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Journal

OF

The Royal Society

OF

Western Australia.

Vol. XXII.

1935-36.

The Authors of Papers are alone responsible for the statements
and
the opinions expressed therein.

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1936.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

OFFICERS AND COUNCIL, 1935–36.

Patron:

His Majesty the King.

Vice-Patron:

His Excellency Sir James Mitchell, K.C.M.G., Lieut.-Governor of the State of Western Australia.

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Professor E. de C. Clarke, M.A.

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L. Glauert, B.A., F.G.S.

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C. F. H. Jenkins, B.A.

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Miss E. Allum.
Miss E. A. Bowley, M.Sc.
C. A. Gardner.
A. Gibb Maitland, F.G.S.
R. T. Prider, B.Sc.
J. F. Filmer, B.V.Sc.
T. H. Wilson.

CONTENTS.

VOLUME XXII.

ROYAL SOCIETY OF WESTERN AUSTRALIA.

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDED 30th JUNE, 1936.

Ladies and Gentlemen,

Your Council begs to submit the following Report for the year ended 30th June, 1936:—

Death of His Majesty, King George V., Patron of the Society.—It was with profound sorrow that Members learnt of the passing of our beloved Patron. The Society's message of condolence and loyalty to King Edward VIII., Queen Mary and the Members of the Royal Family, transmitted through His Excellency the Lieutenant-Governor of Western Australia, has been graciously acknowledged.

Membership.—The number of members has altered but little during the year. Honorary and Corresponding Memberships are unchanged, being respectively nine and six. Ordinary Members (ninety-one) have diminished by one, but Associate Members have increased from fifty-six to sixty-four. There are now two Student Members, compared with eight at the beginning of the year. The roll includes two Ordinary Members and thirteen Associate Members elected during the year, whilst with profound regret are recorded the deaths of Mr. H. W. Bevilaqua, Mr. W. N. Hedges, Mrs. H. J. Lotz, and Mr. D. G. Murray.

Council.—Nine Ordinary Meetings and two Special Meetings of the Council were held during the 1935-1936 Session. In February there was an interchange of Officers. Dr. Serventy, owing to pressure of work at the University, felt obliged to relinquish the post of Joint Honorary Secretary to become Assistant Librarian and Mr. C. F. H. Jenkins, previously Assistant Librarian, was appointed Joint Honorary Secretary.

Finance.—By able service and careful supervision, the Honorary Treasurer, Mr. H. Bowley, and the Editor, Mr. B. L. Southern, have controlled revenue and major expenditure so that the sound financial position of the Society has been maintained.

It must be mentioned again that the publication of our Journal in its present form is rendered possible by Government subsidy. Since July 1, 1935, this grant has amounted to £90, and the Council is indeed grateful for the aid which makes it possible to publish and distribute throughout the world the records of scientific research concerning Western Australia.

The Honorary Treasurer's Report discloses funds to the amount of £97 5s. 4d. lying to the credit of the Society in the General Account, but it must be remembered that approximately £50 will be needed to complete the current volume of the Journal, and a further £30 is earmarked for expenses in connection with the Incorporation of the Society.

The Journal.—Volume XXI. has now been published and distributed amongst Members and Scientific Institutions throughout the world. Volume XXII. is in active preparation, five papers having been completed and three others are in the hands of the printer. It is anticipated that the completed volume will be available early in the new session. As was the case last year, it has been found necessary to defer the publication of papers communicated by Members on behalf of authors not resident in Western Australia. It was considered that whilst any doubt remained as to the financial ability of the Society to print all the papers approved for publication, priority should be given to local authors.

The Government Printer and his staff have co-operated whole-heartedly with the Editor, and the Council desires to thank them sincerely. Mr. B. L. Southern remains in the office of Editor, his willing and efficient services in that capacity being much appreciated.

Library.—Exchange publications now arrive regularly from 150 scientific institutions, 47 of which are in Australia, 17 in the United Kingdom, 17 in other parts of the British Empire, 35 in the United States of America, 31 on the Continent of Europe, and three in Asia. There is an increasing number of requests that our Journal be exchanged for the publications of scientific institutions in all parts of the world.

The thanks of the Society are accorded to Mr. A. Gibb Maitland, Honorary Member of the Society, for the gift of numerous volumes, including series of Geological Records of New South Wales and Tasmania, many of which are out of print and rare.

