three centres. The remaining portion, a distance of twenty-four chains, consists of sandstone concrete for invert and side walls, covered with rolled girders and buckled plates; the interior of the channel is rendered with cement mortar. The channel is provided with flushing and silt basins. In order to provide for the discharge of storm-water from a portion of the southern slope and to abolish an old polluted ditch, a storm-water sewer was constructed along Dowling-street from the head of Shea's Creek to join with a length constructed by the Redfern Council. This sewer is entirely constructed of concrete; the length is thirty-seven chains and four feet six high by three feet six inches wide. Where the sewer crosses the main outfall an intercepting point is fixed in such a way that any sewage passing down is carried by the outfall to the sewage farm. Storm water, by its great velocity, is carried over the openings and discharged into Shea's Creek. All the manholes on this section can be used as flushing stations.

BAPTIST ESTATE STORM-WATER SEWERS.

In order that this portion of the system may be relived from storm-water and the dangers arising from the existence of a foul ditch in a populous neighbourhood, a system of storm-water sewers was carried out, consisting of 13.5 chains of a circular section four feet in diameter, and 6.36 chains of oviform section three feet six inches high by two feet nine inches wide, each constructed of concrete and rendered on the inside with cement mortar. Again thirty chains of stoneware pipe twenty-four inches in diameter have been connected with the main sewer by means of branches.

The whole system of sewerage is amply provided with manholes, lampholes, and street gulleys, and it is proposed to add special ventilation shafts and syphon flushing tanks as the system is extended. The author has visited the works described for the southern section at various times during their construction, in company with the engineer, Mr. J. Smail, M. Inst. C.E., and can testify to the substantial character of the work. The northern and southern sections are now provided with outfalls for their sewage, and the various works for connecting the districts which they are intended to drain are in progress. There still remains a large area known as the Western Suburbs, which it is proposed to drain independently of the existing systems. The area referred to includes ten thousand six hundred and thirty-two acres embracing the following municipalities:—Marrickville, St. Peters, Ashfield, Burwood, Strathfield, Concord, Five Dock, Canterbury, and the southern slopes, and portions of the following not included in either the northern or southern systems—namely, Petersham, Newtown, Leichhardt, Macdonaldtown, and Alexandria. The scheme for the drainage of the Western Suburbs has been thoroughly considered by Mr. G. Stayton, M. Inst. C.E., and in a report published in the early part of this year he proposes to construct an outfall sewer commencing at Webb's Grant at a spot about twenty chains east of Muddy Creek, and, after passing through the additional land proposed to be resumed, the route selected would enable the sewer to pass under the two main roads, and the Illawarra railway at Tempe in tunnel, across Wolli Creek, through Unwin's Hill, in tunnel under the high ground on the west of the "Warren," terminating in a penstock chamber at the junction of the intercepting sewers in Premier-street, the length being two miles three hundred and eighty yards. Some parts of this outfall sewer will be raised above the level of the surface in an embankment; whilst in others it will be carried by aqueducts over creeks, swamps, and flats. At the crossing of Cook's River, the level of the bottom of the sewer will be at least fourteen feet above high-water mark. The invert level at the outfall is nine feet above high-water mark, which will command filtration through at least six feet of earth at any portion of the western part of the sewage farm. The distance from the outfall to the penstock chamber in Premier-street is eleven thousand seven hundred feet, and as the intended grade is one in seven hundred, or 3.11 feet per mile, the invert at the intercepting chamber will therefore be 15.88 above high-water mark. Mr. Stayton says that the estimated maximum flow is thirteen thousand nine hundred and ninety-seven cubic feet per minute, which would require a sewer nine feet in diameter. He recommends, however, three sewers each six feet in diameter for various practical reasons, and for the present one of these sewers will be sufficient, but it would be advisable to construct the outfall sewer in duplicate. For the effectual drainage of the western area, it will be necessary to provide for the construction of four intercepting sewers, all of which will commence at the penstock chamber already referred to. In order that the low-lying districts may be included in the system, pumping engines will be erected at Marrickville to raise the sewage up to the level of the intercepting sewer of the districts. There are several other low-lying districts, such as portions of the Glebe, Leichhardt, Balmain, Ashfield, Five Dock, Burwood, Concord, and Strathfield, which will require to be provided for by some method of raising the sewage to the level of the intercepting sewers, such as the hydro-pneumatic system, which has been in operation in Eastbourne and Southampton in England with very satisfactory results. The sewage delivered by the outfall sewers at Webb's Grant will be disposed of on the sewage farm in a similar manner to that of the southern section. Mr. Stayton has thoroughly considered and reported on the drainage of North Shore and Manly, and is at present engaged in devising schemes for Newcastle and other towns. (See Pl. XLII.)

HARBOUR AND DOCK WORKS.

The city of Sydney being provided with a natural harbour there has been no necessity for the construction of wet docks for the accommodation of shipping, and all that has been done consists of wharfs, slips, and graving docks. The most important graving dock is now nearly completed. It is situated at the south-west corner of Cockatoo Island, and it is excavated almost entirely in the sandstone rock. The length of the dock from the inner stop to the head is six hundred feet, but by placing the caisson against the outer stop a total length of six hundred and thirty feet will be available. The width will be one hundred and nine feet between copings, diminishing by a series of altars to an average width of forty-seven feet six inches at the level of the floor. The depth of water over the sill at neap tides will be twenty-eight feet, and at spring tides thirty feet six inches. The width of the entrance will be eighty-four feet, and the opening and the closing of the dock will be effected by a wrought-iron sliding or rolling caisson. The dock will be the largest single graving dock yet constructed, and will be capable of receiving the largest vessel afloat at low water. It will be provided with all the appliances adopted in modern graving docks, including the electric light, so that the dock will be available both night and day.

A pontoon dock has just been completed by the Atlas Engineering Company from plates, &c., imported ready for erection. The dock is in two parts, each part being complete in itself and fitted with machinery and pumping gear, so that they may be used separately, or together, as required, one half being capable of docking, the other half for cleaning and repairs. The lifting power of the dock is in the pontoons, which are twelve in number, each sixty feet long, thirteen feet wide, and nine feet deep. The pontoons are connected at one end to a longitudinal cellular girder or tower, two hundred and forty-two feet long, thirteen feet wide, and nine feet deep; and in this the pumping machinery is placed. Between Sydney and Kiama several jetties have been erected for loading coal, and basins and wharfs have been constructed at Kiama and Wollongong for the accommodation of shipping. A good harbour has been made at Newcastle, and works will shortly be commenced for improving the navigation of the Rivers Clarence and Richmond, according to designs prepared by Sir John Coode, M. Inst. C.E. In conclusion, the author desires to thank Mr. W. C. Bennett, M.I.C.E., Engineer-in-Chief for Sewerage, for supplying him with the necessary information to enable him to compile that portion of the paper which refers to sewerage.

SATURDAY, SEPTEMBER 1.

The President, Professor W. C. Kernot, M.A., C.E., in the Chair.

The following paper was read :—

1.—UNDERGROUND ELECTRICAL WIRES.

By K. L. MURRAY, Esq., C.E., M.S.T.E., President of the Victorian Engineers' Association.

THAT the placing of wires carrying electric currents underground is a question of general interest does not, I think, require to be demonstrated, for how few persons there are who have not wished the network of wires, which stretched from pole to pole, along the streets of all the chief cities and towns of the world, out of sight somewhere; and where can they be put out of sight, but underground.

It is thought by very many people to be an easy matter to so deal with wires; there are many too who imagine that electric wires have been successfully placed under ground in other parts of the world for years past. The object of this paper is to give a few of the reasons why wires still remain overhead, and in so doing to state what has been the history of underground wires, and what is now being done to place wires carrying electric currents underground.

We must go back to the earliest days of electric telegraphy to find the first attempts to place wires underground. Cooke and Wheatstone, the inventors of the first working telegraph in England, and Morse, the father of electric telegraphy in America, both placed their wires underground at first. Messrs. Cooke and Wheatstone's first plan was to have triangular-shaped lengths of wood boiled in tar, with two grooves cut along each of the sides, and one along the apex. In each of these five grooves a wire, which was covered with cotton soaked in resin, was strained, and the whole then covered with thin pieces of wood tacked on so as to protect the wires in the grooves. This was a very clumsy contrivance, fit only for experimental purposes, so that directly the success of the telegraph was assured, the wires similarly insulated were drawn into lead pipes. They worked for a year or so, when the insulation failed and overhead wires on posts were resorted to. That was in the year 1841, and from that time for five years no further attempt was made to try working with underground wires.

Then, however, Messrs. Cooke and Wheatstone once more tried placing some underground. They were covered with two thick layers of cotton wound round them in opposite directions, and were then drawn into a lead pipe which, with its wires was placed in a cauldron containing a mixture of pitch, resin, and beeswax, and boiled for twenty-four hours, by which time it was found that the hot compound had thoroughly filled the pipe. These wires worked for a short time, the compound gradually lost its insulating properties, and then, wires covered with cotton, over which was a thick coating of shellac and other insulating varnishes, were drawn into iron pipes. These and other somewhat similar methods to insulate and protect conducting wires underground, continued to be tried in England with very little success until 1846, when the use of gutta percha as an insulator was experimented with, first by Mr. C. W. Siemens, and afterwards by his brother Dr. Siemens, in Berlin, where that scientist laid an underground telegraph line about four miles long in 1847. This line was so successful at first that similar works were enthusiastically pushed on until over two thousand miles of gutta percha coated wire were placed underground, these lines worked fairly well for two or three years, after which period they began to fail and had to be abandoned in favour of overhead wires.

About the time Messrs. Cooke and Wheatstone were experimenting in England, Professor Jacobi placed telegraph wires underground near St. Petersburgh. These wires were enclosed in glass tubes, the ends of which were cemented together. Very little success was met with in this way, and Jacobi tried to insulate his wires by winding indiarubber tape round them. He failed, however, to secure an efficient telegraph line, and finally the wires in Russia, as elsewhere, were fixed to poles overhead.

The first telegraph line constructed in America by Professor Morse, was an underground one. Copper wires covered with cotton and shellac varnish were placed in lead pipes and laid underground. These wires only worked for a very short time before the insulation broke down, and they were taken out of the pipes and placed on poles. A few years later another attempt was made in America to place wires insulated with gutta percha under ground. As was the case with Dr. Siemens' wires in Prussia, these worked very well for about two years, when the gutta percha perished and the wires had to be abandoned.

Up to a very few years ago all telegraph wires in America and on the Continent of Europe were overhead. In England Telegraph Engineers never gave up trying to devise a successful system of underground wires, all attempts being on the lines of Messrs. Cooke and Wheatstone's plan, which was to form insulated wires into cables, and draw them through pipes laid carefully in the ground.

The difference between the various attempts consisted chiefly in the material used as an insulator and in the kind of pipes employed. Lead pipes were tried at first but soon found to be unsuitable. Earthenware was employed with considerable promise of success but was found open to such serious objections that it was abandoned, and iron pipes have been universally used for many years. Of the different insulators employed gutta percha and india rubber have been the most successful and are now almost universally used to insulate wires, either pure or mixed with some other material. Paraffin and asphalte have also been tried and under certain conditions with success.

In 1875 I find from a paper read in December of that year, before the Society of Telepraph Engineers by Mr. Charles Fleetwood of the London Post Office Telegraph, that there were in London three thousand five hundred miles of wire laid underground in iron pipes. These wires were of copper, No. 18 gauge, covered with gutta percha to No. 7 gauge. Mr. Fleetwood described the method of laying the wires, and as that method is still employed in England, I would refer those interested to Mr. Fleetwood's paper. This may be found in the Proceedings of the Society of Telegraph Engineers for 1875, together with the discussion upon it by many prominent members.

I find that much stress is laid upon the advisability of using iron and not earthenware pipes, upon the fact that the pipes should not be more than four inches in diameter, and upon the very great difficulty of making good joints anywhere, especially in the streets wherein curious people passing interfere with the jointer, and where the wet and dirt almost prevent good joint making.

So long as telegraph wires only had to be dealt with, the English Post Office authorities were able to keep the nuisance of overhead wires within bounds, but the introduction of telephones promised to so rapidly increase the number of wires required in the streets, that municipal authorities began to agitate for a more rapid extension of the underground system, and in 1885 a Committee of the House of Commons was appointed to consider the question of underground telegraph and telephone wires. The Committee took a great deal of evidence and reported in favour of the continuance of the system of overhead wires subject to proper supervision. During the discussion by the Committee it was proposed that where more than ten wires run along a line, the local authorities should have power to compel them to be taken underground. This proposal was negatived. Evidence was given before this Committee by most or the leading engineers and experts interested in the question, and their opinions clearly proved that the difficulty and cost of placing wires underground was such that there is little room for wonder that the Committee could not recommend the passing of an Act of Parliament to compel the placing of wires underground. It was doubtless felt that such an Act would practically prevent the extention of telegraphs and telephones.

There is little further to be said about the condition of things in England. The mileage of telegraph wires placed underground has continued to increase, but so far as I can learn nearly all the telephone and electric light wires are overhead. The underground wires are still in three-inch iron pipes, it having been satisfactorily established that that size, with iron as a material, is much the best. Engineers are not satisfied as to which is the best insulator and various substances have been tried, among them asphalte has found considerable favour and I find a method of placing wires in asphalte thus described by Mr. Alexander J. S. Adams. Open up a trench of sufficient depth and width, and in it lay a concrete foundation and sides, two inches thick; dress this concrete trough with hot pitch. The trough should be carefully made. In it place a diaphragm of wood, perforated with equi-distant holes; pass the copper wires through the holes and fasten them upon one side. This board should be rigid. A second board, through the holes of which the wires have been threaded, is carried along the trough to a convenient distance and the wires strained up by it. Hot liquid asphalte, of a specially prepared kind, should then be poured into the trough until level above the wires. A coating of hot pitch is applied, and when cold the top dressing of concrete is raised conically to resist downward pressure. The whole is then filled in and carefully rammed with wooden punners. Wires laid in this way lasted for three years, when they were taken up for some reason or other.

I find mention made by several other Telegraph Engineers of trials with asphalte, but none very extensive, though all promised well.

I tried myself in a small way to similarly deal with a few wires. It was as a temporary expedient, and was quite successful; the wires worked excellently buried in the asphalte. I think it is of importance that only the best asphalte should be used.

Paraffin wax has also been tried in England but it has not been successful, owing chiefly to the fact that commercial paraffin and copper do not agree together, an action being set up which destroyes the insulation.

Many compounds have been tried at different times most of them being mixtures of earthy substances with gutta percha or indiarubber. Lately wires have been insulated by having first a coat of indiarubber or gutta percha, and being then covered with twisted or plaited cotton saturated with paraffin.

In France, Telegraph Engineers have tried to lay wires underground with more or less success. First, wires covered with gutta percha and with india rubber were buried without any metallic protection outside the insulation. These did not last long. Then similarly treated wires were drawn into a lead pipe, and laid down. These did not last very long either, for gas got in through the joints of the lead pipe and destroyed the gutta percha. Then attempts were made to place wires in asphalte. Ten miles of such a line was laid down in Paris at a cost of £40 per mile per wire, and the wires worked well for two or three years, but loss of insulation finally was experienced; the insulating compound cracked and lost its qualities, particularly where exposed to the action of gas from the street mains which softens it. Many experiments were made before the plan which has been used for some years past was adopted.

In Paris, I need hardly say, there is a very complete system of sewers, and the advantage of placing in them the telegraph wires in addition to water and other pipes was naturally utilised. The wires so placed are made up into cables. The conductors are copper wires which are covered first with a coating of Chatterton's compound and then with two layers of gutta percha; tarred hemp is wound round, and then seven of the wires are twisted into a cable round which stout tarred hemp strand is wound, and finally this is covered with strong tarred tape. Both the hemp and the tape are steeped in sulphate of copper solution before being tarred, and only the best Stockholm tar is used. Over all a coating of lead is pressed and the cable is then hung in the sewer.

Cables made in the same way but placed in iron pipes instead of being lead coated are laid (to some extent) underground. Great care is taken both in the lead covered cable, and in that placed in iron pipes to see that the lengths are properly jointed together. The lead joints are made as follows:—The copper wires are joined and insulated in the usual way, and are then tightly wound round with a broad band of stout vulcanized indiarubber, which is tied round with yarn, tarred canvas is laid on over this, and tied also, then a piece of lead piping about two feet long (which is slipped on to the cable before the joint is commenced) is brought over the joint and its ends pinched tightly round the sound cable. The whole joint together with a few inches on each side of it, is wrapped with tarred canvas closely bound on with galvanized iron wire. The cost of this cable is from £25 to £30 per wire per mile, and it is said to work well. I cannot find what the life of this cable has been in France with any degree of certainty. I have found frequent mention of failures, but whether they have been such as to destroy the cable's usefulness altogether, I have not been able to ascertain. One statement I met with in a French journal was to the effect that a lead covered cable placed in an iron pipe had worked for twenty years. If so it has by far the best record of any I have heard of.

In America more than in any other country, the attention of those interested in electrical conductors has been directed towards finding a successful method of placing them underground. Wires have multiplied more rapidly in America than elsewhere. So many applications of electricity are used in the different cities, and the telephone wires are more numerous in the United States than in all the rest of the world. The network of wires in the streets became a serious matter, and several municipalities passed rules requiring Electrical Companies to place their wires underground. This of course stimulated invention, and hundreds of different systems have been devised, and many of the most promising of them tried and abandoned.

In 1885 the Franklin Institute in America issued reports on underground conduits, and in them (published in the Proceedings of the Institute for the Year) may be seen a large number of systems fully described and reported on; not one of them being recommended as having been proved successful, or free from serious objections. I would recommend all persons interested to read these reports. It would seem as if every possible plan to place wires underground has been tried in America. The ingenuity shown is remarkable, and the description of the different systems is extremely interesting and instructive; as well as the methods used by the Committee of the Institute to test the various sections submitted to them.

The proverbial inventive genius of our American friends is plainly shown, but in spite of that inventive genius, and the persistence with which the underground wire question has been experimented with, it is still only in the experimental stage.

In the early months of the present year a number of papers upon the undergrounding of wires (as it is termed in America) were read before the National Electric Light Association at Pittsburgh. From these I find that the question is looked upon as being in an unsatisfactory and unsettled state.

Professor Thomson, in his address said, that it was generally agreed, that except for expense and the difficulty of insulation and making satisfactory connections from mains to houses, underground wires were preferable. If a difference of potential of only one hundred to two hundred volts existed, it was not difficult to insulate, but where the difference amounted to two or three thousand volts very great difficulty existed; and the problem was not only to secure an insulating covering which would adapt wires to the use of high potentials without leakage, but to find an insulation which was of indefinite durability where exposed to weather, great toughness and power to resist abrasion, and at not too high a cost.

Mr. Leggett said that with underground wires, both telegraph and telephone, the difficulty was much the same. Moisture must be excluded. Insulation must be good and induction reduced to a minimum. Then as regarded electric light wires, the Board of Commissioners of Electric Subways instituted a thorough investigation, and reported in 1887. The Board said:—With regard to electric light conductors, this Board has found no device which would with certainty, in its opinion, enable the wires carrying arc light currents to be safely and successfully operated in the same conduit with telephone and telegraph wires without disturbance or injury to the latter. And the Board desires to say emphatically that those fluent critics who talk of putting electric light conductors underground, making no distinction between arc and incandescent lights, are ignorant of the alphabet of the subject. The President of the Board visited all the principal cities of Great Britain and Europe, found no arc light wires underground, and although a few years since such wires were trained in the Paris sewers they have been removed.

At Washington an officer of the Electric Light Company wrote in September, 1887 :—"We have many committees coming here to see what we have accomplished, as they have heard that we have met with great success. We will say this to you—our experience after great outlay—have nothing to do with underground cables for lighting if you can possibly avoid it. Many will tell you that it is perfectly practicable. Look out for such parties, they are probably interested in cables. There is no city or town in the world where a cable has been made to work for two years that has been subjected to two thousand volts of pressure."

At Philadelphia elaborate experiments have been carried out. All kinds of cables have been employed and a great variety of conduits. Much trouble has been experienced. In most cases the insulating compound rapidly deteriorated and became useless—in others it would rot and become water soaked. It was found that gas could not be kept from the ducts although these were apparently gas tight. Many explosions followed. Recourse was had to ventilation by lamp posts, but the trouble was not corrected. After several explosions in one system, a power fan was adjusted to force air through the conduit deeming it better to do so than to draw the air through, since this might simultaneously draw in gas. When shortly afterwards the lighting company was congratulating itself that it had overcome the difficulty, a tremendous explosion occurred. The entire system of lights had to be abandoned. This was six months ago. It was then determined by the manager that as the result of experience no conduit would suffice for arc light wires in which were open ducts, and that success lay in the employment of lead covered cables buried solid. This plan was tried and success seemed assured, but they now report the experiment unsuccessful. The section buried was not great but bad faults have recently developed. The various companies of Philadelphia are at a loss what to try next.

A letter from an officer of the Consolidated Company in Chicago thus explains the situation there. He says—"We have had an enormous lot of trouble with our underground light circuits, averaging, I would say, for the last three months one burn out every day. The expense of re-construction and the losses in rebates have been enormous and the annoyance to our customers more damaging still."

The constant tearing up the pavements for all kinds of purposes, makes our street department very unwilling to grant permits for laying additional conduits, and several times they have been refused altogether. No streets have ever been lighted by electricity here, in fact the whole industry is in a very backward condition, and is likely to remain so, except in the most densely crowded portions of the city, unless some arrangement can be made with the city authorities for overhead wires. So much for the experience in Chicago.

The difficulty from gas explosions has been met with many times, and seems insurmountable where gas is used. At New York men have been suffocated in the man-holes, and in the Western Union Building the escape of gas from the wire conduits has been almost unbearable. At Detroit an explosion took place last October in the middle of the night in a fire alarm conduit with close man-holes. The man-hole cover was thrown high into the air, the street torn up, and the paving blocks scattered over a distance of eighty feet or more.

In 1886 an Underground Wire Commission was appointed in New York, and as the result of its deliberations reported that a large conduit be constructed under the streets, and in it all wires and pipes be placed. This report has been adopted by the Municipal authorities, and attempts have been made to oblige all Electrical Companies to agree to place their wires in such a conduit. The Companies, however, do not readily comply—the Telegraph and Telephone Companies especially. Indeed the strongest opposition is shown to the plan, which, so far, has not been carried out.

I have dwelt so long upon the experience of America because necessity (the mother of invention) has caused more attention to be given to the subject of underground wires there than elsewhere. I find Professor Plumpton, who was a member of the Brooklyn Underground Committee, speaking in October 1886 contemptuously of what had been done in the matter in Europe, which he had just visited. It must be remembered, however, that in Europe the question has not been of such urgency as it has in America, owing to the extremely rapid increase in the number of telephones used in the latter country, and the great number of electric light and other wires day by day coming into use in all the chief cities of the United States. In London, it should be remembered also, that the overhead wires are on the roofs of the buildings chiefly, whereas in America they are on poles in the streets.

It must be admitted, I think, that if a satisfactory system has not been discovered in America, the difficulties surrounding it must be very great indeed.

In Victoria there has not been very much done towards placing the telegraph, telephone, and electric light wires underground. The Post Office has about two miles each of one hundred wire, and of fifty wire telephone cable laid under the streets in Melbourne. They are of two kinds; one known as the Patterson cable, which is formed of cotton covered wires loosely twisted together and pulled through lead pipe into which paraffin and carbonic acid gas are forced under pressure. This is not very favourably spoken of by the Post Office officers, as moisture has a tendency to get in at the ends, and so reduce the insulation. The wires in the other kind of cable are covered with gutta percha and then with lead, which is tightly pressed on so as to exclude all moisture.

Both kinds of cable have been laid for about four years and are working fairly well. They are used only for one purpose, telephone working, and are never tapped or interfered with in any way.

At Sandhurst too, the Post Office has had about three miles of telephone cable buried under the streets and working fairly well for the last three years under conditions similar to those existing in Melbourne.

In 1886 the Government of Victoria appointed a Board to enquire into and report upon the merits of any systems for placing wires underground which might be brought before it. Of the systems mentioned to the Board two were reported on upon their merits, the other systems submitted being very imperfectly worked out. The two were:—1st. that of Mr. T. R. James, Manager of the Melbourne Telegraph Office; and 2nd. that of Mr. E. Seitz, a consulting engineer in private practice in Melbourne.

Mr. James' system very much resembles several others which were enquired into by the Committee of the Franklin Institute in America in 1885; and unfortunately resembles those systems in points which have been condemned. It is not surprising therefore, that the Board could not recommend the Government to try Mr. James' plan in Melbourne.