The Departure of Mr. L. W. Phillips for London.—At the August, 1935, Ordinary Meeting of the Society, opportunity was taken to congratulate Mr. Phillips on his securing a Carnegie Fellowship for Educational Research and to wish both Mr. and Mrs. Phillips bon voyage on the eve of their departure for London. In order to mark the appreciation of the Society for the long-continued and valued services of Mr. Phillips a presentation was made, the cost being defrayed by special contributions made by a large proportion of the Members of the Society. At the time of writing this report, the return of Mr. Phillips is drawing near and the Council hopes that in the next session he will once more assume office as Joint Honorary Secretary.

Incorporation of the Society.—At the Ordinary Meeting on May 12th, 1936, it was moved by Mr. H. Bowley, seconded by Mr. T. H. Wilson, and carried unanimously, "That this Society proceed to Incorporation." At the same meeting the Secretary of the Council was instructed to do all things necessary to effect the Incorporation of the Society. Steps are now being taken to give effect to those resolutions.

Revision of the Constitution and Rules of the Society.—As the result of the labours of a Committee of the Council, a draft of the revised Constitution and Rules was circulated amongst Members in November, 1935. Resulting comments and suggestions were considered by Council, and a final draft was adopted at the Ordinary Meeting held on May 12th, 1936. In view of the approaching Incorporation of the Society, legal advice is being obtained concerning the phraseology. It is expected that printed copies of the Rules will soon be available to Members.

E. de C. CLARKE,
President.

WM. E. SHELTON,
Joint Hon. Secretary.

As President of the Society I wish to place on record my appreciation of the work done by the Members of Council during my term of office, especially the Joint Honorary Secretary—Mr. W. E. Shelton.

E. de C. CLARKE.

ROYAL SOCIETY OF WESTERN AUSTRALIA.

Statement of Receipts and Expenditure for the Period ended 30th June, 1936.

General Fund—

Receipts.

	£	s.	d.
Balance, 21st June, 1935	116	14	0
Interest, 1934–5	2	2	7
Subscriptions	102	18	3
Government Grant, June, 1935, to June, 1936	96	13	4
Authors' Reprints and Refunds for Half Cost of Blocks	4	14	11
Excursion	4	4	6
	£327	7	7

Payments.

	£	s.	d.	£	s.	d.
Petty Expenses, including Postages, etc.				14	16	7
Clerical Assistance				9	0	0
Stationery				3	0	11
Annual meeting, Rent				3	3	0
,, ,, Catering, Heating, etc.				7	10	6
Ordinary Meetings, Catering				9	10	0
Museum Trustees, Rent				12	0	0
,, ,, Attendants' Fees				7	2	0
Editor, Honorarium				15	15	0
Excursion Expenses				4	10	0
Transfer to Medal Fund				7	10	0
Box L906, G.P.O., Perth				3	0	0
Government Printer—						
Journal XXI., completing	58	12	0			
Journal XXII., part cost	61	3	9			
Notice of Meetings	3	7	6			
Miscellaneous Printing	10	1	0			
				133	4	3
Balance, 30th June, 1936				97	5	4
				£327	7	7

Medal Fund—

Receipts.

	£	s.	d.
Balance, 21st June, 1935	15	3	3
Interest	0	5	9
Transfer from General Fund	7	10	0
	£22	19	0

Payments.

	£	s.	d.
Balance, 30th June, 1936	22	19	0
	£22	19	0

Endowment Fund—

Receipts.

	£	s.	d.
Balance, 21st June, 1935	167	1	3
Interest	9	3	8
	£176	4	11

Payments.

	£	s.	d.
Balance, 30th June, 1936	176	4	11
	£176	4	11

Note.—£176 4s. 11d. placed on fixed deposit at Commonwealth Bank, Perth, on 12th June, 1936, for 24 months, bearing interest at 3% per annum.

Summary of Funds at 30th June, 1936.

	£	s.	d.
Credit Balance, General Fund	97	5	4
,, ,, Medal Fund	22	19	0
,, ,, Endowment Fund	176	4	11
	£296	9	3

Perth, 11th July, 1936.

H. BOWLEY, Hon. Treasurer.

Audited and found correct, with books, receipts and vouchers produced, and we consider this a true statement of the Royal Society's Accounts.

R. E. GATHERER,
THOS. H. WILSON,
Hon. Auditors.

ABSTRACT OF PROCEEDINGS, 1935-36.

9TH JULY, 1935—

Annual General Meeting held at Karrakatta Club. Presidential Address: "Plants Poisonous to Live-stock in Western Australia."

13TH AUGUST, 1935—

Addresses—"An Entomologist in the Mandated Territory of New Guinea," Mr. B. A. O'Connor.

"History of the Royal Society of Western Australia," Mr. L. W. Phillips.

10TH SEPTEMBER, 1935—

Paper—"Contributions to the Mineralogy of Western Australia, Series IX.," Dr. E. S. Simpson.

Address—"Building of the Canning Dam," Mr. R. J. Dumas.

8TH OCTOBER, 1935—

Paper—"Basalt from Cape Gosselin," by Dr. A. B. Edwards, communicated by Professor Clarke.

Lecture—"The Denmark Wasting Disease," J. F. Filmer and Dr. E. J. Underwood.

12TH NOVEMBER, 1935—

Lecture—"The Habits of Some Little-known Marsupials," Mr. L. Glauert.

10TH DECEMBER, 1935—

Exhibits—"New and Rare Native Plants," Mr. C. A. Gardner.

"Petrological Exhibit with Transparent Screen," Messrs. R. T. Prider and S. Terrill.

"Soil Sample Showing Columnar Structure and Field Soil Survey Apparatus," Mr. G. H. Burvill.

"Seed Germination Tests," Mr. G. R. Meadly.

"Green-stained Wool with Culture of Staining Organism," Dr. H. W. Bennetts.

"Mineral Specimens," Dr. E. S. Simpson.

"Native Carving," Mr. R. C. Wilson.

"Coccid Galls," Mr. C. F. H. Jenkins.

10TH MARCH, 1936—

Papers—"New Species of Western Australian Psyllid," Mr. M. E. Solomon.

"Soil Survey of an Area at Gingin," Messrs. J. S. Hosking and G. A. Greaves, communicated by Mr. Greaves.

"Upper Devonian Corals from Western Australia," Dorothy Hill, communicated by Professor Clarke.

28TH APRIL, 1936—

Combined meeting with Biological Section.

Paper—"New Species of Apioceridae (Diptera)," Mr. K. R. Norris.

Lecture—"Environmental Factors in Sheep Distribution," Professor J. E. Nichols.

12TH MAY, 1936—

Paper—"Essential Oils of Western Australian Eucalypts, Series III.," Dr. E. M. Watson.

Incorporation and Rules—The members decided to incorporate the Society and, with amendments, adopted the new rules.

8TH JUNE, 1936—

Paper—"Contributiones Florae Australiae Occidentalis, No. IX.," Mr. C. A. Gardner.

Lecture—"Geology of the Toodyay Area," Mr. R. T. Prider.

EXHIBITS.

8th October, 1935—A Kerguelen Island Petrel (*Pterodroma brevirostris*). This was the second specimen found on Western Australian shores, the first having been found on Leighton Beach in 1925; Mr. L. Glauert.

12th November, 1935—Fragments of fossil bones found in the lower greensand at Gingin, the first reported discovery in this formation; Mr. F. R. Feldtmann. Phosphatised wood, previously mistaken for fossil bones, from Dandarragan; Dr. E. S. Simpson.

8th June, 1936—Mr. Glauert exhibited specimens of three species of *Panulirus* occurring on the west coast of Australia. As a result of a re-examination of the material with the help of literature borrowed from the Australian Museum, Sydney, and of a key supplied by Dr. Isabella Gordon, of the British Museum (Natural History), the two common species have to be renamed. The common crayfish of Fremantle is *Panulirus longipes* M. Ed. not *P. penicillatus* Divier, as formerly supposed, whilst the green crayfish of Northern waters must bear the name *P. versicolor* Latr. instead of *P. Ornatus* (Fabricius). A third species *P. homarus* (Herbst.) is represented by a specimen No. 35-35 forwarded to the Museum by Mr. M. Miragliotta, of Geraldton.

PROCEEDINGS BIOLOGICAL SECTION.

Office Bearers:

Chairman .. Dr. D. L. Serventy.
Secretary .. Mr. K. R. Norris.

Ten meetings were held during the year, the average attendance being 15.

23rd July, 1935—
Lecture—"Food Fishes of Western Australia," Mr. F. Aldrich, communicated by Dr. Serventy.

27th August, 1935—
Visit to the State Herbarium led by Mr. C. A. Gardner. Mr. G. R. Meadly opened a "Discussion on Seed Testing."