Mr. Seitz's system was one possessing many claims to attention. He proposed to form under the flagging of the street footpaths and next the curb-stones, a channel lined with cement asphalt or other suitable material, and on properly made supports place well insulated, lead covered cables. At each street corner Mr. Seitz proposed to fix an iron mast, the base of which should be used as a test box and a Post Office letter box. All cables were to be brought into these test boxes and from the top of the poles service wires of thin hard drawn copper were to be carried wherever required. Arrangements were also made for leading the service wires into buildings direct wherever practicable. Across the streets Mr. Seitz proposed to carry his cables underground protected by thick corrugated iron. Arrangements were made for carrying off any water which might find its way into the channels.

The Board reported favourably of Mr. Seitz's plan which appeared to possess many points of merit.

I may add that Mr. Seitz explained to me only a few days ago some alterations and additions made by him since the date of the Board's enquiry and which seemed to me to much increase the value of the system. As he is applying for a patent for his system I am not at liberty to mention the details.

I think I have said enough to show that a great many schemes of various kinds have been devised to try and satisfactorily arrange for working wires carrying electric currents under ground; and when it is seen that not one has yet been proved to have overcome the difficulties, it must be confessed that these difficulties are very serious indeed. It has been proved easy enough to work telegraph wires underground, and telephone wires also, from any one place to any other; but after once laying down wires, the adding to them and tapping them has been found to be the trouble. Then the electric light wires present quite a different problem to overcome; the current they require to carry being so much larger and so much stronger than that used on telegraph and telephone wires. The lead covered cables which seem to be satisfactory for telegraph and telephone purposes will not do for electric lighting. The conductors of the lead coating separated by the insulating material are like the inner and outer coatings of a Leyden jar, and sooner or later (particularly where alternating currents are used) sparks pass from one to the other and destroy the cable. What then are the essentials? First—wires must be insulated so that the current they carry cannot escape to the earth or to each other. Then the material used as an insulator must not be of high inductive capacity, and must be tough and lasting in quality. Next the wires and insulation must be mechanically protected from injury. Then the whole arrangement must be simple in construction and easy to repair if it get out of order. There must be as few joints as possible in wire, insulation, or protecting covering, and the wires must be capable of being added to, or tapped for distribution purposes. To comply with these requirements it has been, I think, conclusively proved that if the wires are laid where they are kept from light, and not subject to changes of temperature, gutta percha is as good an insulator as any known substance. If, however, they are to be laid loosely in a conduit, gutta percha will not last any considerable length of time.

It has been proved too, that the difficulties from induction between wire and wire used for telegraph and telephone signalling can be overcome by twisting the wires round each other into cables. The induction difficulty with respect to electric light wires has not been satisfactorily overcome. It has also been proved that iron is the best material to protect the cables from injury under ground, and that earthenware pipes are very unsatisfactory.

It has also been proved that joint making in streets is so difficult that whichever system is adopted there must be no joint making if it can be avoided, and from this I think it follows that any system which requires a wire to be cut and jointed every time a fresh subscriber is added to a telephone exchange must be practically unworkable.

Now, what are the alleged reasons for wanting to place wires underground? Chiefly that wires on poles are unsightly and likely to interfere with the use of fire escapes. I cannot find any well authenticated case of interference with fire escapes, so that such interference cannot, I think, have occurred often. As to unsightliness, that is undoubted, but I think it could easily be lessened by suspending the wires more regularly, and by making the posts more ornamental than the great hideous wooden structures used among us all.

And would there be no inconveniences connected with an underground system? I think we should find plenty connected not only with the electrical difficulties but also with those connected with the continued tearing up of the streets and consequent interference with the traffic. Indeed, I believe the nuisance would be found to be much greater than any caused by overhead wires.

Taking all things into consideration, I do not think it is a matter for surprise that Telegraph Engineers have always preferred overhead to underground wires. They have felt that faults in the former could be set right much more speedily and easily, that the life of such wires is much longer, that the speed of signalling is greater, and that finally overhead is enormously less costly both to construct and maintain.

I think that perhaps large street-sewers like the Paris sewers would be best where practicable aud I have been inclined to view with much favour a plan like that of Mr. Seitz, by which the wires would be always underground excepting where being distributed into buildings. The poles at street corners could be made use of for various purposes, such as Post Office pillars and lamp posts, as well as wire distributing posts. They could be made ornamental too, and from them the wires could be taken along the buildings, as is done in Edinburgh, or across the streets; in any case these wires would be fine wires of copper which would hardly be seen.

Finally, there can be no doubt as to the fact that wires can be placed underground. It is simply a question of expense, but if the expense of a system be out of proportion to the benefits received from it, then it is prohibitive.

Speaking as a Telegraph Engineer who has had to do with the construction and maintenance of all kinds of electrical applications for thirty years, my experience tells me to place my wires overhead where I can see them; but if I cannot do so, then I must find a way, or make one, to place them underground.

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TO THE

TRANSACTIONS OF THE SECTIONS.

LIST OF THE MEMBERS

OF THE

AUSTRALASIAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

1888-89.

(*Notice of change of address should be sent to the Permanent Hon. Secretary, Royal Society's Home, 5 Elizabeth Street, Sydney.*)

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Touch, J. Edward, c/o Booth, Macdonald & Co., Carlyle Ironworks, Sydenham, Christchurch. N.Z.
Treatt, F. B., The Bank of New South Wales, St. Leonards, Sydney.
Treatt, Mrs. F. B., The Bank of New South Wales, St. Leonards, Sydney.
Tregarthen, Greville, Government Statistician's Office, 74 Bridge-street, Sydney,
Tritton, J. L., Acting District Surveyor, Goulburn, N.S.W.
Trotter, W., 104 Pitt-street, Sydney.
Tryon, H., Queensland Museum, Brisbane.
Turri, G. Garibaldi, 104 Elizabeth-street, Melbourne.
Twynam, Edward, Acting Surveyor General, Survey Department, Sydney.
Twynam, George E., M.R.C.S., *Eng.*, L.R.C.P., 38 Bayswater Road Darlinghurst. Sydney.
Tyas, John Walter, Registrar, University of Adelaide.

Uhr, Charles I. K., 105 Elizabeth-street, Sydney.
Ulrich, George, H. F., F.G.S., Professor of Mining and Mineralogy, University of Otago, New Zealand.
Ungher, Jupiter, M.A., *Paris*, 279 George-street, Sydney.
Urquhart, Arthur Torrane, Drury, Auckland, N.Z.

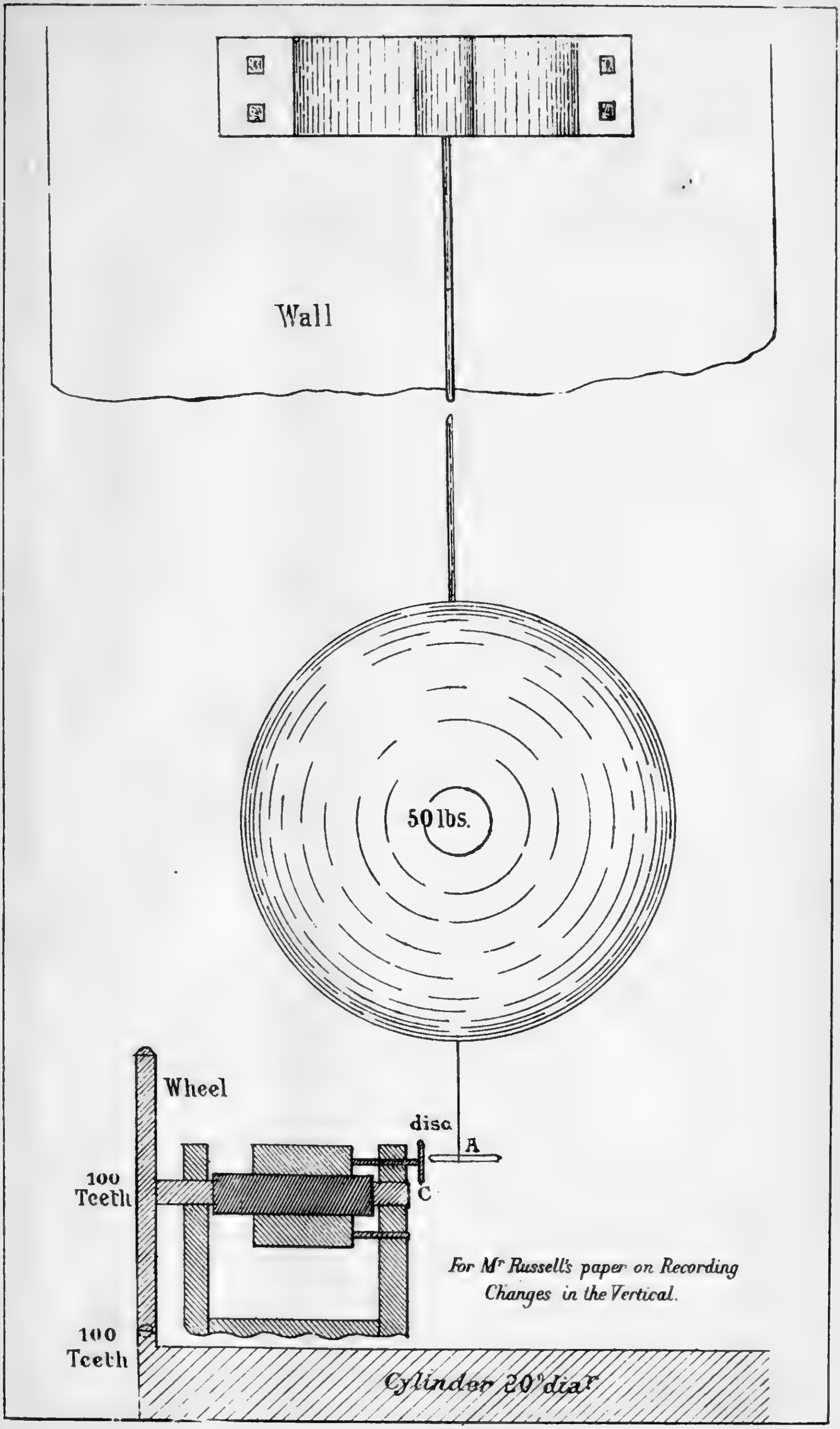
Vautin, Ernest S., Survey Department, Sydney.
Vaux, William Edward, 12 Collins-street, W., Melbourne, and Box 337, G.P.O,, Melbourne.
Vicars, James, B.E., "Ochil Bank," Palace-street, Ashfield, Sydney.
Vickery, Hon. E., M.L.C., "Edina," Waverley, Sydney.

Walch, James H. B., Holbrook Place, Hobart, Tasmania.
Waldron, Henry Ryder, 56 Upper Fort-street, Sydney.
Walker, F. W., 58 Castlereagh-street, Sydney.
Walker, J. T., Waltham Buildings, Bond-street, Sydney.
Walker-Smith, John, L.R.C.P., *Edin.*, 82 Glebe Road, Sydney.
Wallace, Frank E., "Bloomfield," Wardell Road, Marrickville, Sydney.
Walsh, Fred., Elizabeth-street, Sydney.
Walsh, Rev. W. M., P.P., St. Joseph's, Townsville, Queensland.
Walton, T. U., B.Sc., F.I.C., F.C.S., Colonial Sugar Co., Sydney.
Ward, R. D., "Romaka," Blue-street, St. Leonards, Sydney.
Ward, W. F., Government, Analyst, Hobart, Tasmania.
Wark, William, Kurrajong Heights, N.S.W.
Warley, Woolcott, "Malva," Grosvenor-street, Croydon, Sydney.
Warren, Mrs. A., Rosendale, Stanmore Road, Sydney.
Warren, W. H., M.I.C.E., Professor of Engineering, University of Sydney.
Waterhouse, John, M. A., *Syd.*, Public High School, West Maitland, N.S.W.
Watson, Archibald, 8 Woodside Crescent, Glasgow, Scotland, also Oxford Hotel, Sydney, N.S.W.
Watson, Hon. James, M.L.C., "Glanworth," Darling Point, Sydney.
Way, Hon. S. J., Chief Justice, Adelaide, South Australia.
Webster, Jonh, Hokianga, New Zealand.
Weir, John, 57 Little Flinders-street East, Melbourne.
Wells, Frederick, Assistant Engineer for Roads. Phillip-street, Sydney.
West-Erskine, Hon. W. A. E., M.A., *Oxon.*, Adelaide Club, Adelaide.
Westgarth, George C., "Tresco." Elizabeth Bay Point, Sydney.
Weston, J. J., 29 O'Connell-street, Sydney.
White, E. J., The Observatory, S. Yarra, Melbourne.
White, Rev. James S., M.A., LL.D., Gowrie, Singleton.
Whtelegge, Thomas, Australian Museum, Sydney.
Whitfield, Louis, "Sevington," Stanmore, Sydney.
Wiesener, T. F., 334 George-street, Sydney.
Wild, John Jas., Ph.D., F.R.G.S., 12 Drummond-street, Carlton, Melbourne.
Wiley, D. T., "Wilton," Park Road, Burwood, Sydney.
Wilkinson, C. S., F.G S., F.L.S., Government Geologist, Geological Branch, Department of Mines, Sydney.
Wilkinson, R. B., M.L.A., Union Club, Sydney.
Wilkinson, Rev. S. Regent House, Regent-street, Petersham, Sydney.
Wilkinson, W. Camac, M.D., M.R.C.P., *Lond.*, M.L.A., "Hereford House," Glebe Point Road, Sydney.
Williams, Henry Maunder, F.R., Stat. Soc. c/o Mason Brothers, Limited, 263 Kent-street, Sydney.
Williams, Mrs. Elizabeth Mary, "Cotswold," Cunningham-street, S. Yarra, Melbourne.
Williams, Percy E., The Treasury, Sydney.
Willis, W. C., The Priory, Burwood, N.S.W.
Wills, S. E., 163 Collins-street E., Melbourne.

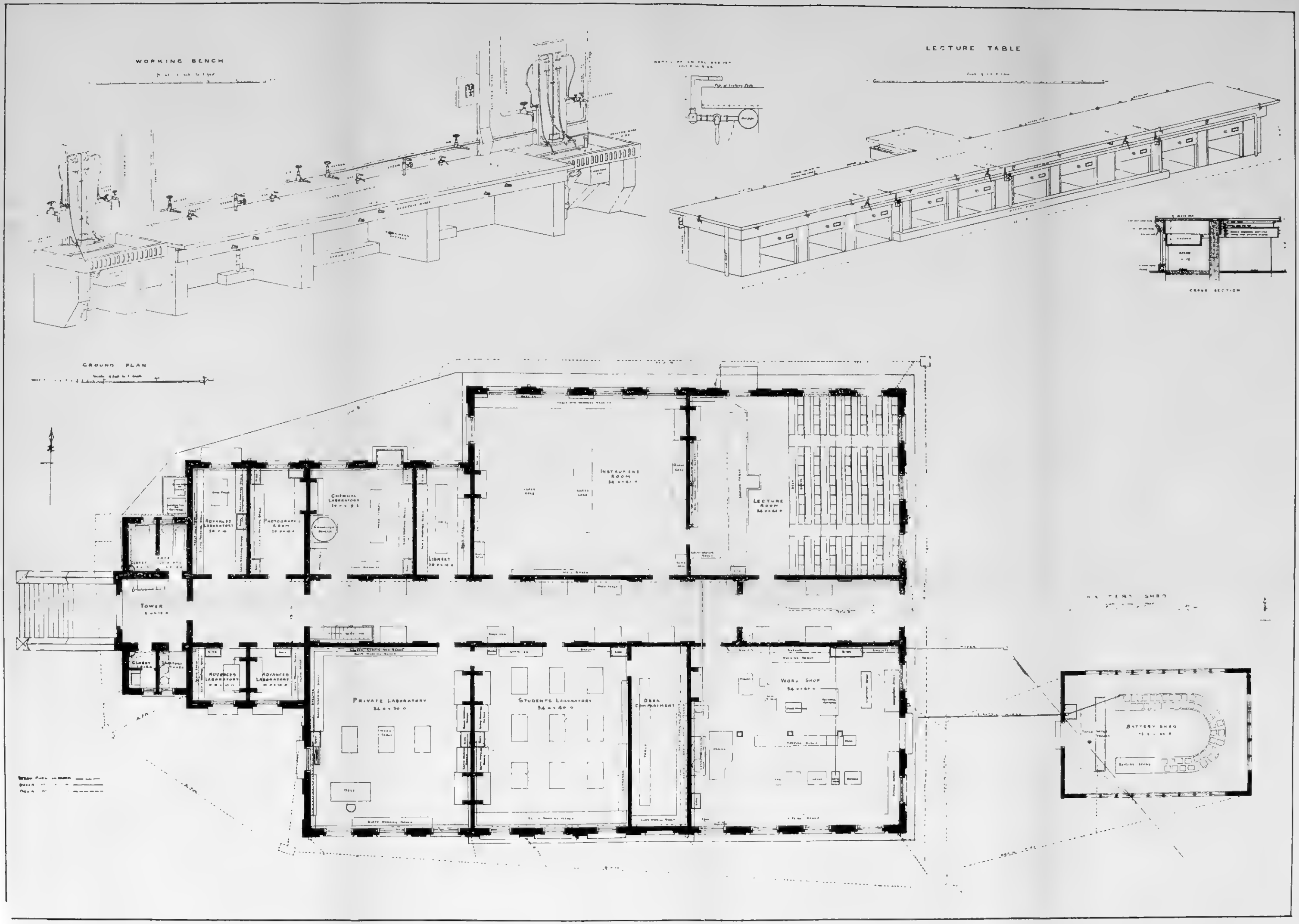
Willsallen, T. P., "Gunnibil," Gunnedah.
Wilshire, F. R., Police Magistrate, Berrima, N.S.W.
Wilshire, J. T., J.P., "Havilah," Emu-street, Burwood.
Wilson, Frederick Alfred Adolphus, "Wimmera," St. Leonards, Sydney
Wilson, James T., M.B., C.M , University of Sydney.
Wilson, J. Bracebridge, M.A., F.L.S., C. of E. Grammar School, Geelong, Victoria.
Wilton, Wyn J. E., Elizabeth-street, Hobart, Tasmania.
Winckler, A. R., 131 Pitt-street, Sydney.
Windeyer, His Honor William C., M.A., LL.D., Judge of Supreme Court, Sydney.
Wise, B. R., M.L.A., "Carisbrook," 22 Macleay-street, Sydney.
Woods, Rev. Julian E. Tenison, F.G.S., F.L.S., 533 Elizabeth-st., Sydney.
Woodthorpe, Rev. Robt. A., B.A., Christ Church, St. Leonards, Sydney.
Woolcock, John L., M.A., Town Hall Chambers, Brisbane, Queensland.
Woolrych, F. B. W., 54 Watkin-street, Newtown, Sydney.
Worrall, Ralph, M.D., C.M., 20 College-street, Hyde Park, Sydney.
Worshop, Thomas, J.P., Town Clerk, Adelaide.
Wright, Arthur, Union Club, Sydney.
Wright, Frederick, 25 Exchange Buildings, Pirie-street, Adelaide .
Wright, H. G. A., M.R.C.S., *Eng.*, L.S.A., *Lond.*, Wynyard Square, Sydney.
Wright, John, 67 Wentworth-street, Forest Lodge, Sydney.
Wright, Robert, Carlton Terrace, Wynyard Square, Sydney.
Wylie, Alexander C., 41 Norwich Chambers, Hunter-street, Sydney.
Wynne, Richard, Yarrawa, Mount Wilson.

Yeates, John, 14 Rupert-street, Collingwood, Melbourne.
Yule, William, 47 William-street, Melbourne.

F. Cunninghame & Co., Steam Machine Printers, 146 Pitt Street, Sydney.

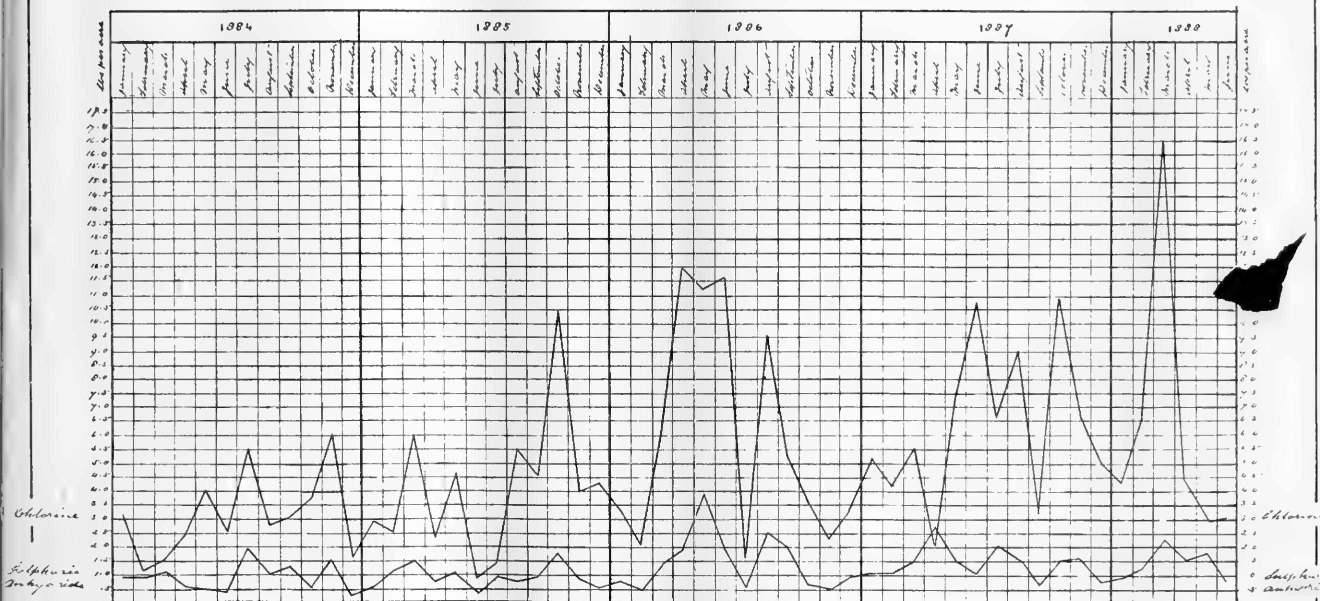


For Mr Russell's paper on Recording Changes in the Vertical.

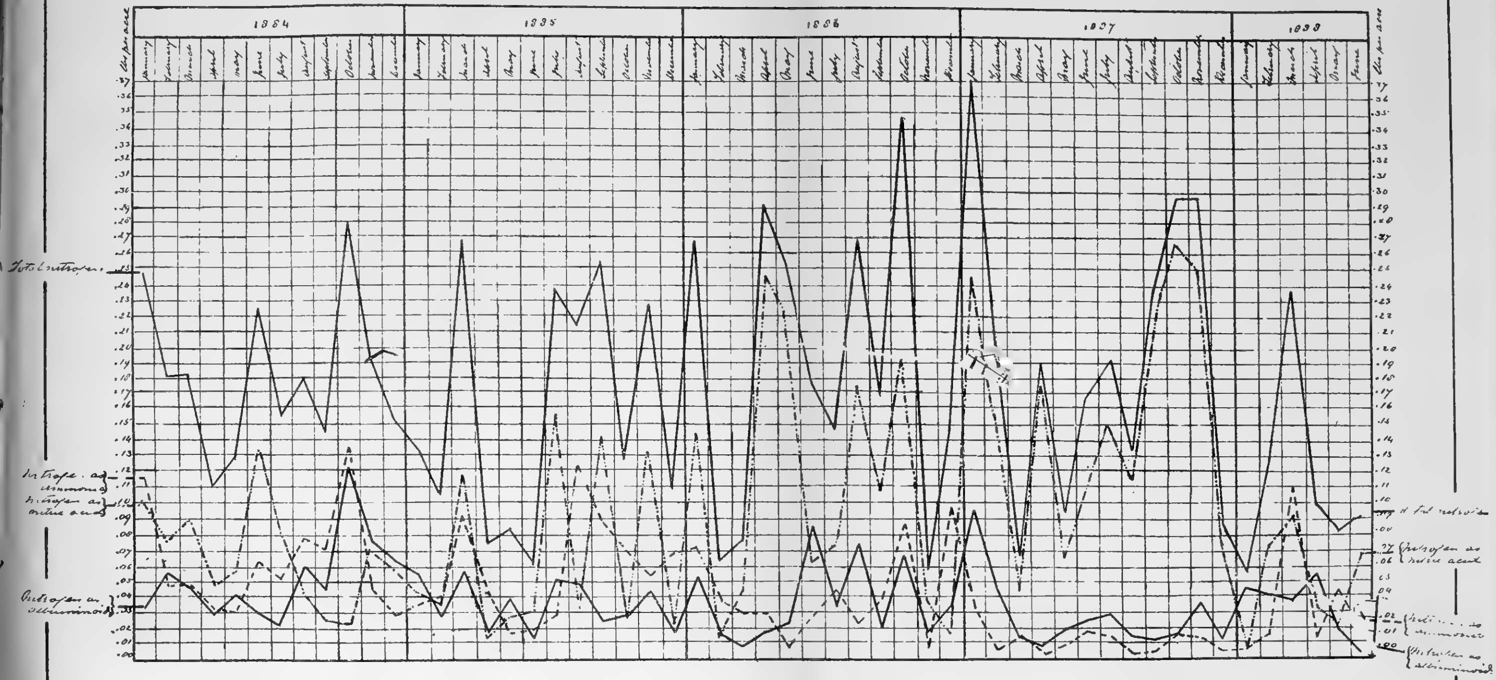


New Physical Laboratory, Sydney University.

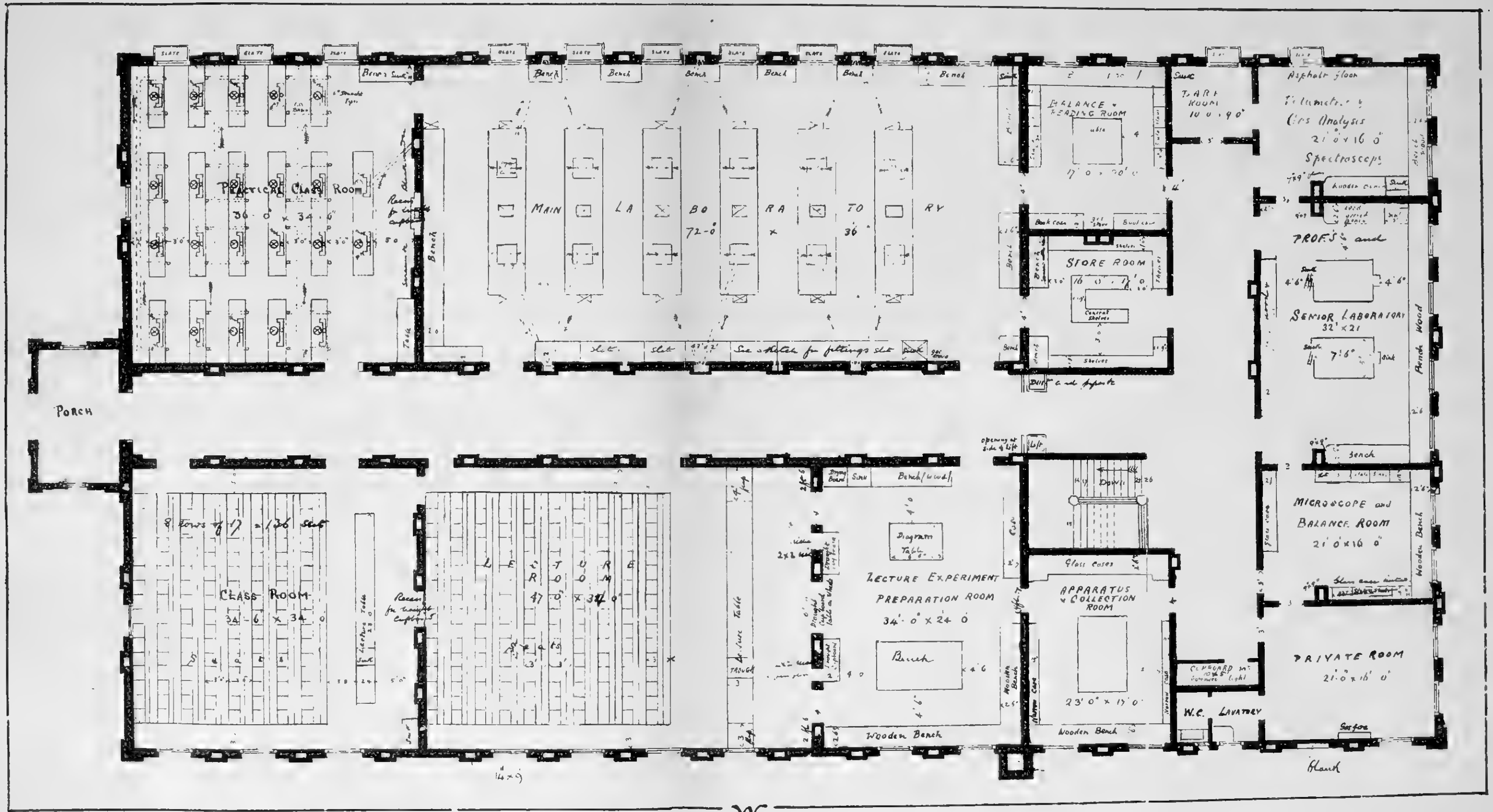
Chlorine & Sulphuric Anhydride received Monthly in Rain by an Acre of Land at Lincoln N.Z.



Nitrogen received Monthly in Rain by an Acre of Land at Lincoln N.Z.



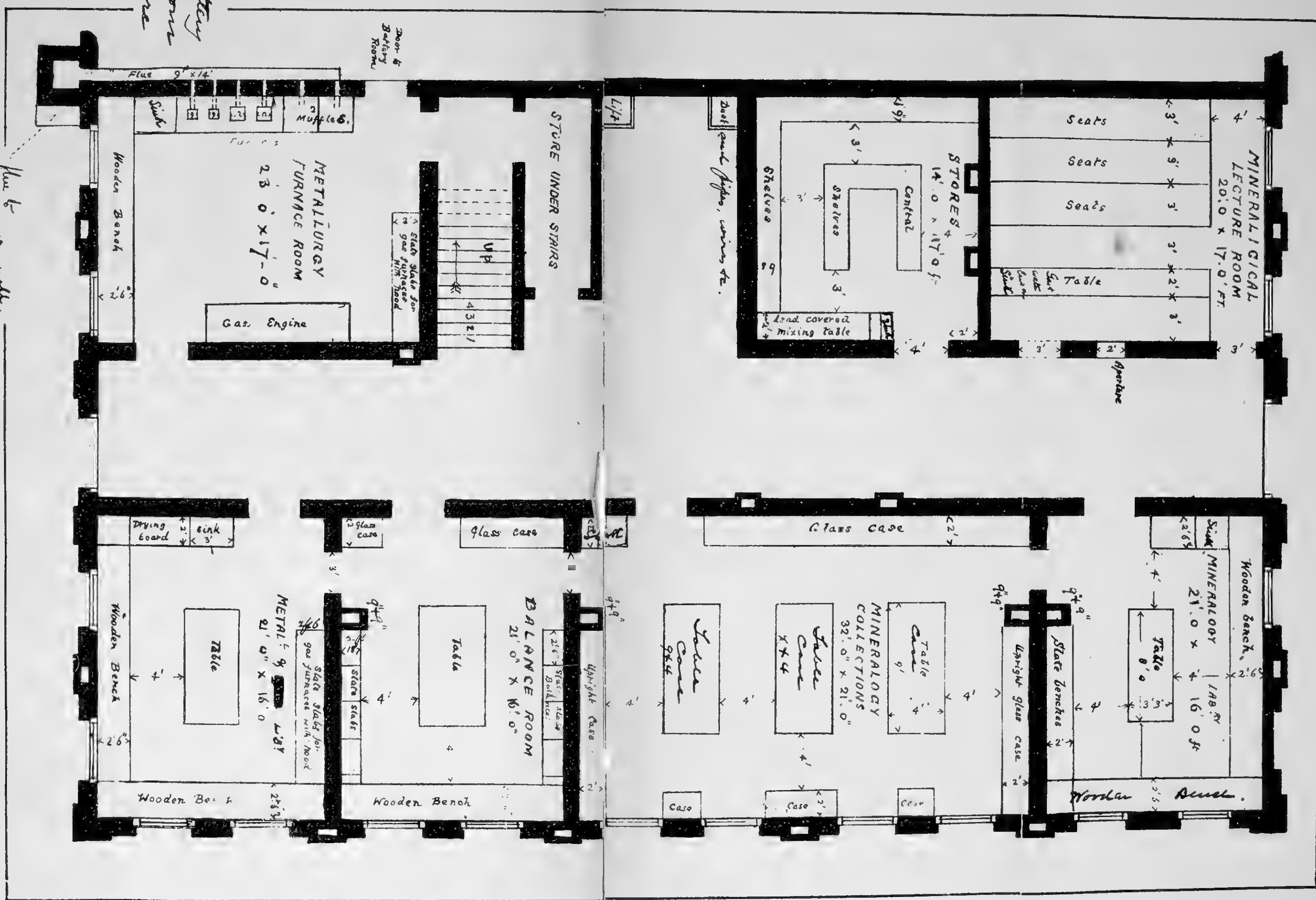
Chemical Laboratory, University of Sydney.



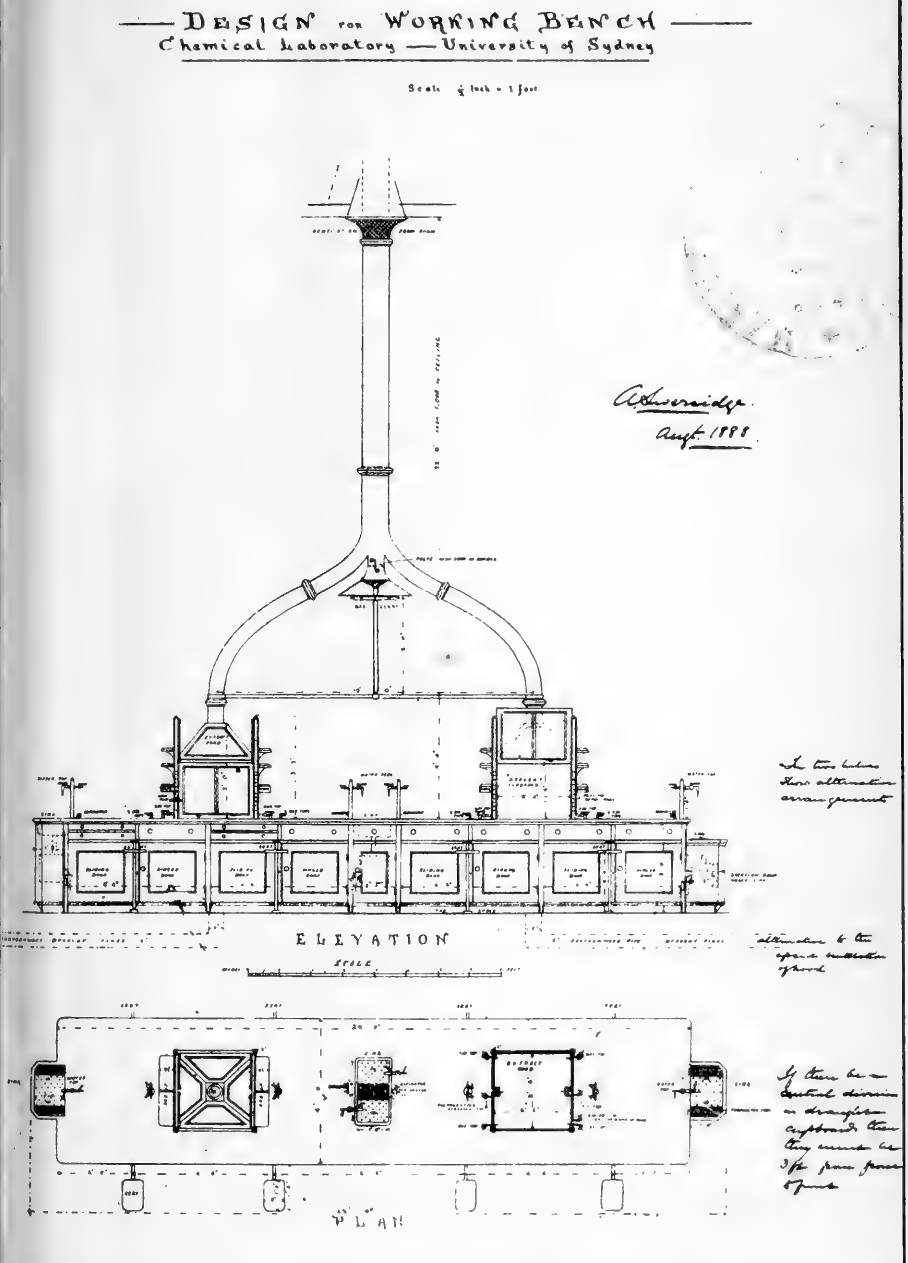
Ground Plan

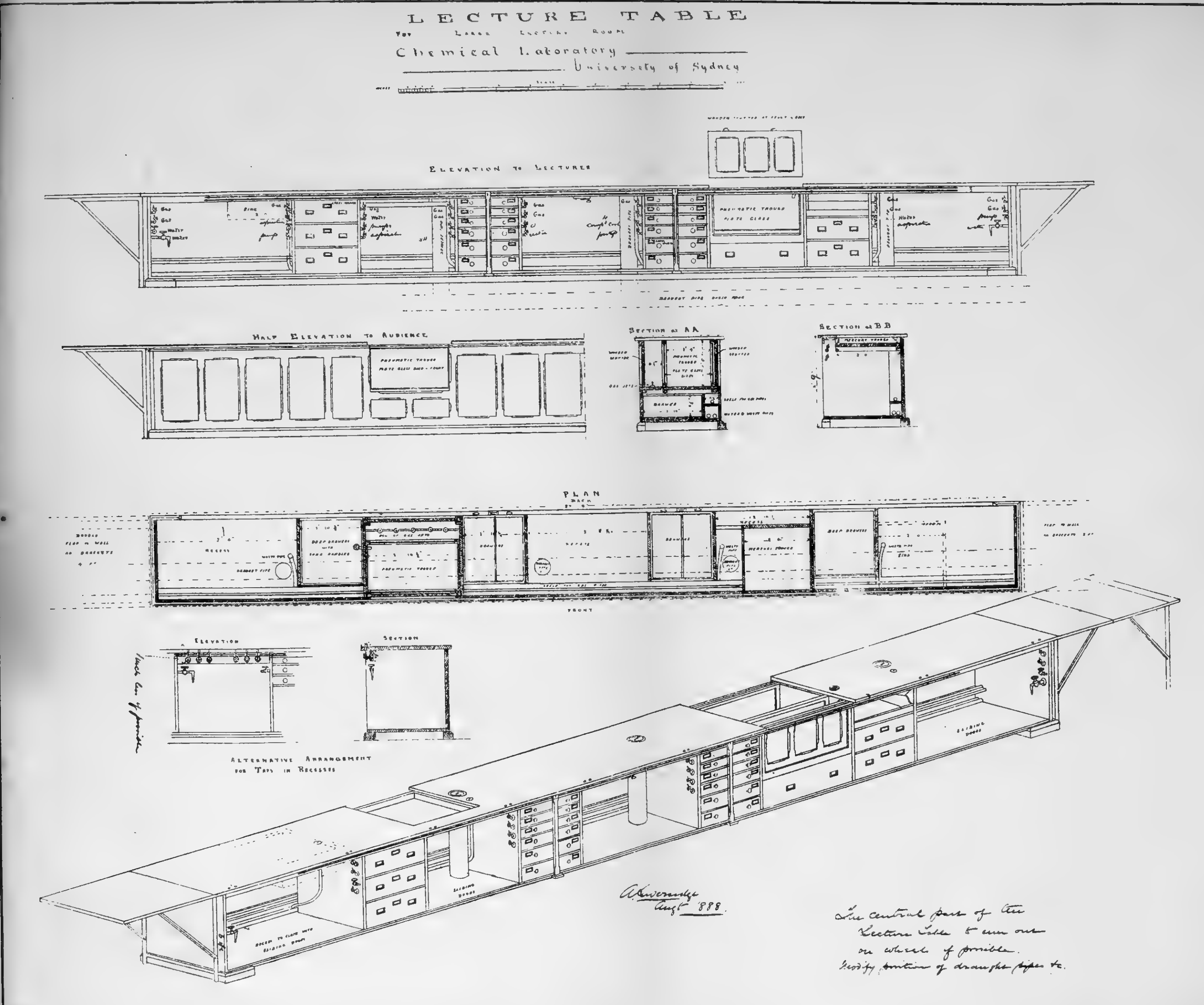
1/8 scale.

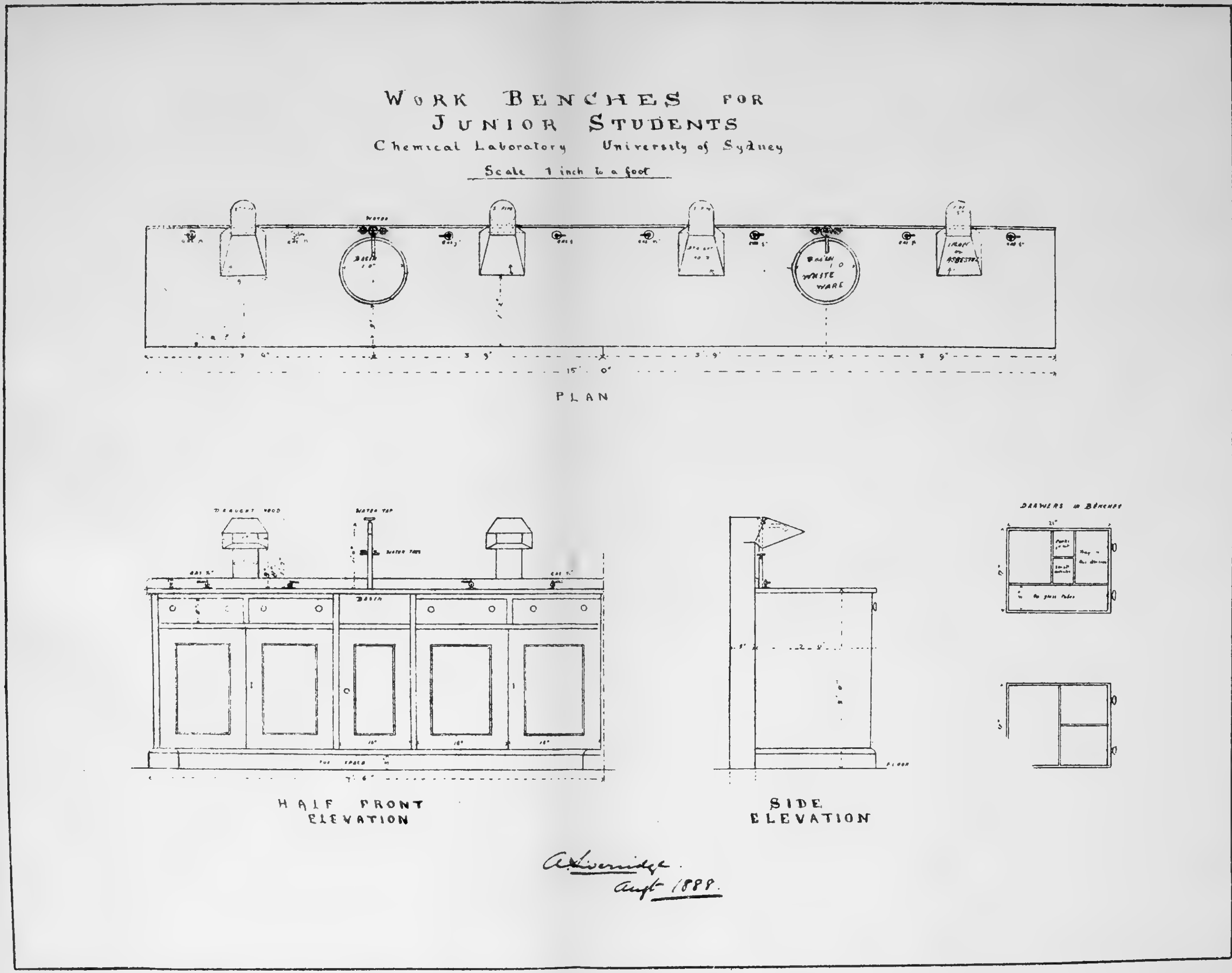
Chemical Laboratory, University of, Sydney.

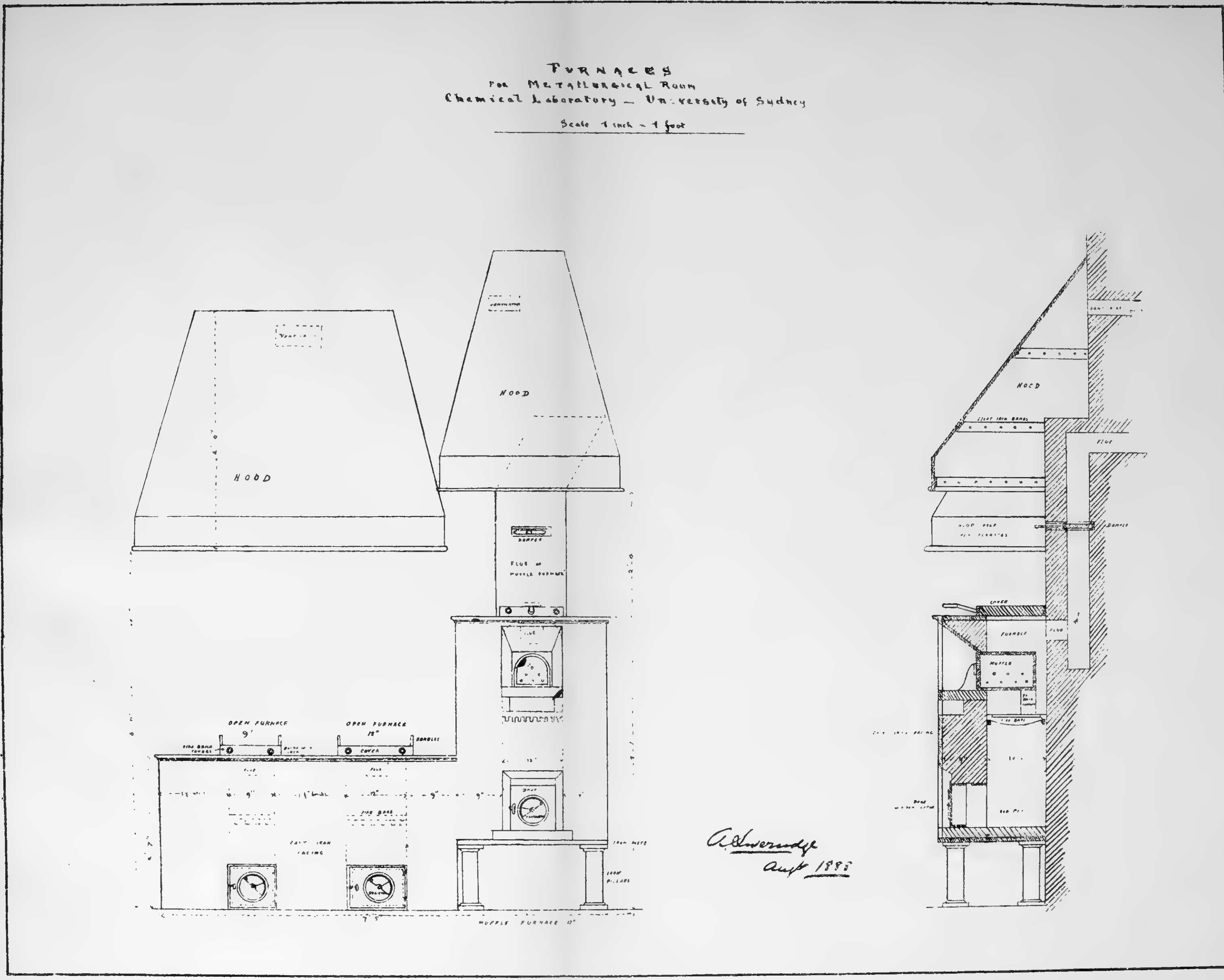


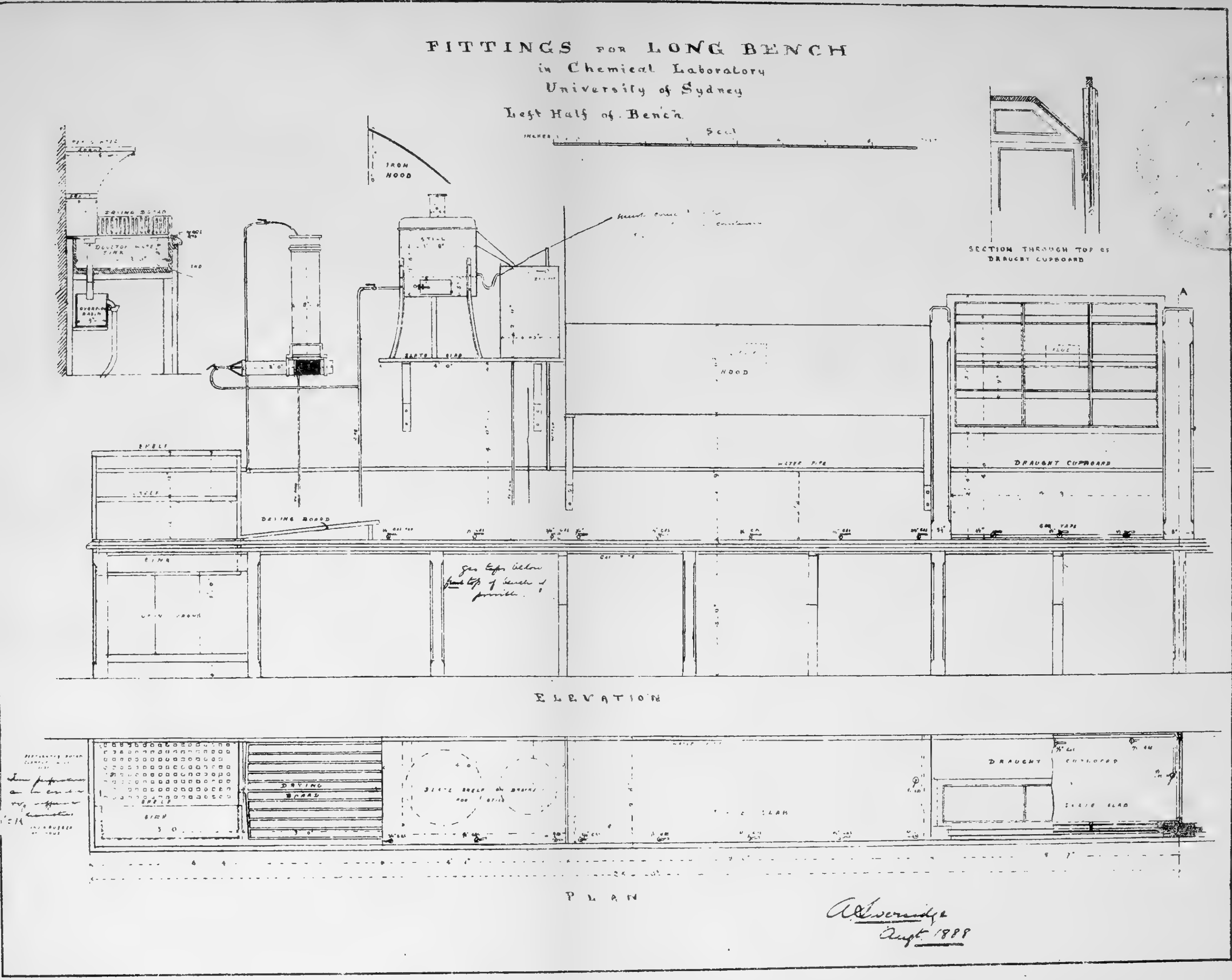
BASEMENT PLAN.

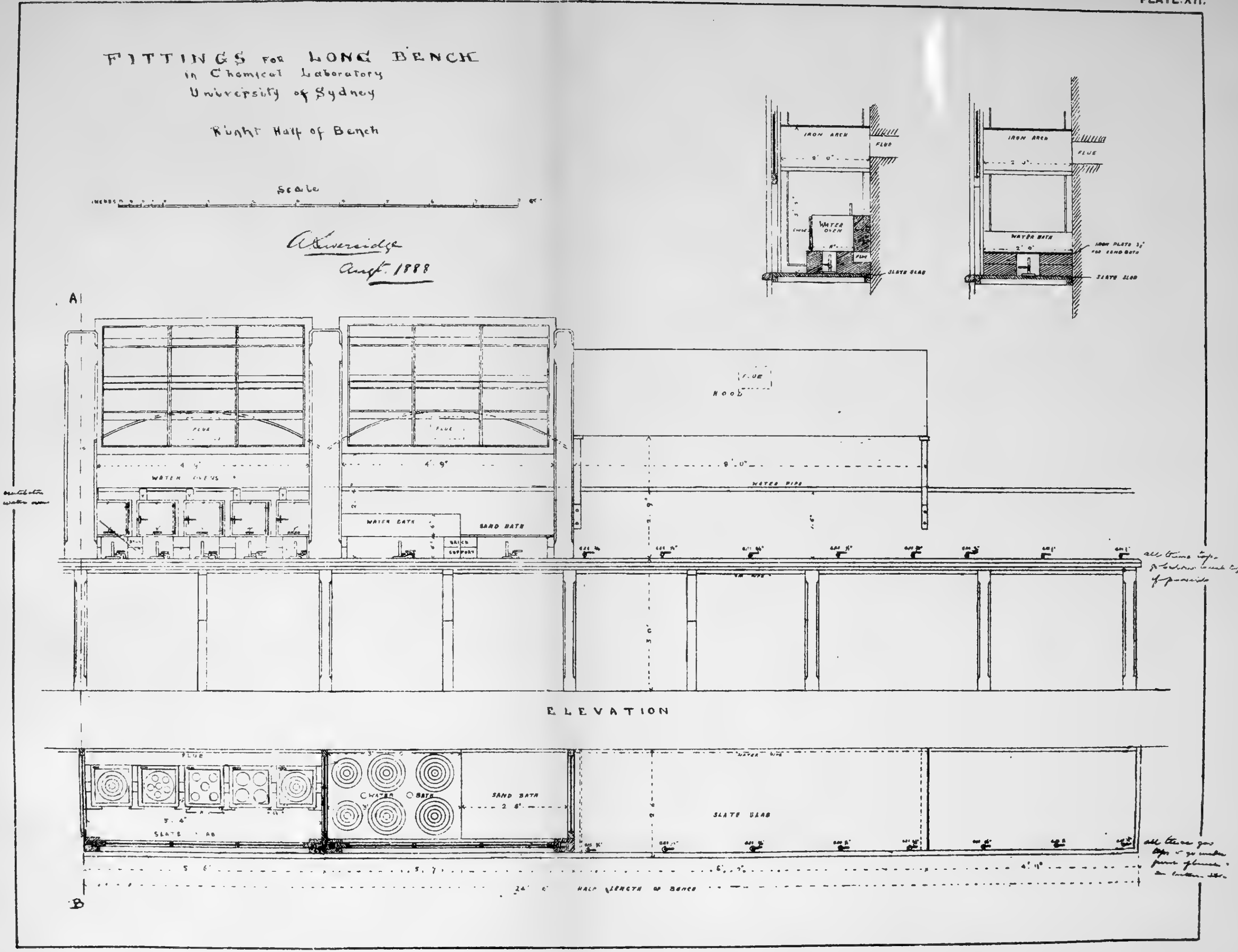

DESIGN FOR WORKING BENCH
Chemical Laboratory — University of Sydney
Scale ¼ inch = 1 foot
ELEVATION
SCALE
PLAN
A. Liversidge.
Augt. 1888.

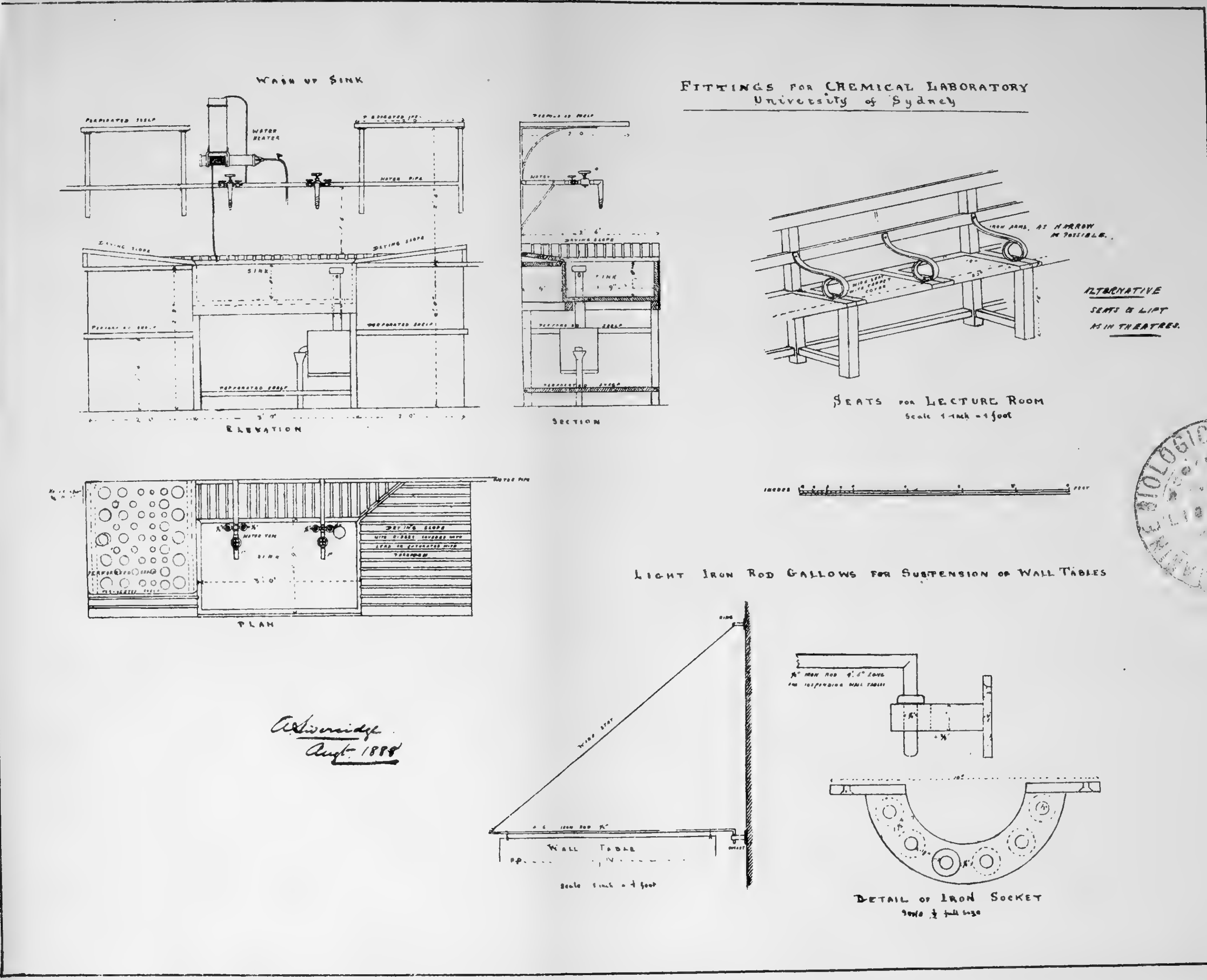

LECTURE TABLE
Chemical Laboratory
University of Sydney
ELEVATION TO LECTURER
HALF ELEVATION TO AUDIENCE
SECTION AT AA
SECTION AT BB
PLAN
BACK
FRONT
ELEVATION
SECTION
ALTERNATIVE ARRANGEMENT FOR TAPS IN RECESSES
SLIDING DOORS
A Liversidge
Augt 888
The central part of the Lecture table to run out on wheels if possible.
Modify position of draught pipes &c.


WORK BENCHES FOR
JUNIOR STUDENTS
Chemical Laboratory University of Sydney
Scale 1 inch to a foot
PLAN
HALF FRONT
ELEVATION
SIDE
ELEVATION
DRAWERS in BENCHES
A Liversidge.
Augt 1888.


Furnaces
for Metallurgical Room
Chemical Laboratory — University of Sydney
Scale 1 inch – 1 foot
HOOD
HOOD
HOOD
DAMPER
FLUE OF MUFFLE FURNACE
OPEN FURNACE
9"
OPEN FURNACE
12"
COVER
HANDLES
CAST IRON FACING
IRON PLATE
IRON PILLARS
MUFFLE FURNACE 12"
FLUE
DAMPER
COVER
FURNACE
MUFFLE
ASH PIT


FITTINGS for LONG BENCH
in Chemical Laboratory
University of Sydney
Left Half of Bench
IRON HOOD
STILL
HOOD
SECTION THROUGH TOP OF DRAUGHT CUPBOARD
SHELF
DRYING BOARD
WATER PIPE
DRAUGHT CUPBOARD
SINK
ELEVATION
DRYING BOARD
DRAUGHT CUPBOARD
PLAN
Augt 1888

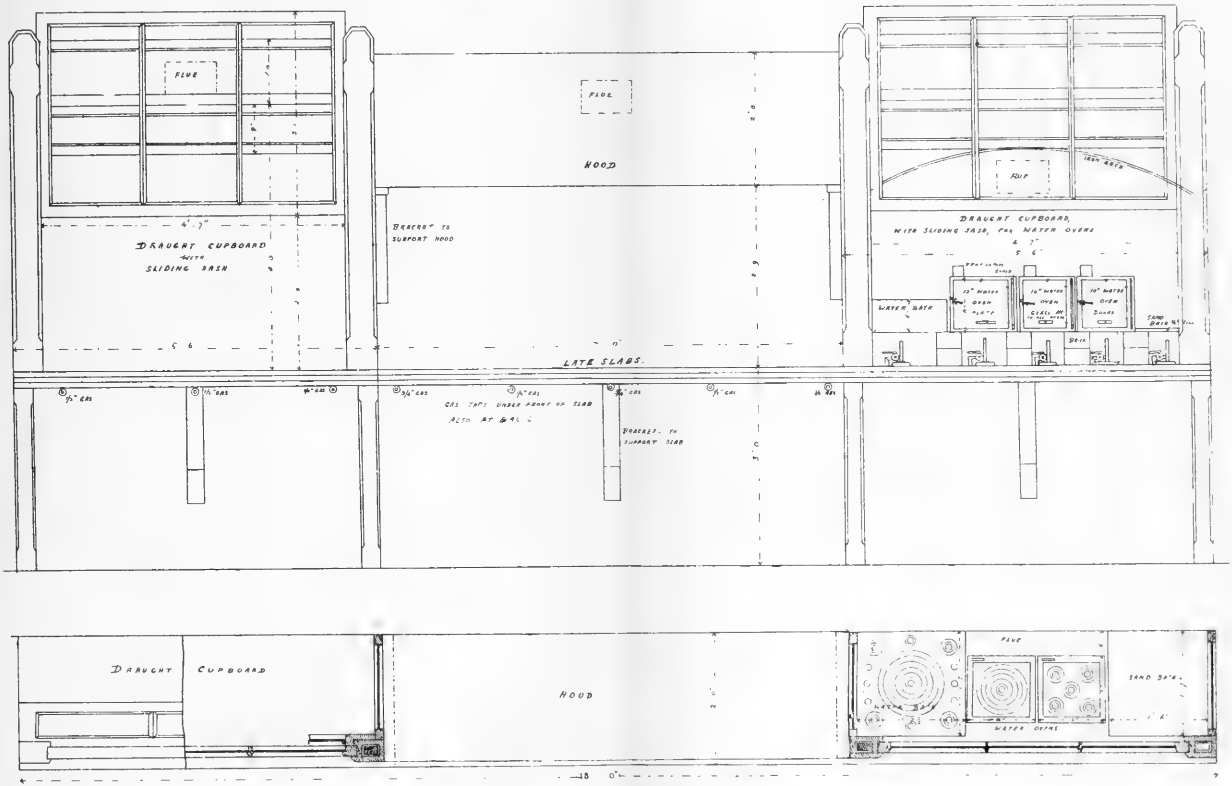

FITTINGS FOR LONG BENCH
in Chemical Laboratory
University of Sydney
Right Half of Bench
Scale
A Liversidge
Aug. 1888
IRON ARCH
FLUE
WATER OVEN
SLATE SLAB
WATER BATH
HOOD
WATER OVENS
WATER BATH
SAND BATH
WATER PIPE
ELEVATION
SLATE SLAB
SAND BATH
HALF LENGTH OF BENCH


Fittings for Chemical Laboratory
University of Sydney
Wash up Sink
Water heater
Water pipe
Perforated shelf
Drying slope
Sink
Elevation
Section
Plan
Iron arms, as narrow as possible.
Alternative seats to lift as in theatres.
Seats for Lecture Room
Scale 1 inch = 1 foot
Light Iron Rod Gallows for Suspension of Wall Tables
Wire stay
Wall Table
Scale 1 inch = 1 foot
Detail of Iron Socket
A. Liversidge
Augt 1888

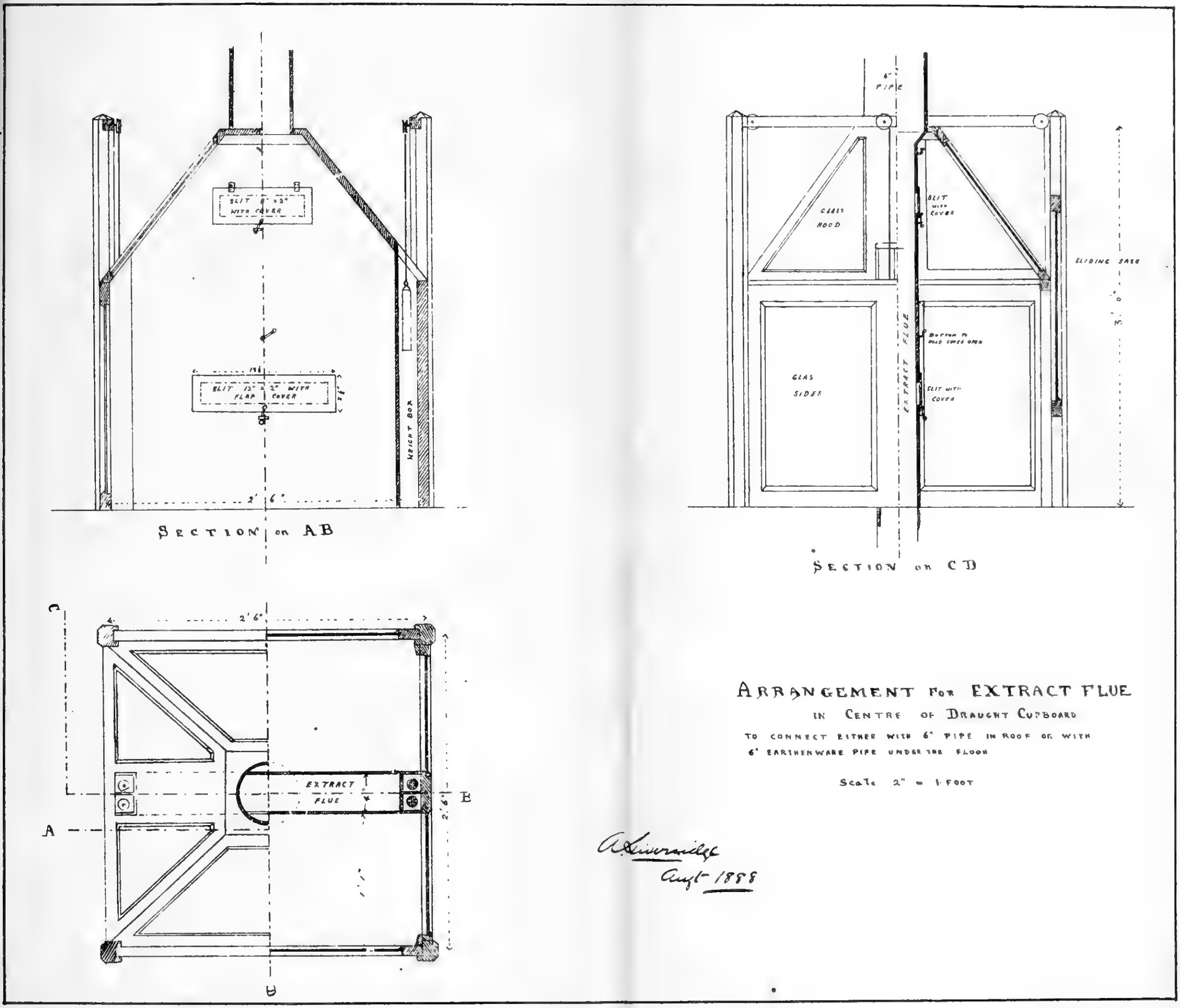
FITTINGS FOR SLATE SLAB IN SENIOR LABORATORY

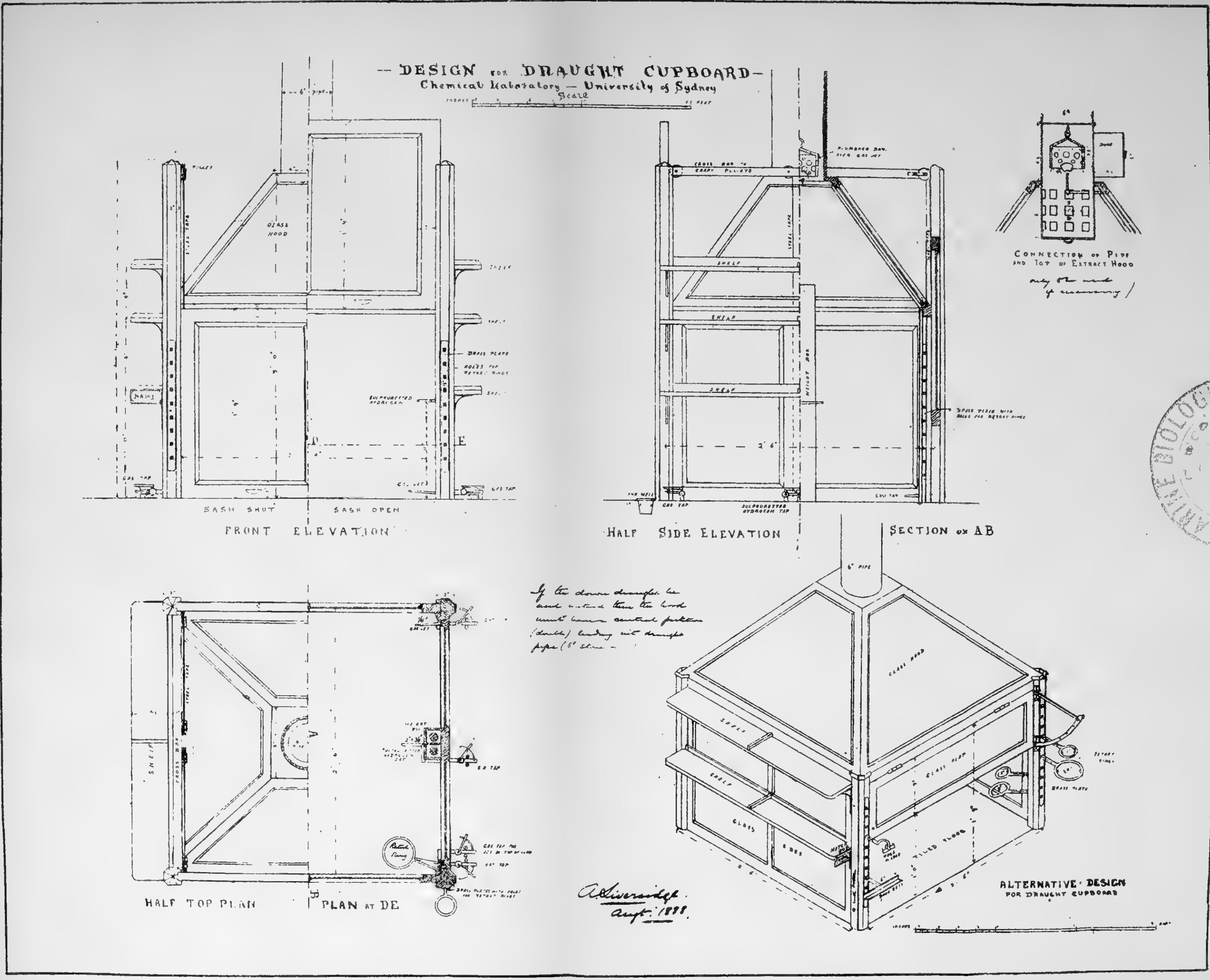
Chemical Laboratory — University of Sydney

Scale 1 inch = 1 foot



A. Liversidge.
Aug^t 1888


SLIT 8" x 2" WITH COVER
SLIT 12" x 2" WITH FLAP COVER
WEIGHT BOX
2' 6"
SECTION ON AB
6" PIPE
GLASS HOOD
SLIT WITH COVER
SLIDING SASH
BUTTON TO HOLD COVER OPEN
GLAS SIDES
SLIT WITH COVER
EXTRACT FLUE
3' 0"
SECTION ON CD
C
2' 6"
EXTRACT FLUE
2' 6"
A
B
D
ARRANGEMENT FOR EXTRACT FLUE
IN CENTRE OF DRAUGHT CUPBOARD
TO CONNECT EITHER WITH 6" PIPE IN ROOF OR WITH
6" EARTHENWARE PIPE UNDER THE FLOOR
Scale 2" = 1 FOOT
A. Liversidge
Augt 1888

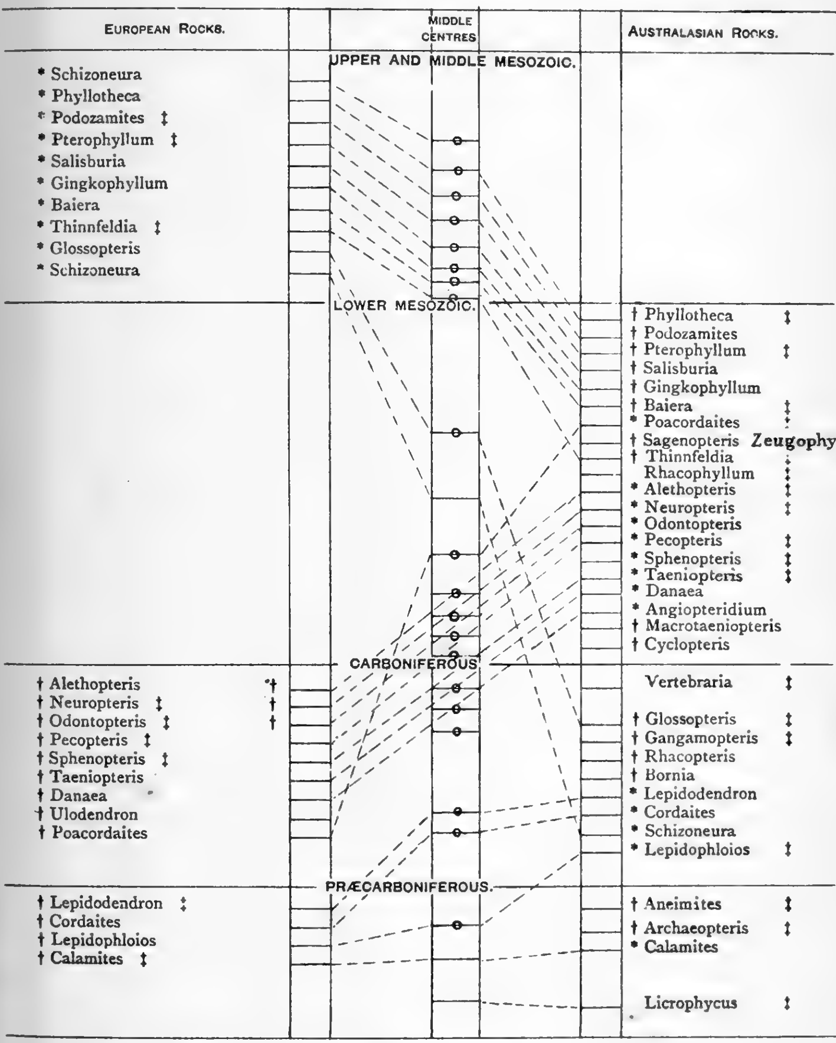


DESIGN FOR DRAUGHT CUPBOARD
Chemical Laboratory — University of Sydney
Scale
6" pipe
GLASS HOOD
SHELF
BRASS PLATE
SULPHURETTED HYDROGEN
GAS TAP
SASH SHUT
SASH OPEN
FRONT ELEVATION
HALF SIDE ELEVATION
SECTION ON AB
CONNECTION OF PIPE AND TOP OF EXTRACT HOOD
HALF TOP PLAN
PLAN AT DE
6" PIPE
ALTERNATIVE DESIGN FOR DRAUGHT CUPBOARD
A Liversidge
Augt 1888

EFFECT OF MIGRATION FROM DIFFERENT CENTRES OF ORIGIN.

APPROXIMATE ORDER OF THE APPEARANCE OF CHARACTERISTIC GENERA OF PLANTS IN THE UPPER PALÆOZOIC AND MESOZOIC ROCKS IN EUROPE AND AUSTRALASIA.

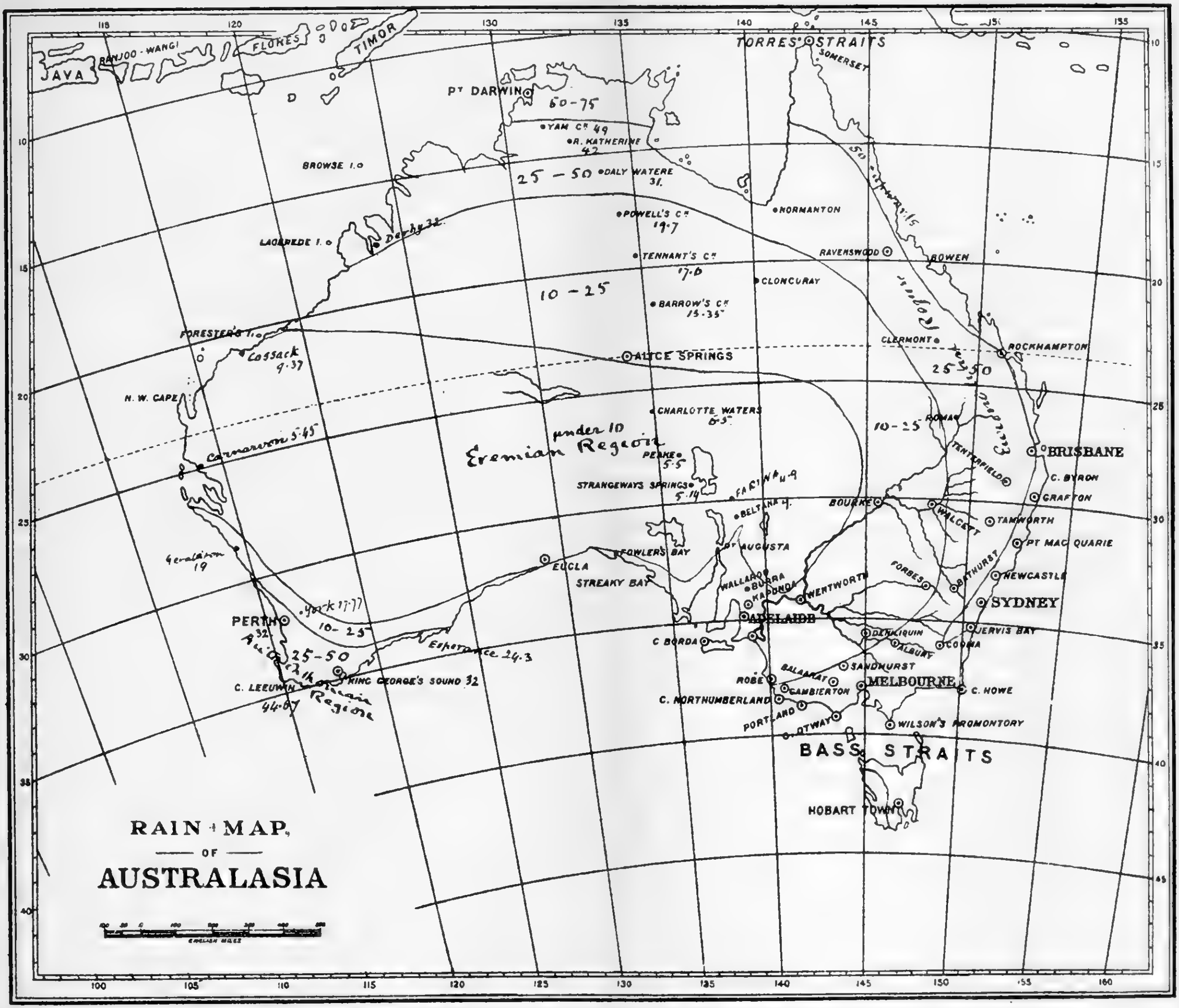
AS ARRANGED BY R. M. JOHNSTON, F.L.S.

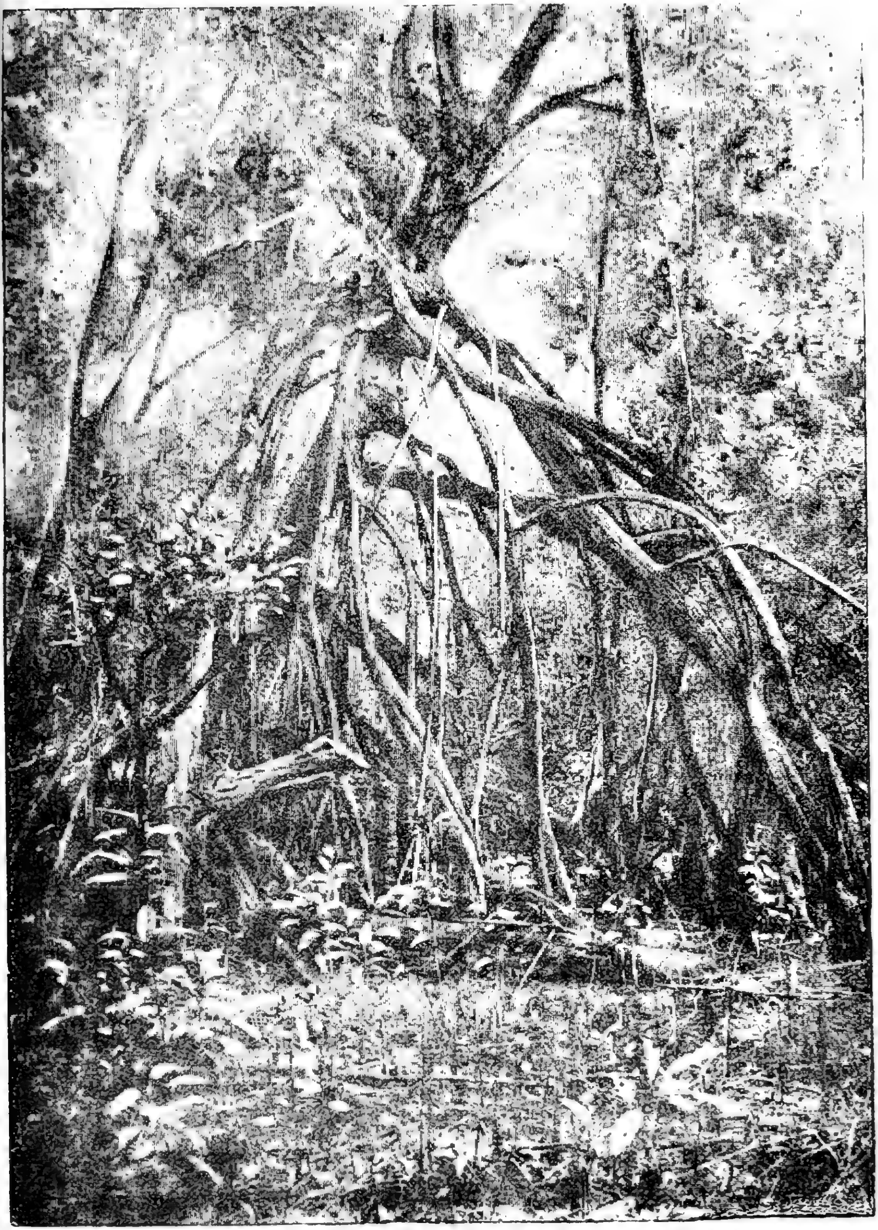


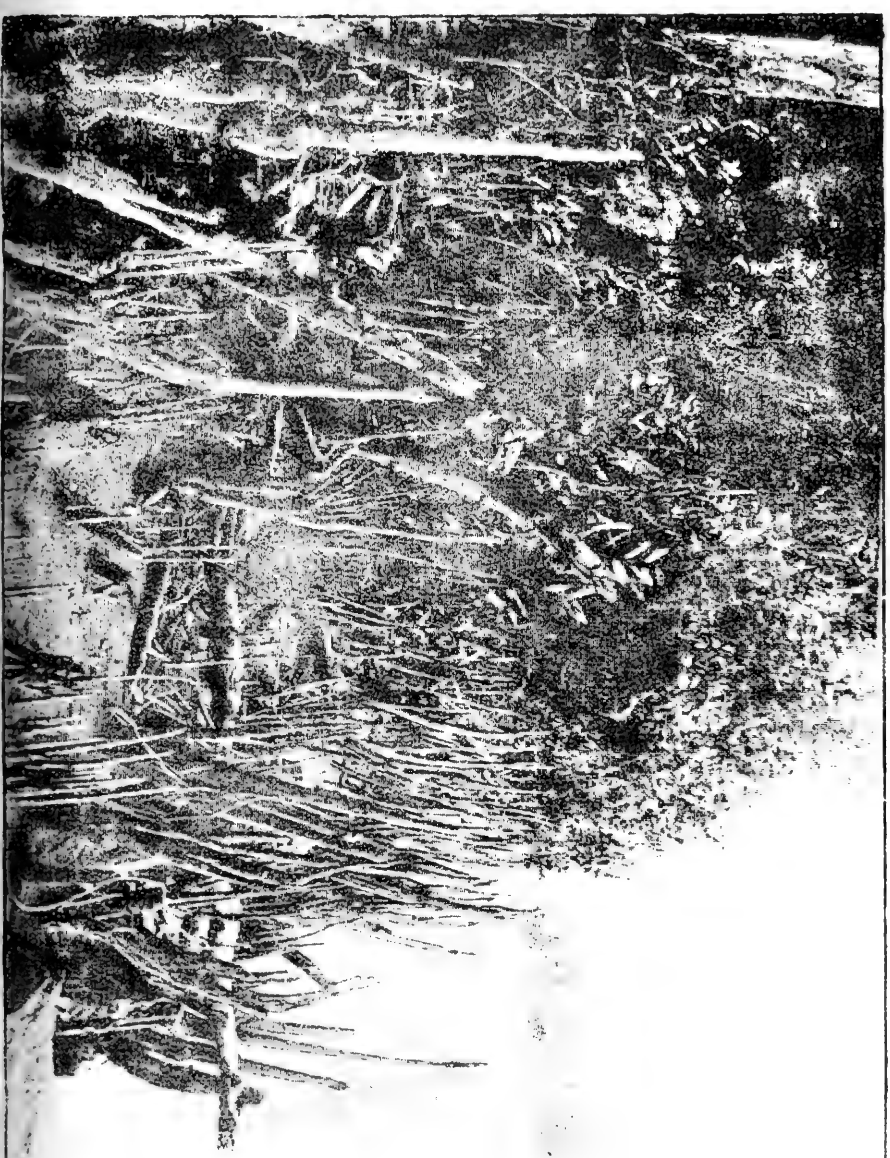
† *Genus first appeared in this horizon.*

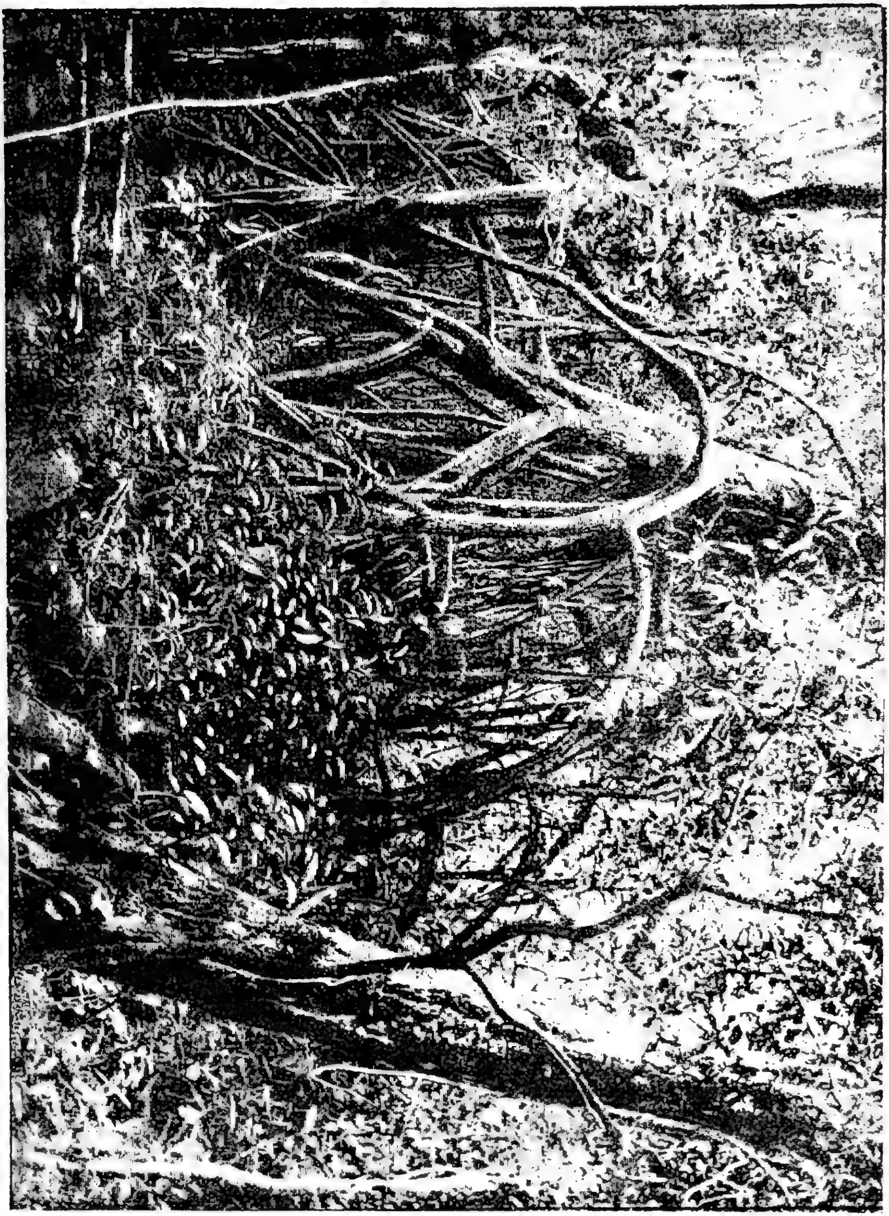
* *Genus derived from parents who first made their appearance in the lower horizon in the opposite hemisphere; also indicates centre of origin.*

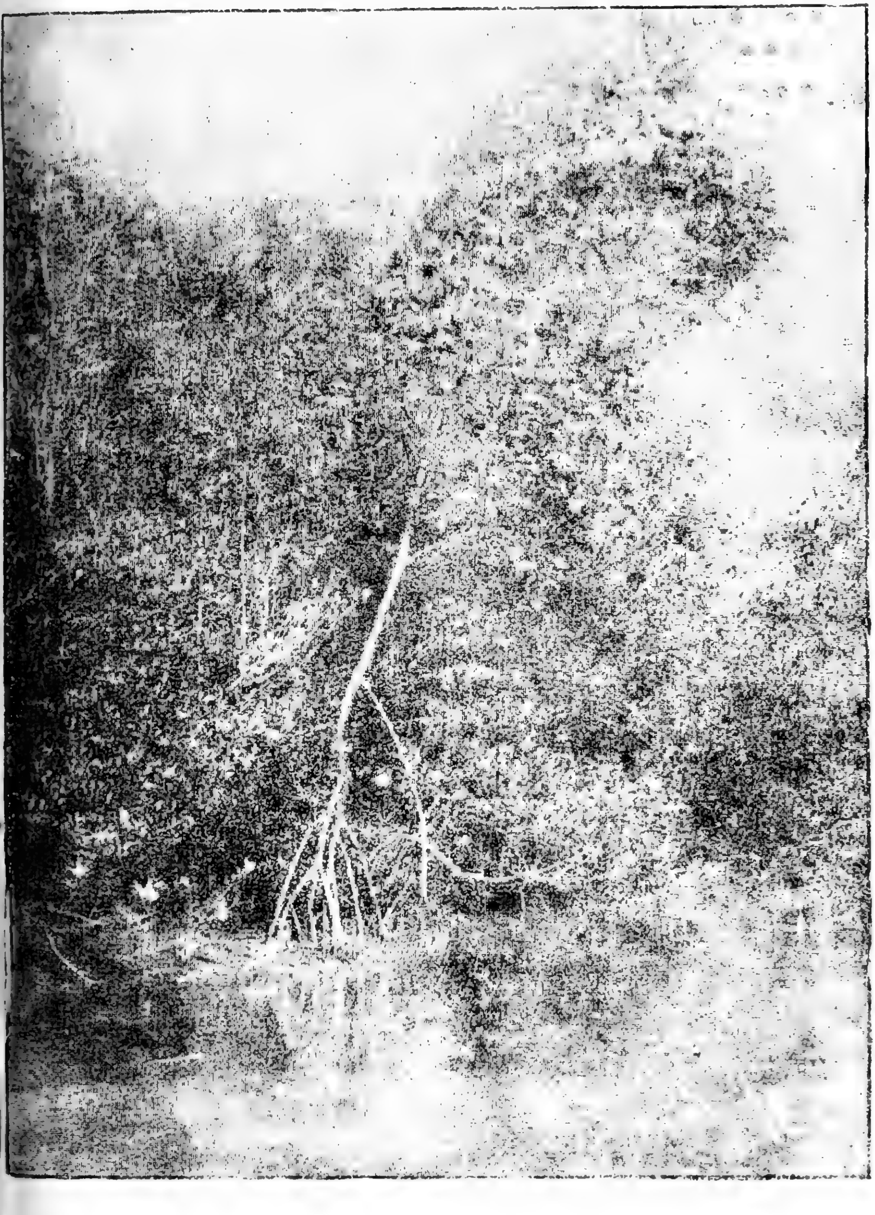
‡ *Indicates the most abundant or most characteristic forms, locally.*

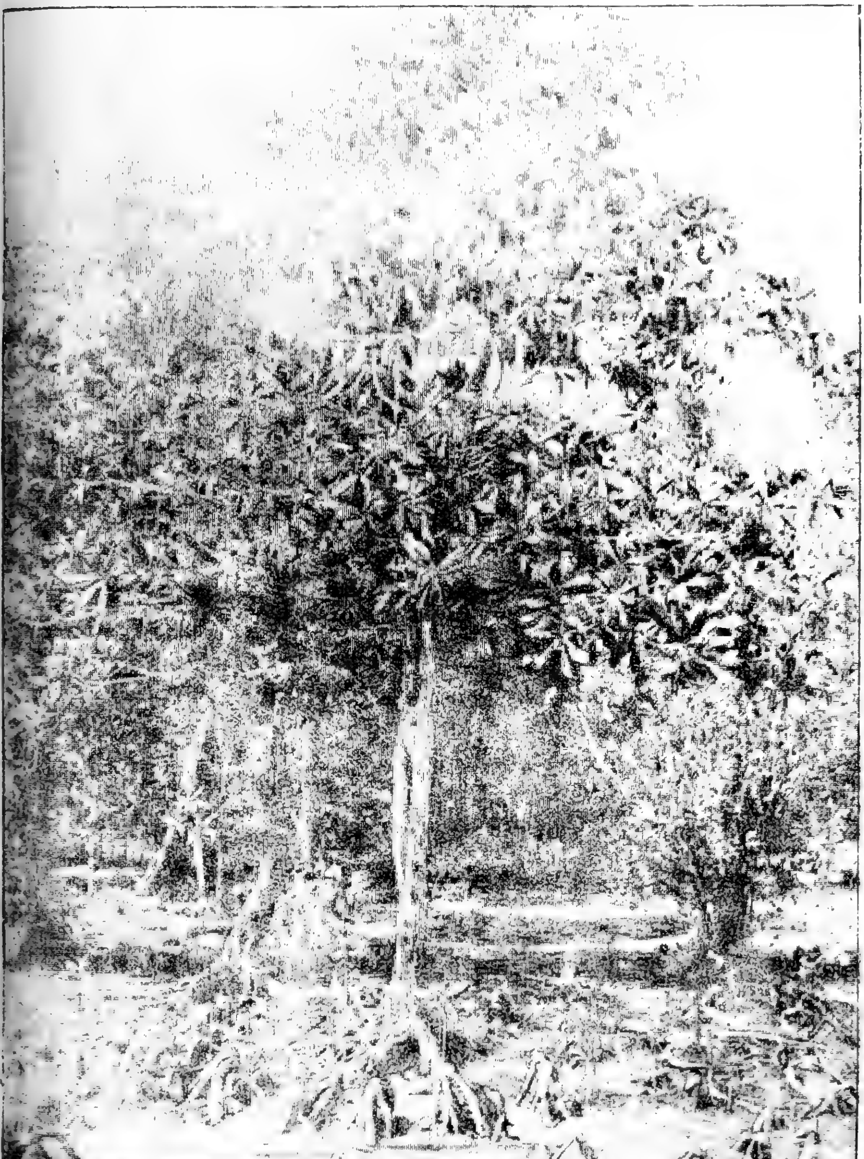

TORRES STRAITS
JAVA
FLORES
TIMOR
PT DARWIN
60-75
YAM CR 49
R. KATHERINE 42
BROWSE I.
25 - 50
DALY WATERS 31.
NORMANTON
POWELL'S CR 19.7
LACEPEDE I.
Derby 32
TENNANT'S CR 17.6
RAVENSWOOD
BOWEN
CLONCURAY
10 - 25
BARROW'S CR 15.35
FORESTER'S I.
Cossack 9.37
CLERMONT
ROCKHAMPTON
ALICE SPRINGS
25-50
N. W. CAPE
CHARLOTTE WATERS 6.5
10-25
ROMA
under 10
Eremian Region
Carnarvon 5.45
PEAKE 5.5
BRISBANE
C. BYRON
STRANGEWAYS SPRINGS 5.14
FARINA 4.9
GRAFTON
BOURKE
WALCETT
TAMWORTH
BELTANA 9
PT AUGUSTA
PT MACQUARIE
FOWLERS BAY
Geraldton 19
EUCLA
STREAKY BAY
WALLAROO
BURRA
FORBES
BATHURST
NEWCASTLE
KAPUNDA
WENTWORTH
SYDNEY
PERTH 32
York 17.77
10-25
ADELAIDE
DENILIQUIN
JERVIS BAY
C BORDA
ALBURY
COOMA
25-50
Esperance 24.3
SANDHURST
KING GEORGE'S SOUND 32
BALLARAT
MELBOURNE
ROBE
C. LEEUWIN 44.67
CAMBIERTON
C. HOWE
C. NORTHUMBERLAND
PORTLAND
C. OTWAY
WILSON'S PROMONTORY
BASS STRAITS
HOBART TOWN
RAIN MAP
OF
AUSTRALASIA
ENGLISH MILES

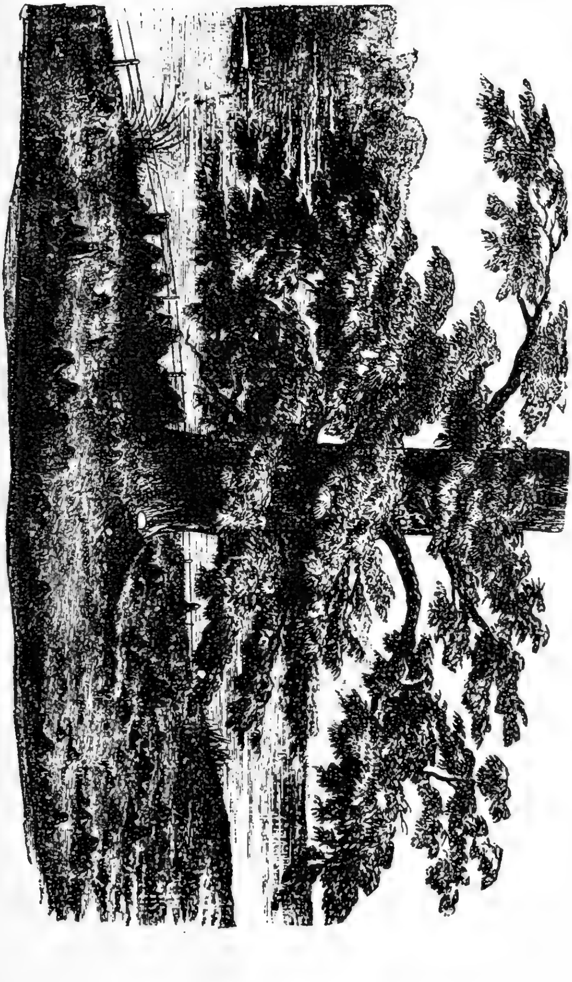












THE DECIDUOUS CYPRESS AND "KNEES."

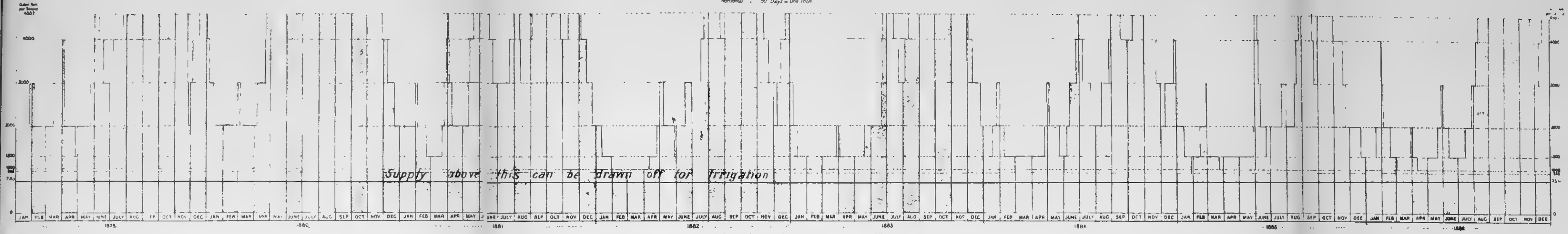

TONGIO GAP
DIVIDING RANGE
Rough inksketch
of
DAYS HILL
MT LIVINGSTONE
DRY HILL
DRY GULLY


Mt Pendergast
(4500 ft
Top Flats
caves
Limestone Ck
Fossiliferous limestone
Stony Ck.
Marble beds
Cobberas Ck
Mt Cobberas
6025

MURRAY RIVER AT ALBURY.

DIAGRAM SHEWING DISCHARGE OF RIVER IN CUBIC FEET FROM 1879 TO 1886.

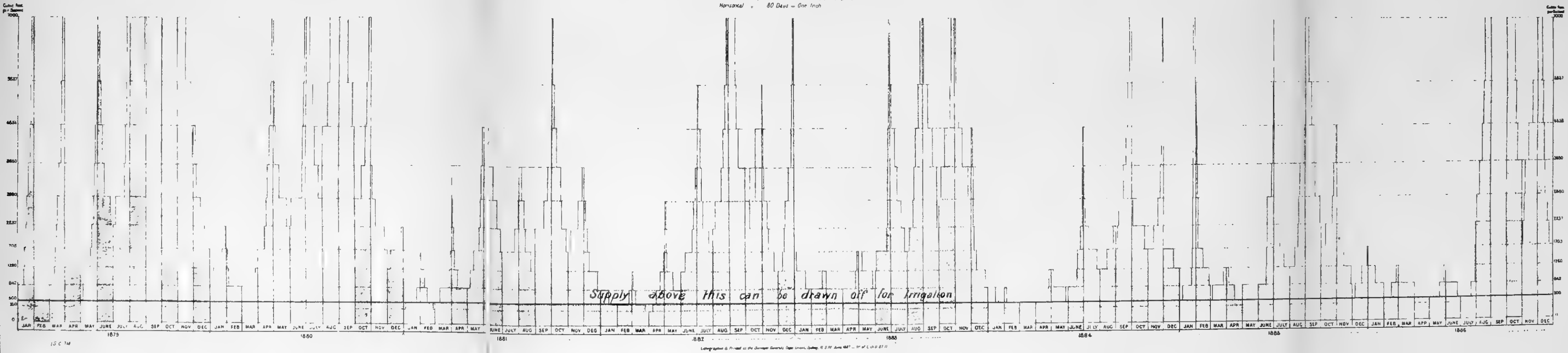
Vertical Scale, One Inch = 1000 Cubic Feet per Second
Horizontal " 80 Days = One Inch

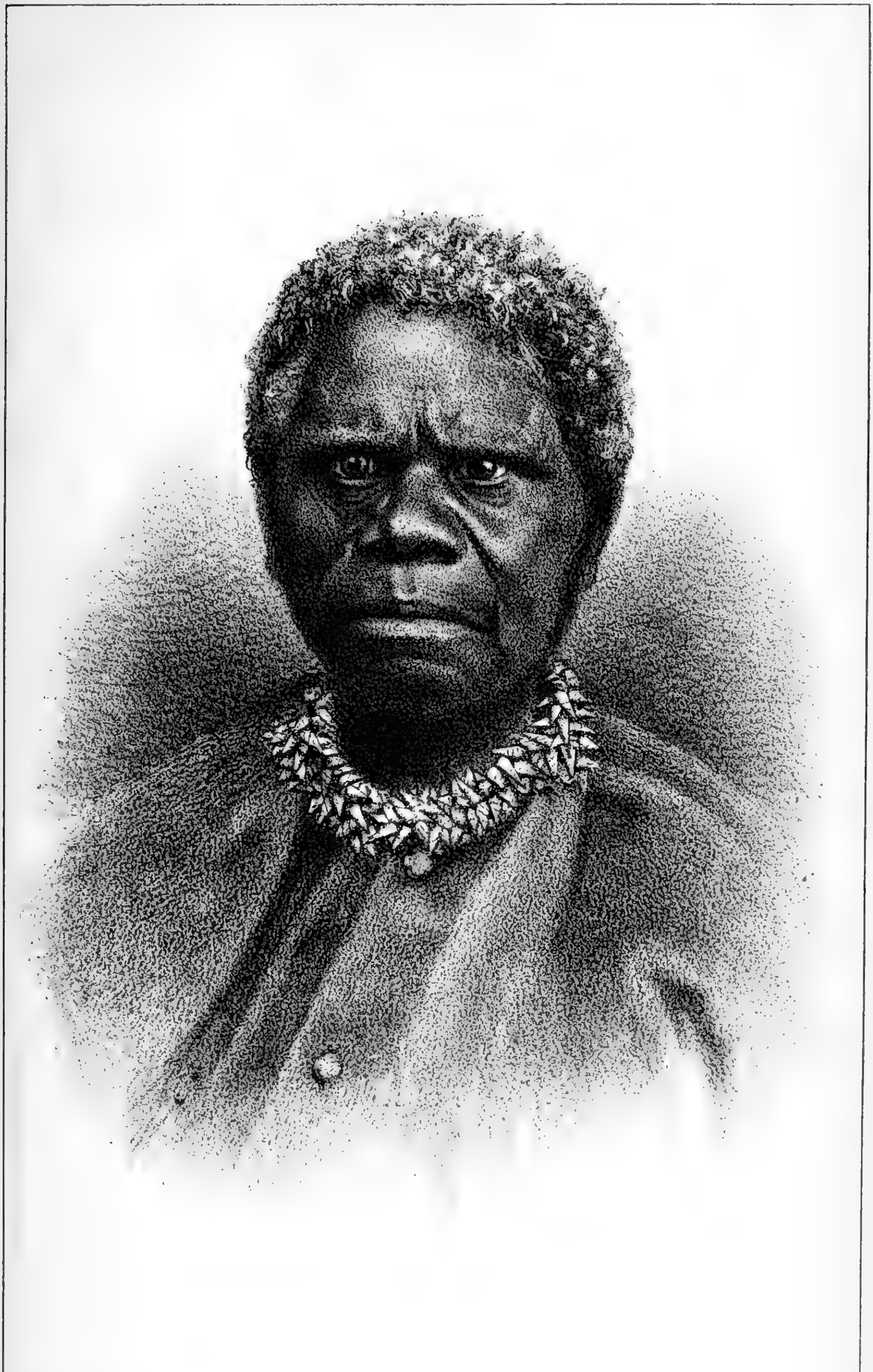


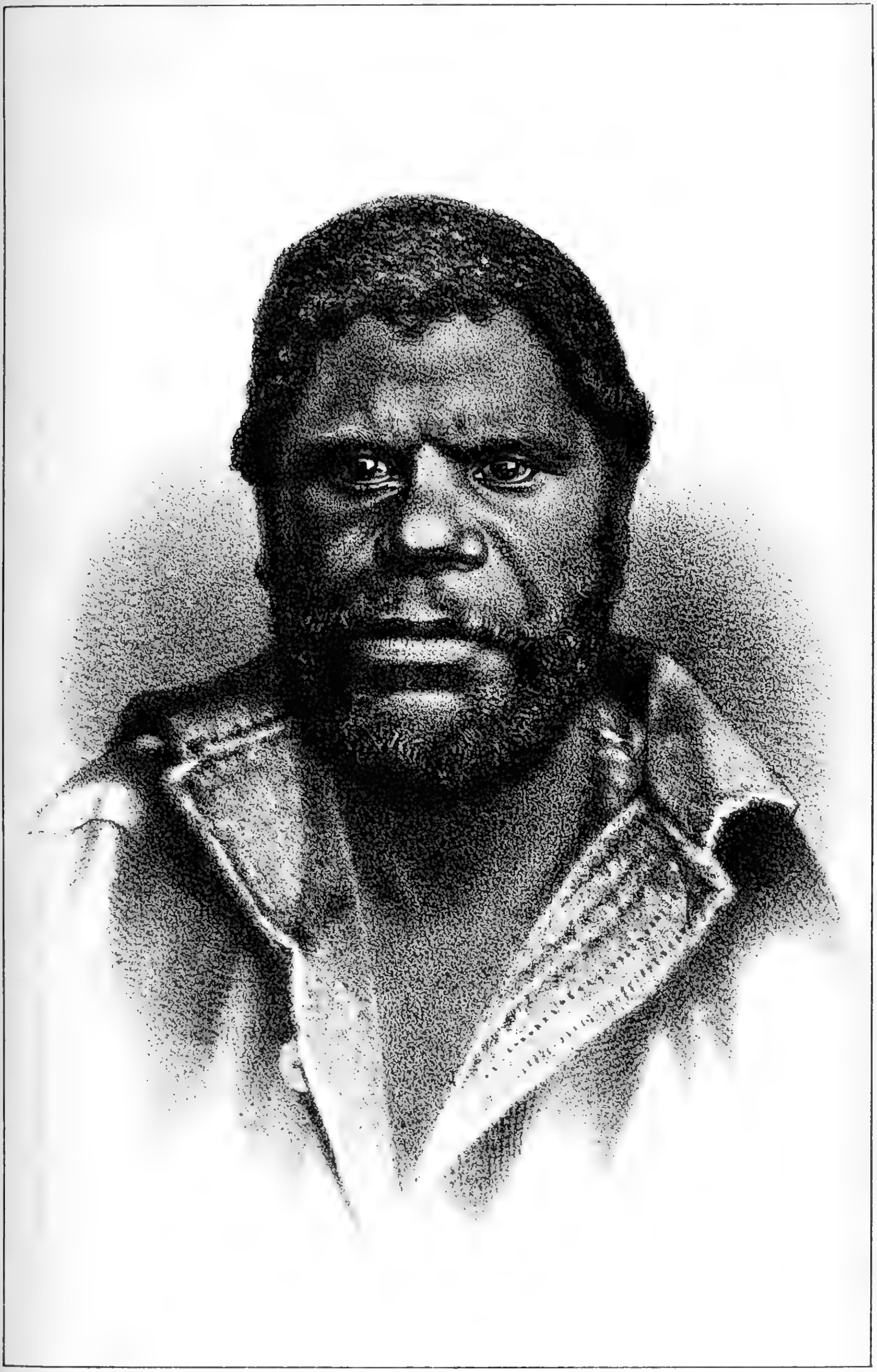
MURRUMBIDGEE RIVER AT WAGGA WAGGA.

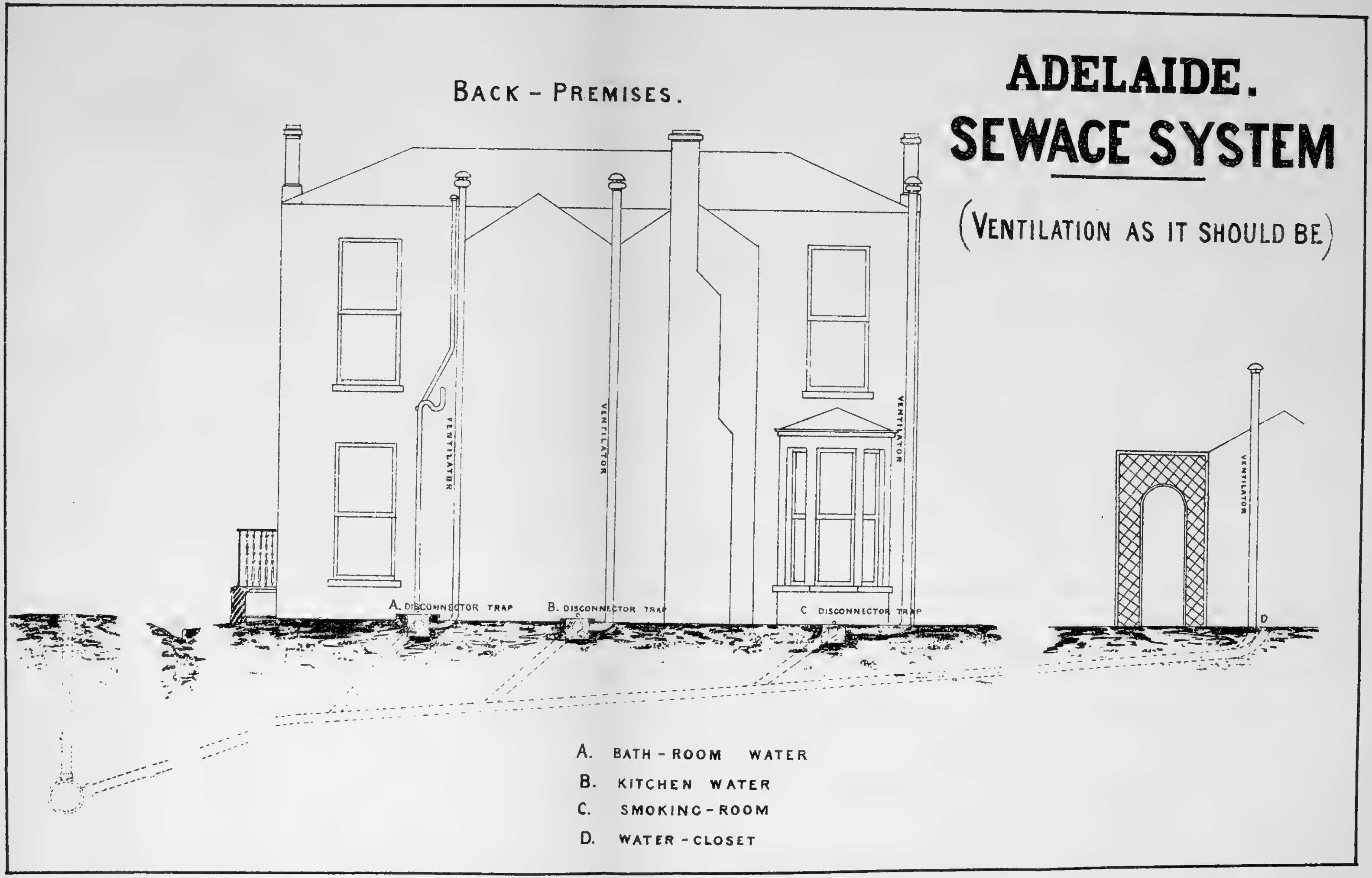
DIAGRAM SHEWING DISCHARGE OF RIVER IN CUBIC FEET FROM 1879 TO 1886

Vertical Scale, One Inch = 1000 Cubic Feet per Second
Horizontal " 80 Days = One Inch



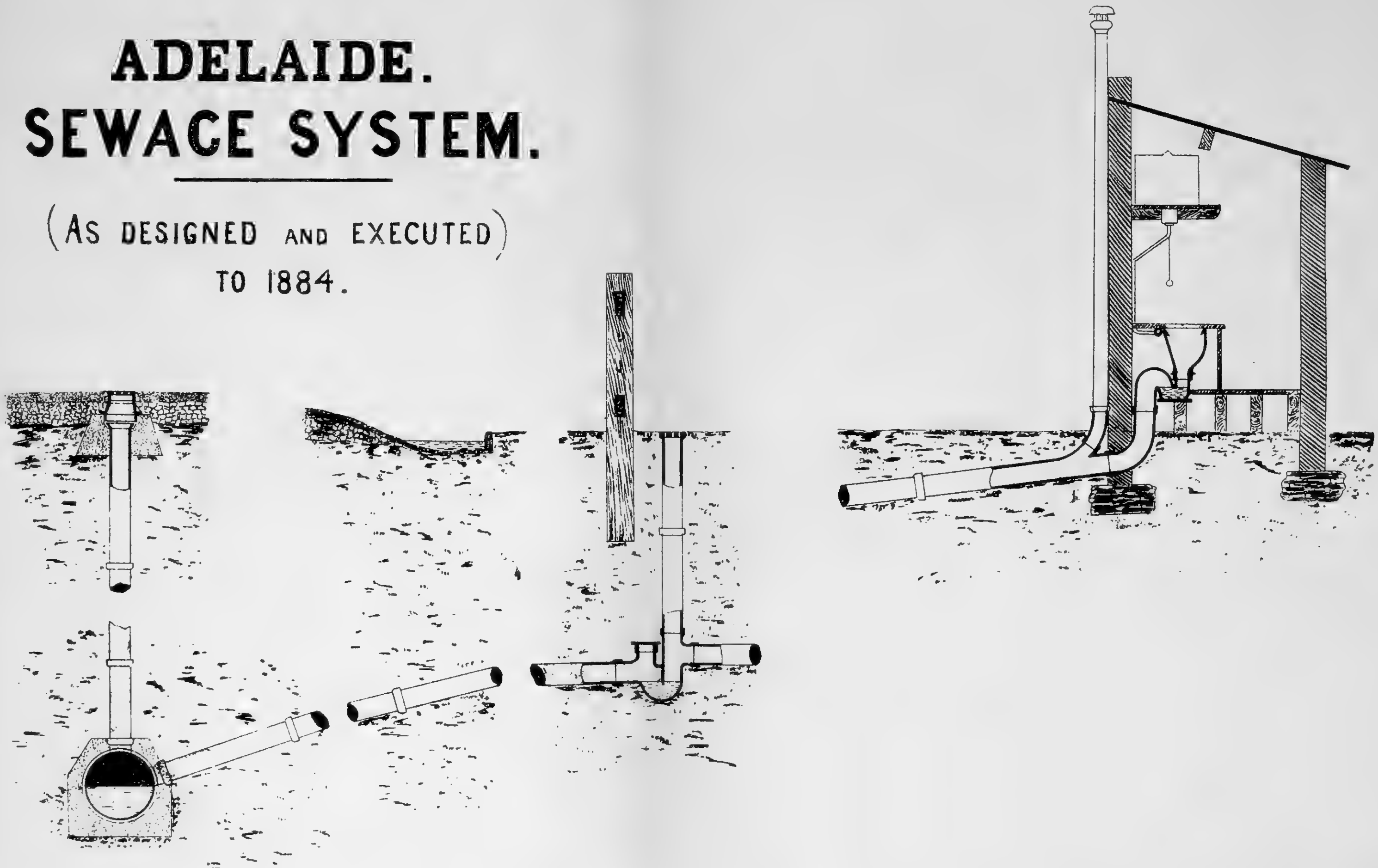


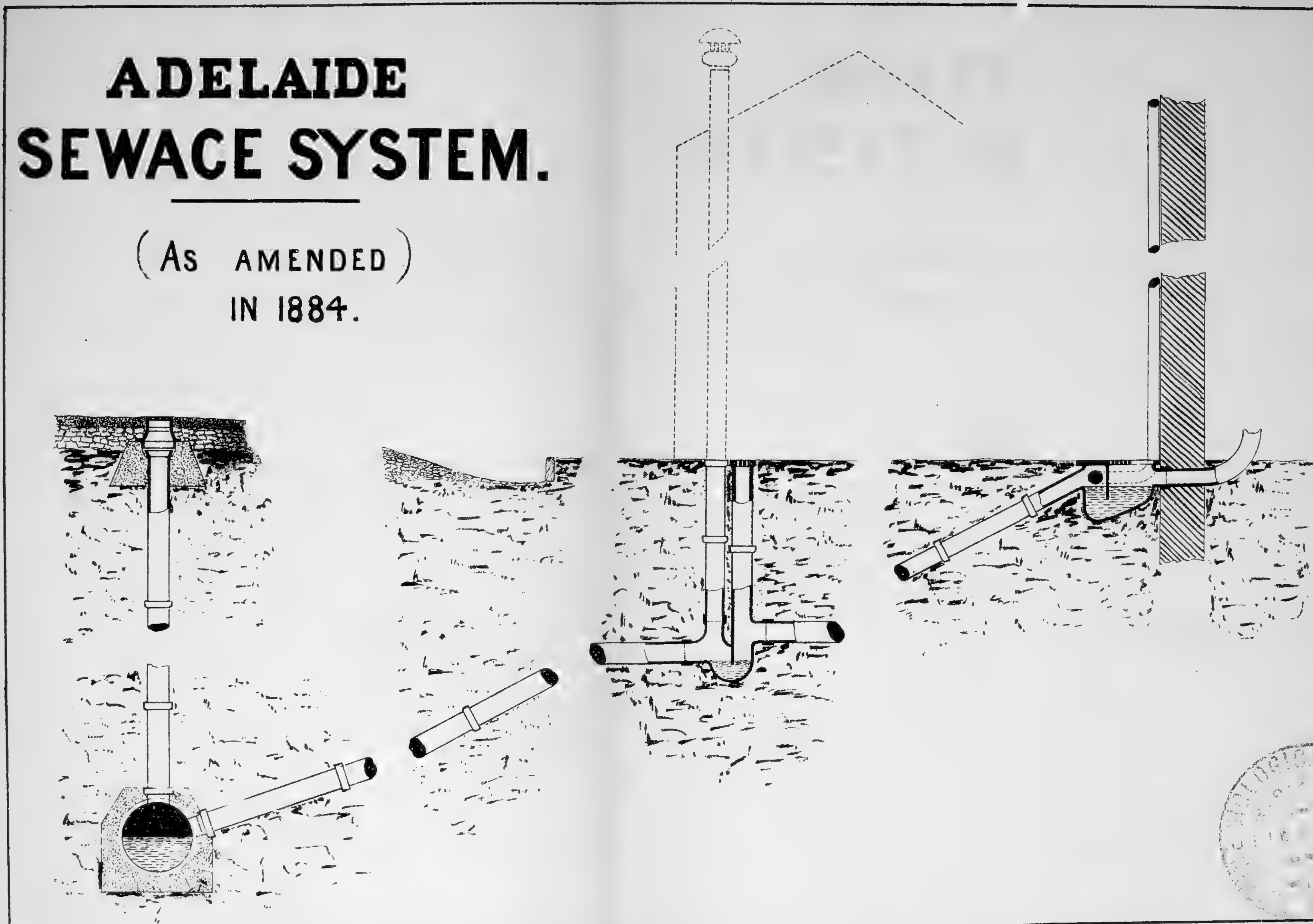



ADELAIDE.
SEWAGE SYSTEM
(VENTILATION AS IT SHOULD BE)
BACK - PREMISES.
VENTILATOR
VENTILATOR
VENTILATOR
VENTILATOR
A. DISCONNECTOR TRAP
B. DISCONNECTOR TRAP
C DISCONNECTOR TRAP
D
A. BATH - ROOM WATER
B. KITCHEN WATER
C. SMOKING - ROOM
D. WATER - CLOSET

ADELAIDE.
SEWAGE SYSTEM.

(AS DESIGNED AND EXECUTED)
TO 1884.




ADELAIDE
SEWACE SYSTEM.
(As AMENDED)
IN 1884.

MORTALITY TABLE

Shewing the death-rate per 1000 of the Population in the CITY of ADELAIDE from the Years 1879 to 1887 inclusive.

	NO DRAINAGE			DRAINAGE IN CONSTRUCTION			DRAINAGE COMPLETED		
	1879	1880	1881	1882	1883	1884	1885	1886	1887
A		21·2	21·4	21·8	17·16	21·18	15·73	16·24	15·95
B	28·8	30·7	23·5	27·5	23·9	24·4	18·9	18·9	19·75
Zymotic Diseases	3·6	4·4	3·8	4·3	3·5	2·7	1·6	1·4	1·1
Diarrhoeal	1·3	2·2	1·9	1·9	2·1	2·3	1·9	·9	1·4
Typhoid	·9	·5	·6	1·5	·9	1·0	·8	·5	·8
Diptheria	·3	·5	·5	·3	·3	·4	·2	·2	·2
Phthisis	3·6	4·4	3·8	4·3	3·5	2·7	1·6	1·4	1·1

A *is the death-rate exclusive of deaths in Public Institutions of persons not resident in the City.*

B *is the death-rate from all Causes.*

TEMPERATURE TABLE.

MONTH	AIR			SOIL	Difference of SOIL over NIGHT Temperature	Increase of VOLUME per 1000 Cub. Ins.	VENTILATION	
	Day		Night	Eight feet below Surface 9 A.M.			Day	Night
	Mean Sun	Mean Shade	Mean					
JANUARY	141°	91°	64°	66°	2°	4	0	Slight
FEBRUARY	139	91	67	69	2	4	0	Slight
MARCH	129	80	61	69	8	16	0	Moderate
APRIL	117	71	55	68	13	28	0	Moderate
MAY	111	64	49	66	17	34	0	Moderate
JUNE	100	59	48	64	16	32	Slight	Fair
JULY	103	58	43	62	19	38	Slight	Fair
AUCUST	110	63	47	60	13	26	Slight	Fair
SEPTEMBER	111	64	49	60	11	22	0	Moderate
OCTOBER	120	69	50	60	10	20	0	Moderate
NOVEMBER	126	75	53	61	8	16	0	Moderate
DECEMBER	134	84	58	63	5	10	0	Moderate

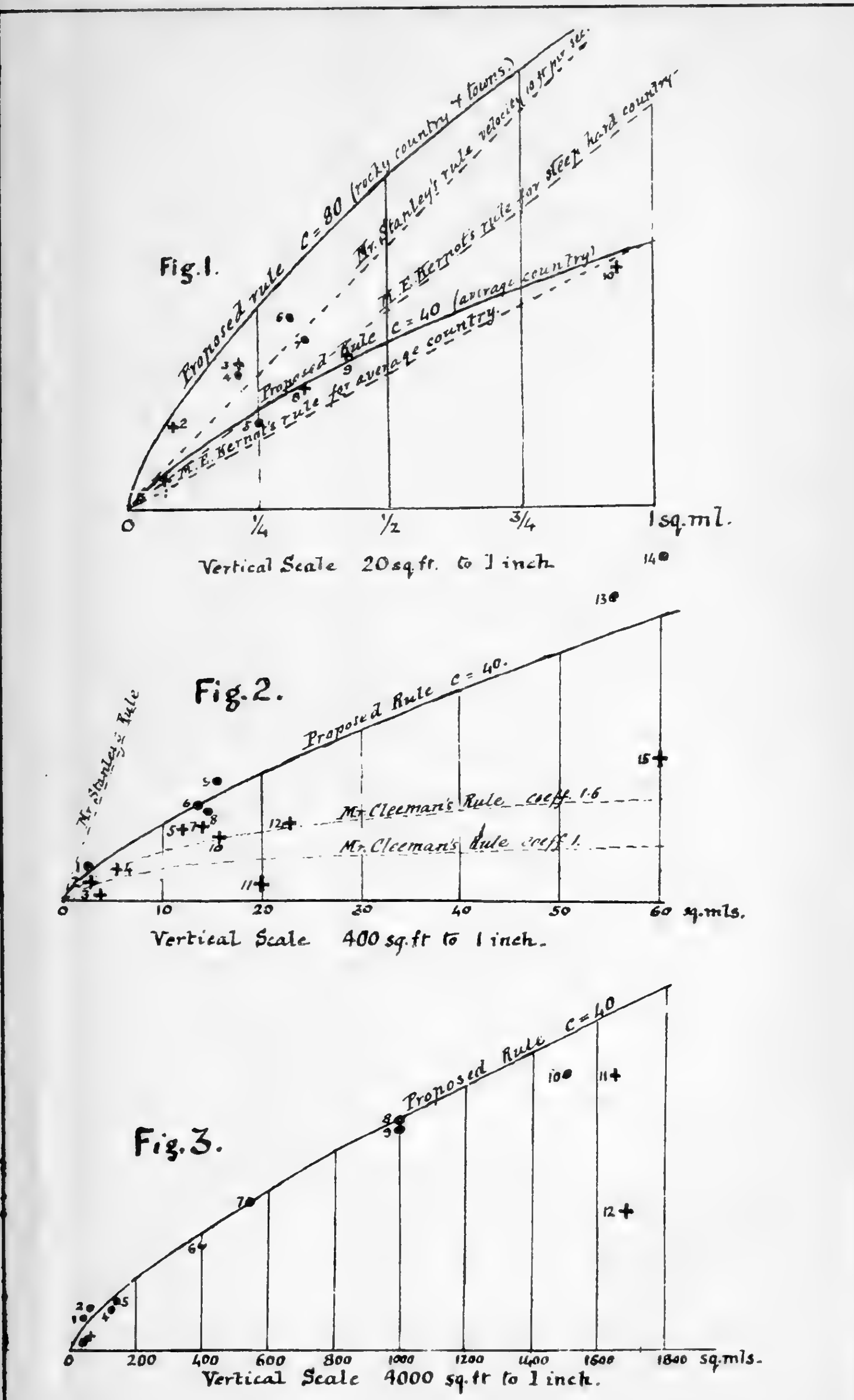
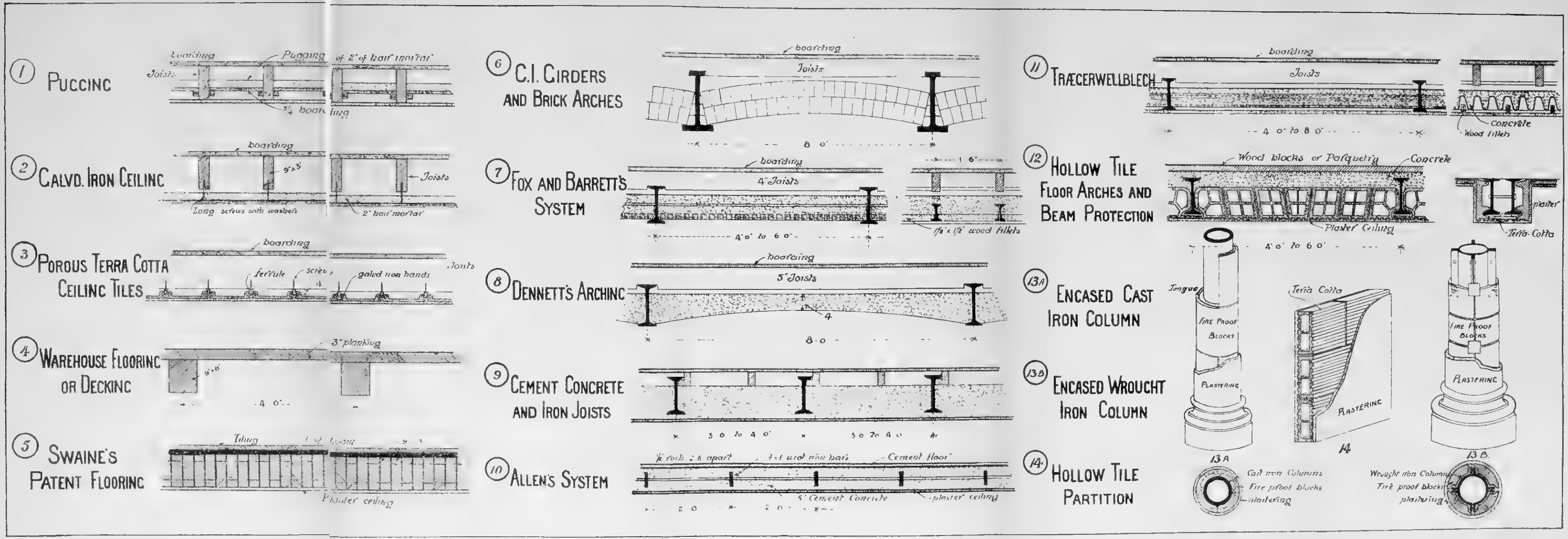
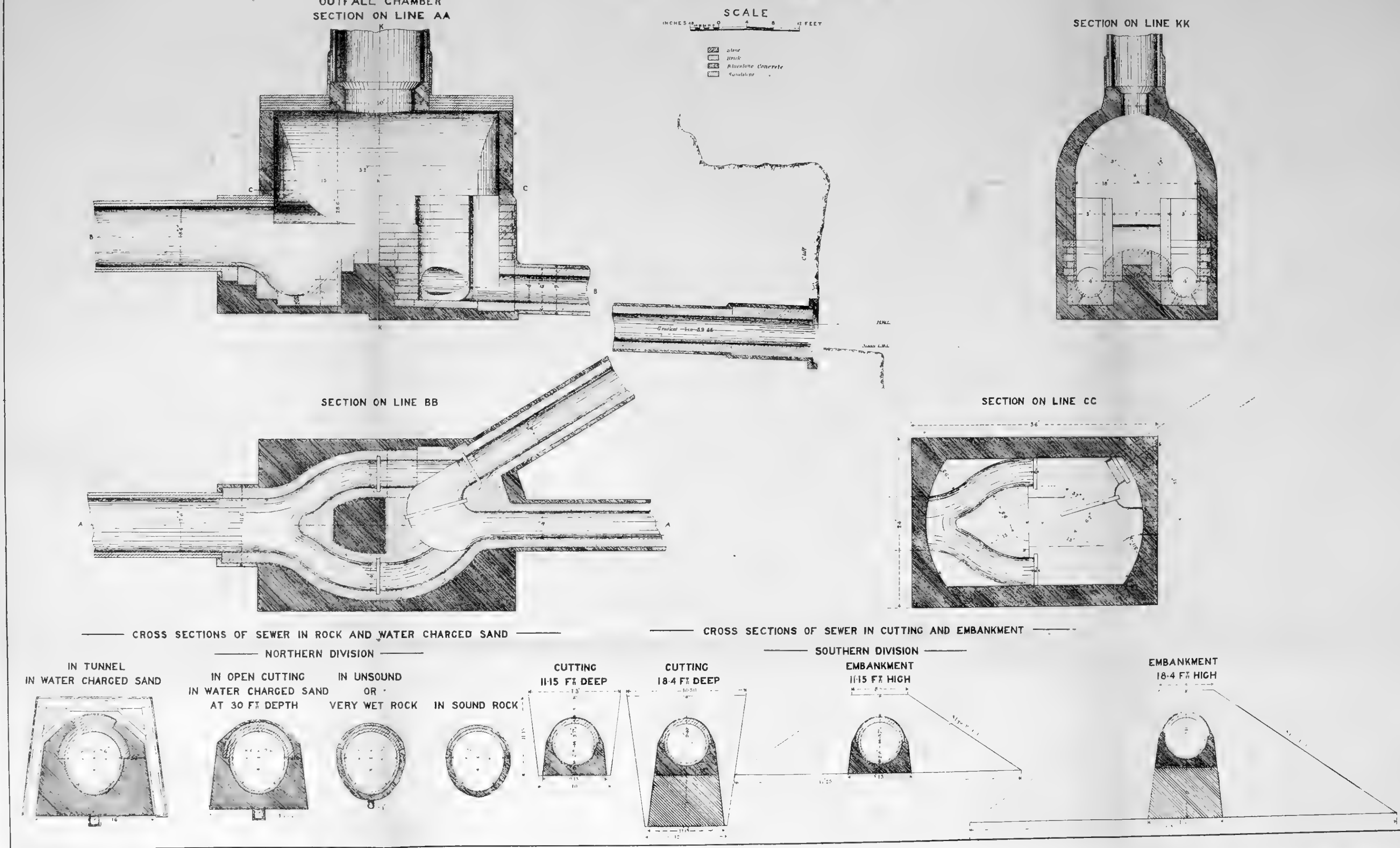
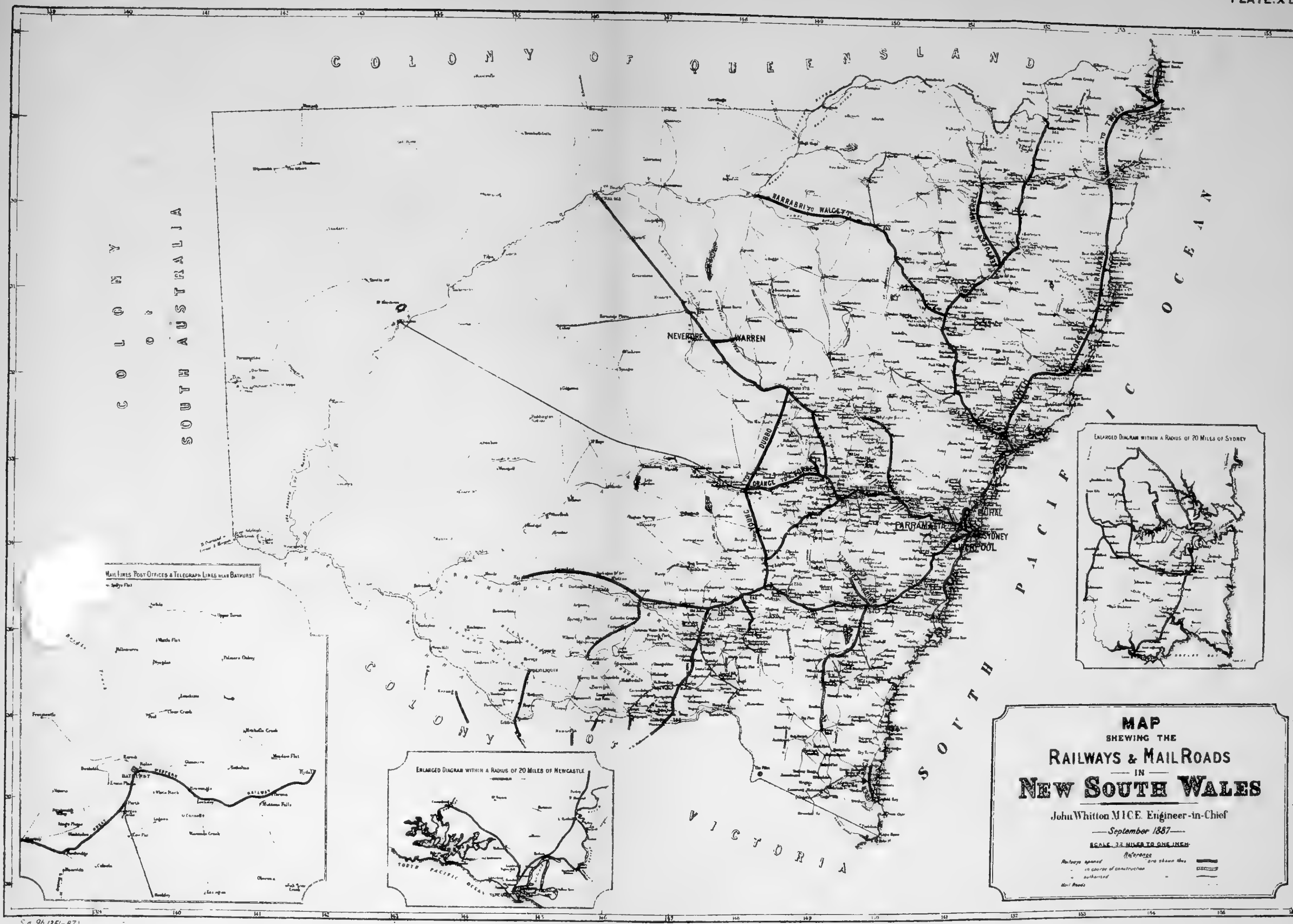


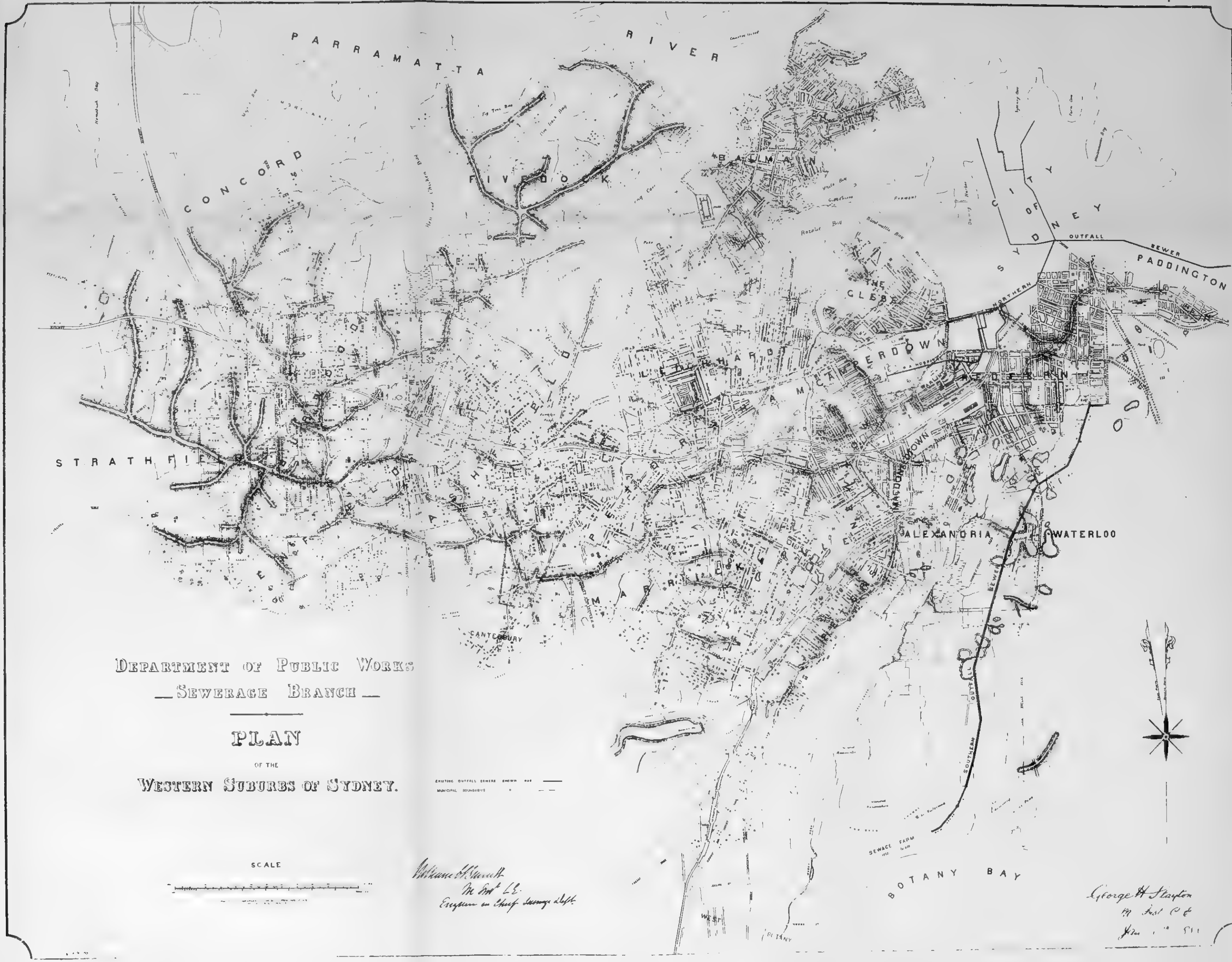
Fig. 1.
Proposed rule C = 80 (rocky country + towns.)
Mr. Stanley's rule velocity 10 ft per sec.
M. E. Kernot's rule for steep hard country
Proposed Rule C = 40 (average country)
M. E. Kernot's rule for average country.
0
1/4
1/2
3/4
1 sq. ml.
Vertical Scale 20 sq. ft. to 1 inch
Fig. 2.
Mr. Stanley's Rule
Proposed Rule C = 40.
Mr. Cleeman's Rule coeff. 1.6
Mr. Cleeman's Rule coeff. 1.
0
10
20
30
40
50
60 sq. mls.
Vertical Scale 400 sq. ft to 1 inch.
Fig. 3.
Proposed Rule C = 40
0
200
400
600
800
1000
1200
1400
1600
1800 sq. mls.
Vertical Scale 4000 sq. ft to 1 inch.

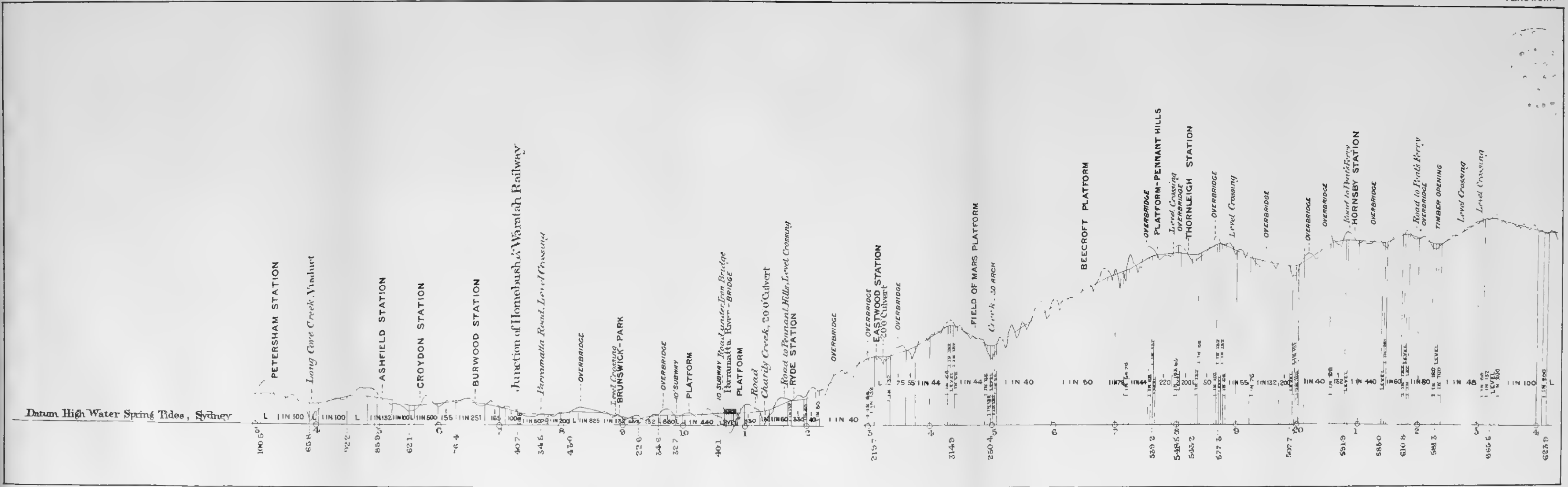

1 Pugging
boarding
Pugging of 2" of hair mortar
Joists
3/4 boarding
2 Galvd. Iron Ceiling
boarding
9"x3"
Joists
Long screws with washers
2" hair mortar
3 Porous Terra Cotta Ceiling Tiles
boarding
Joists
ferrule
screw
galvd iron bands
4 Warehouse Flooring or Decking
3" planking
9"x8"
4 0"
5 Swaine's Patent Flooring
Tiling
Plaster ceiling
6 C.I. Girders and Brick Arches
boarding
Joists
8 0"
7 Fox and Barrett's System
boarding
4" Joists
4' 0" to 6' 0"
1' 6"
1/2" x 1/2" wood fillets
8 Dennett's Arching
boarding
5" Joists
4
8-0
9 Cement Concrete and Iron Joists
3 0 to 4 0
3 0 to 4 0
10 Allen's System
Cement floor
5" Cement Concrete
plaster ceiling
2 0
2 0
11 Traegerwellblech
boarding
Joists
4' 0" to 8' 0"
Concrete
Wood fillets
12 Hollow Tile Floor Arches and Beam Protection
Wood blocks or Parquetry
Concrete
Plaster Ceiling
4' 0" to 6' 0"
plaster
Terra-Cotta
13A Encased Cast Iron Column
13B Encased Wrought Iron Column
14 Hollow Tile Partition
Tongue
Fire Proof Blocks
Plastering
Terra Cotta
Plastering
Fire Proof Blocks
Plastering
13 A
14
13 B.
Cast iron Columns
Fire proof blocks
plastering
Wrought iron Columns
Fire proof blocks
plastering

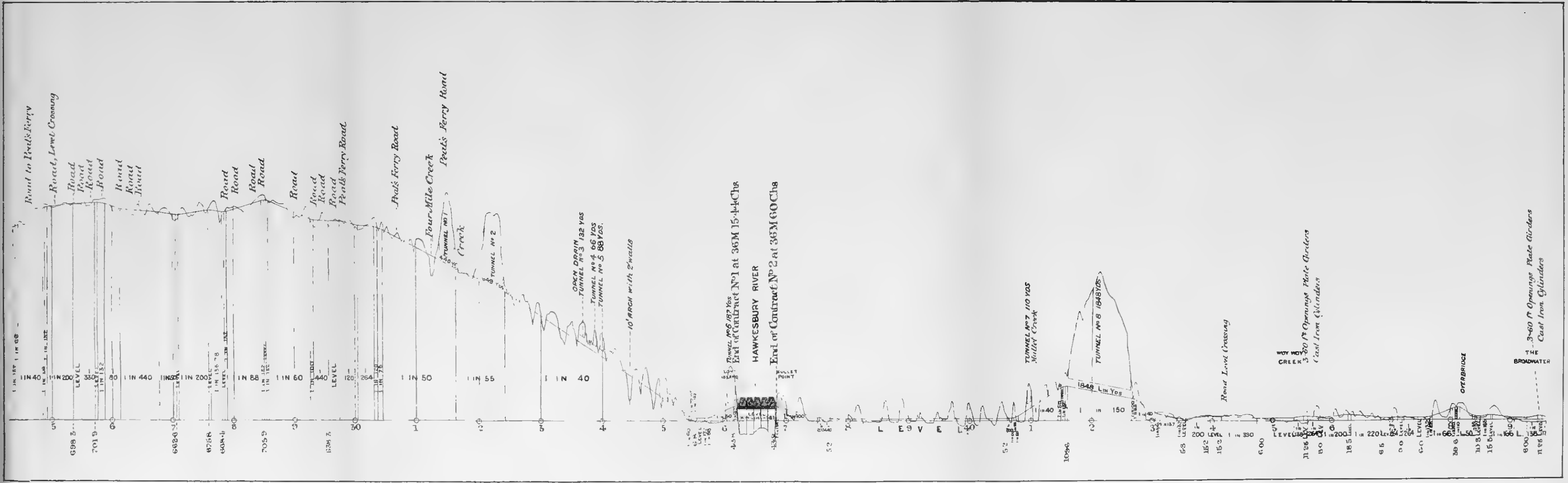
SYDNEY SEWERAGE

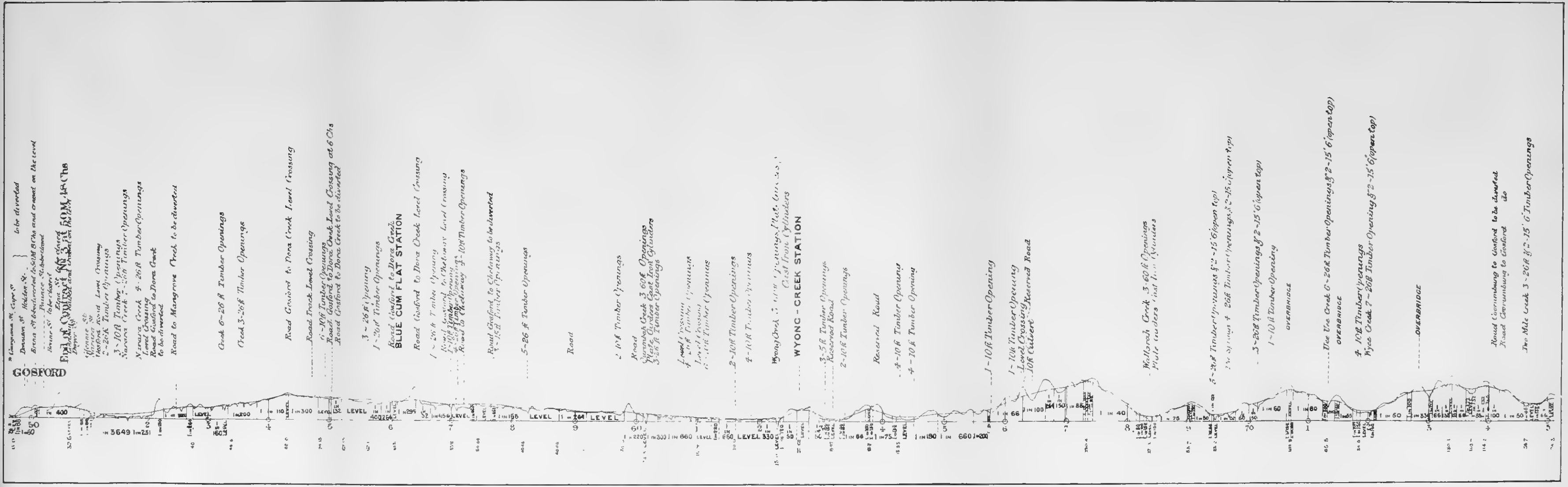


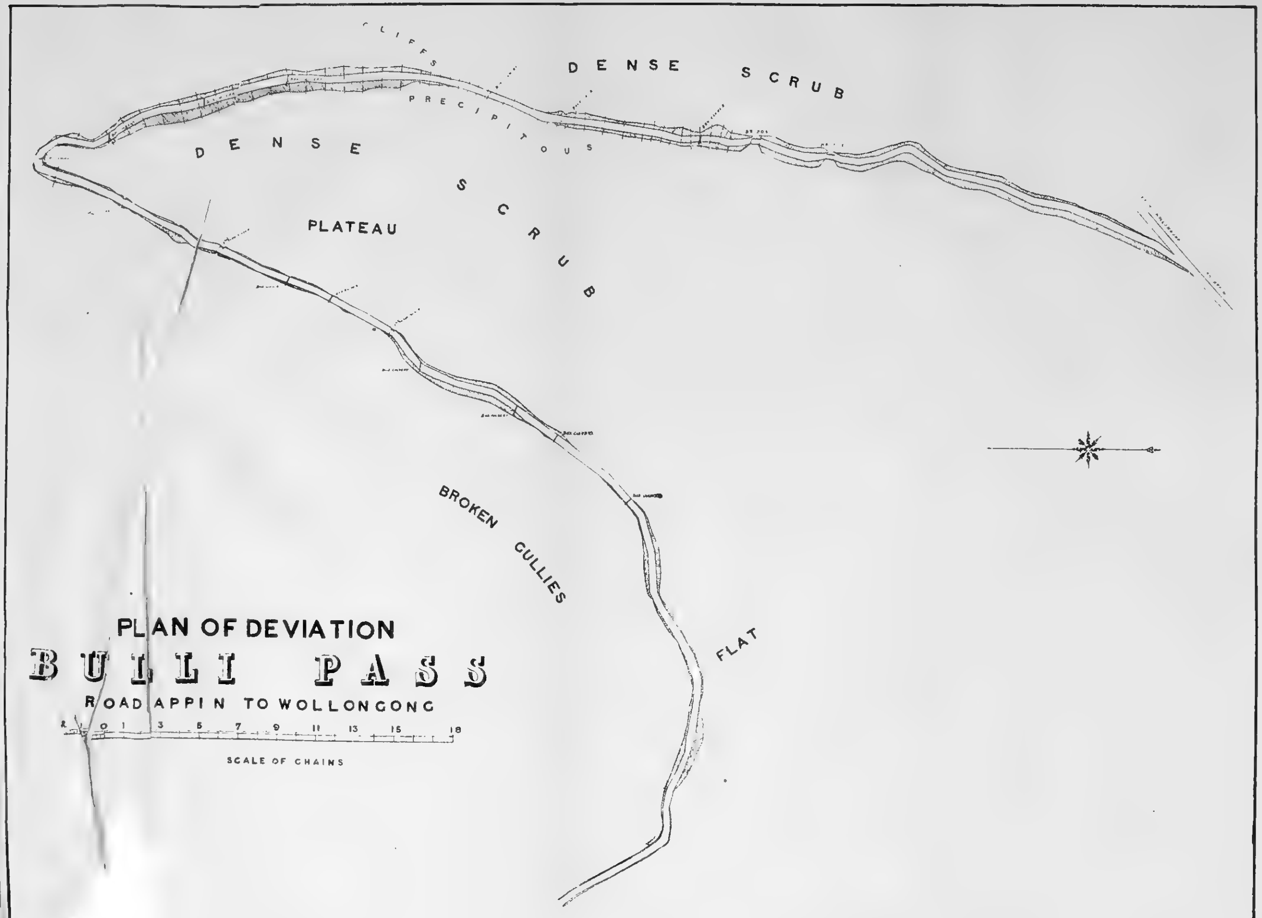

MAP
SHEWING THE
RAILWAYS & MAIL ROADS
IN
NEW SOUTH WALES
John Whitton M.I.C.E. Engineer-in-Chief
September 1887
COLONY OF QUEENSLAND
COLONY OF SOUTH AUSTRALIA
COLONY OF VICTORIA
SOUTH PACIFIC OCEAN
WARRABRI TO WALGETT
NEVERTIRE
WARREN
DUBBO
ORANGE
PARRAMATTA
SYDNEY
LIVERPOOL
YOUNG
ENLARGED DIAGRAM WITHIN A RADIUS OF 20 MILES OF SYDNEY
ENLARGED DIAGRAM WITHIN A RADIUS OF 20 MILES OF NEWCASTLE
MAIL LINES POST OFFICES & TELEGRAPH LINES NEAR BATHURST
BATHURST

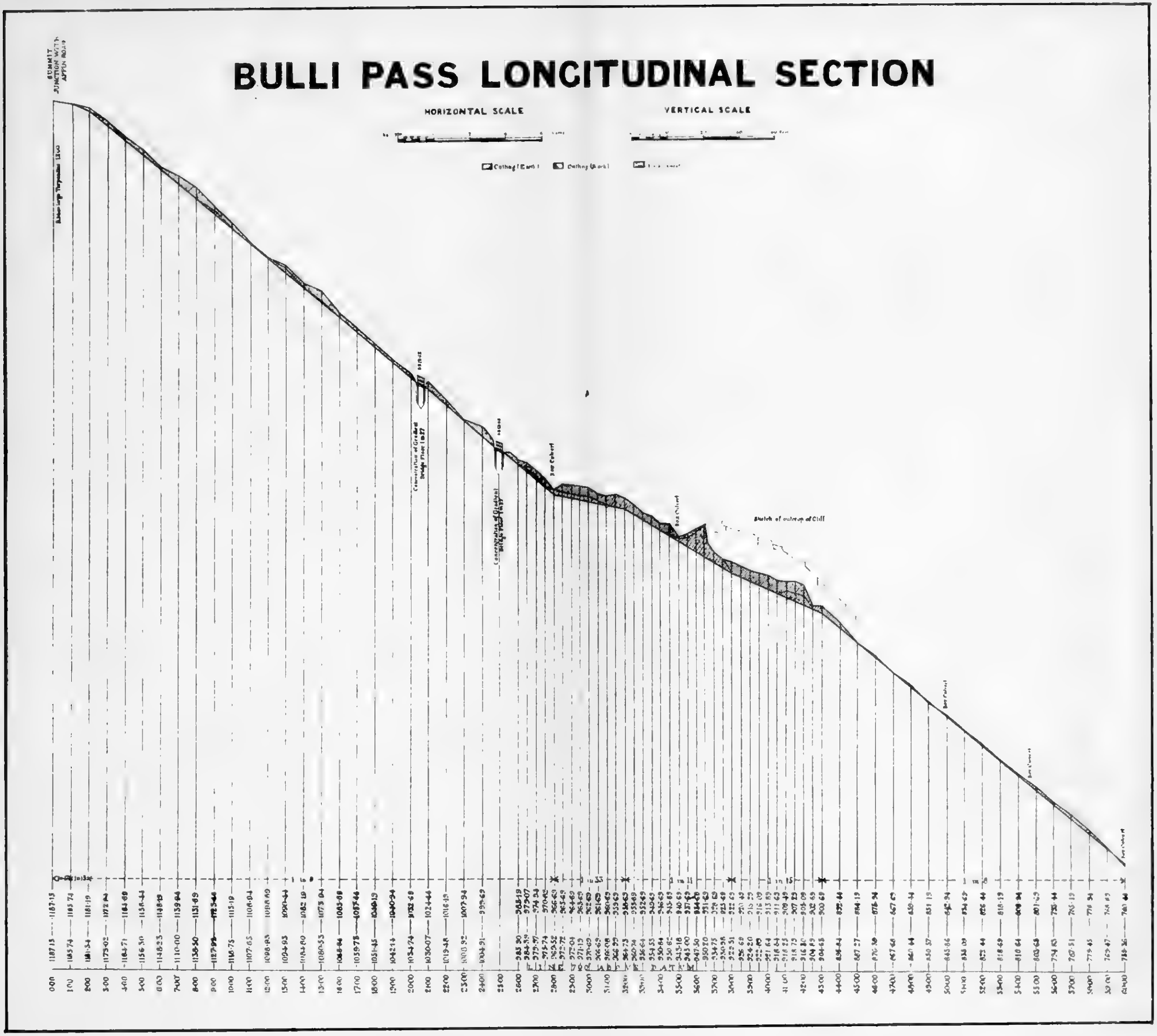

PARRAMATTA RIVER
CONCORD
FIVE DOCK
BALMAIN
CITY OF SYDNEY
OUTFALL SEWER
PADDINGTON
THE GLEBE
NORTHERN
CAMPERDOWN
LEICHHARDT
STRATHFIELD
MACDONALDTOWN
ALEXANDRIA
WATERLOO
CANTERBURY
SOUTHERN OUTFALL SEWER
SEWAGE FARM
BOTANY BAY
DEPARTMENT OF PUBLIC WORKS
SEWERAGE BRANCH
PLAN
OF THE
WESTERN SUBURBS OF SYDNEY.
SCALE
George H. Stayton

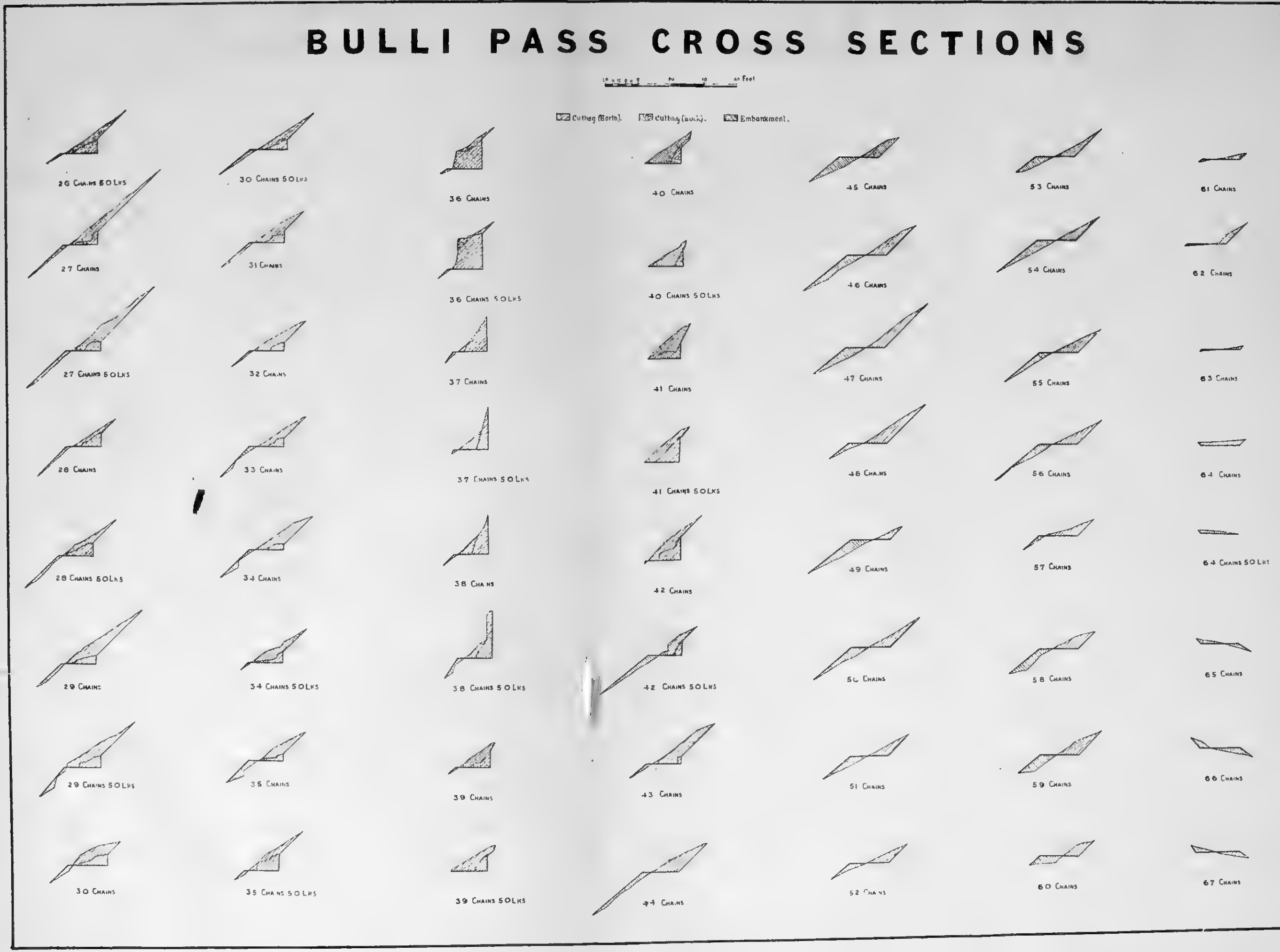

Datum High Water Spring Tides, Sydney
PETERSHAM STATION
Long Cove Creek Viaduct
ASHFIELD STATION
CROYDON STATION
BURWOOD STATION
Junction of Homebush & Waratah Railway
Parramatta Road, Level Crossing
OVERBRIDGE
Level Crossing
BRUNSWICK-PARK
OVERBRIDGE
10' SUBWAY
PLATFORM
10 SUBWAY Road under Iron Bridge
Parramatta River - BRIDGE
PLATFORM
Road
Charity Creek, 20 ft Culvert
Road to Pennant Hills, Level Crossing
RYDE STATION
OVERBRIDGE
OVERBRIDGE
EASTWOOD STATION
20 ft Culvert
OVERBRIDGE
FIELD OF MARS PLATFORM
Creek, 30 ARCH
BEECROFT PLATFORM
OVERBRIDGE
PLATFORM - PENNANT HILLS
Level Crossing
OVERBRIDGE
THORNLEIGH STATION
OVERBRIDGE
Level Crossing
OVERBRIDGE
OVERBRIDGE
OVERBRIDGE
Road to Peat's Ferry
HORNSBY STATION
OVERBRIDGE
Road to Peat's Ferry
OVERBRIDGE
TIMBER OPENING
Level Crossing
Level Crossing


Road to Peat's Ferry
Road, Level Crossing
Road
Peat's Ferry Road
Peat's Ferry Road
Four Mile Creek
Peat's Ferry Road
TUNNEL No 1
Creek
TUNNEL No 2
OPEN DRAIN
TUNNEL No 3 132 YDS
TUNNEL No 4 66 YDS
TUNNEL No 5 88 YDS
10' ARCH with 2 walls
TUNNEL No 6 187 YDS
End of Contract No 1 at 36M 15·44 Chs
HAWKESBURY RIVER
End of Contract No 2 at 36M 60 Chs
MULLET POINT
TUNNEL No 7 110 YDS
Mullet Creek
TUNNEL No 8 1848 YDS
1848 L IN YDS
Road Level Crossing
WOY WOY CREEK
3-60 ft Openings Plate Girders
Cast Iron Cylinders
OVERBRIDGE
THE BROADWATER
3-60 ft Openings Plate Girders
Cast Iron Cylinders
1 IN 40
LEVEL
1 IN 440
1 IN 88
1 IN 60
1 IN 50
1 IN 55
1 IN 40
L E V E L
1 IN 150


GOSFORD
BLUE GUM FLAT STATION
WYONG - CREEK STATION
OVERBRIDGE


CLIFFS
DENSE SCRUB
PRECIPITOUS
DENSE SCRUB
PLATEAU
BROKEN GULLIES
FLAT
PLAN OF DEVIATION
BULLI PASS
ROAD APPIN TO WOLLONGONG
SCALE OF CHAINS


BULLI PASS LONGITUDINAL SECTION
HORIZONTAL SCALE
VERTICAL SCALE
Box Culvert
Sketch of outcrop of Cliff


BULLI PASS CROSS SECTIONS
Feet
Cutting (Earth). Cutting (Rock). Embankment.
26 Chains 50 Lks
27 Chains
27 Chains 50 Lks
28 Chains
28 Chains 50 Lks
29 Chains
29 Chains 50 Lks
30 Chains
30 Chains 50 Lks
31 Chains
32 Chains
33 Chains
34 Chains
34 Chains 50 Lks
35 Chains
35 Chains 50 Lks
36 Chains
36 Chains 50 Lks
37 Chains
37 Chains 50 Lks
38 Chains
38 Chains 50 Lks
39 Chains
39 Chains 50 Lks
40 Chains
40 Chains 50 Lks
41 Chains
41 Chains 50 Lks
42 Chains
42 Chains 50 Lks
43 Chains
44 Chains
45 Chains
46 Chains
47 Chains
48 Chains
49 Chains
50 Chains
51 Chains
52 Chains
53 Chains
54 Chains
55 Chains
56 Chains
57 Chains
58 Chains
59 Chains
60 Chains
61 Chains
62 Chains
63 Chains
64 Chains
64 Chains 50 Lks
65 Chains
66 Chains
67 Chains