28th September, 1935—
Lecture—"The Practical Applications of Genetics," Mr. C. B. Palmer.

22nd October, 1935—
Lecture—"The Physiology of the Blood," Mr. L. Barr.

25th November, 1935—
Discussion on "Recapitulation" led by Mr. M. E. Solomon.

17th December, 1935—
Meeting held at the Department of Biology, University, Crawley.
Lecture—"Experimental Entomology," with particular reference to the ecology and physiology of the red-legged earth mite *Halotydeus destructor*, by Messrs. M. E. Solomon and K. R. Norris.

17th March, 1936—
Discussion on "Migration" led by Dr. Serventy on birds and Mr. C. F. Jenkins on mammals.

28th April, 1936—
Lecture—"Environmental Factors in Sheep Distribution," Professor J. E. Nichols. Combined meeting with the general section.

26th May, 1936—
Lecture—"Locust Problems," Mr. C. F. Jenkins.

23rd June, 1936—
Lecture—"Some Impressions of a Recent Visit to the Museums in the Eastern States of Australia," Mr. L. Glauert.

WATER SUPPLY IN THE KALGOORLIE AND WHEAT BELT REGIONS OF WESTERN AUSTRALIA.

PRESIDENTIAL ADDRESS.

By E. DeC. Clarke, M.A.

Read 16th July, 1936; Published 31st August, 1936.

WATER SUPPLY IN THE KALGOORLIE AND WHEAT BELT REGIONS.

CORRIGENDA.

Page XIV, third line from bottom, for " were " read " was."
" XXIII, 7th line, for " Wheat Belt " read " Kalgoorlie Region,"
" " section (1) of Introduction, 3rd line, for " Kalgoorlie Region," read " Kalgoorlie Region—"
" " section (3) of Introduction, first line, for " perenially " read " perennially."
" " fifth line from bottom, for " plant " read " plain."
" XXVI, 20th line, for " Coolgardie." read " Coolgardie ; "
" XXXIV, 25th line, for " bore-sights " read " bore-sites "
" XLI, fig. 23, part left blank in centre of diagrams is granite or gneiss.

posed to deal, but it seems to an interested spectator that an attempt might be made to describe the various phases of a very strenuous game against Nature, from its opening, when the odds seemed all against Man, to the present, when he is on the road to victory.

The water supply problems of the whole State are too many to be discussed in a short address. Consideration will therefore be limited to two inland geographical "regions," which are shown in Fig. 1 with the same boundaries as in an earlier paper (Clarke, 1926), except that the southern part of the Wheat Belt as there defined is now made into a distinct region —the Stirling—because, for reasons primarily geological, it is unsuited for wheat-growing.

The following population figures, supplied by the Government Statistician, show that the Kalgoorlie and Wheat Belt are two of the most populous natural regions of the State:—

Population of whole State on June 30, 1935		445,692
"	Perth Region " " about	244,800
"	Wheat Belt " " "	78,200
"	Jarrah " " "	61,100
"	Kalgoorlie " " "	32,400
"	Greenough " " "	10,600

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CONTENTS.

INTRODUCTION.

The familiar saying that the man in the pavilion sees the most of the game is some excuse for an address on such a subject as this. There are many still with us who have borne or are bearing the burden and heat of the day and are fully qualified to deal with matters of which I have only a general knowledge. Indeed several authoritative papers have been written on various aspects of water supply in the area with which it is proposed to deal, but it seems to an interested spectator that an attempt might be made to describe the various phases of a very strenuous game against Nature, from its opening, when the odds seemed all against Man, to the present, when he is on the road to victory.

The water supply problems of the whole State are too many to be discussed in a short address. Consideration will therefore be limited to two inland geographical "regions," which are shown in Fig. 1 with the same boundaries as in an earlier paper (Clarke, 1926), except that the southern part of the Wheat Belt as there defined is now made into a distinct region —the Stirling—because, for reasons primarily geological, it is unsuited for wheat-growing.

The following population figures, supplied by the Government Statistician, show that the Kalgoorlie and Wheat Belt are two of the most populous natural regions of the State:—

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,,	Kalgoorlie	,,	,,	,,	32,400
,,	Greenough	,,	,,	,,	10,600

I propose first to describe how the problem of obtaining supplies adequate for then-existing needs was attacked in the days of exploration, in the days of the great gold rush and during the expansion of agriculture; second to consider what are the causes—climatic, physiographic and geologic

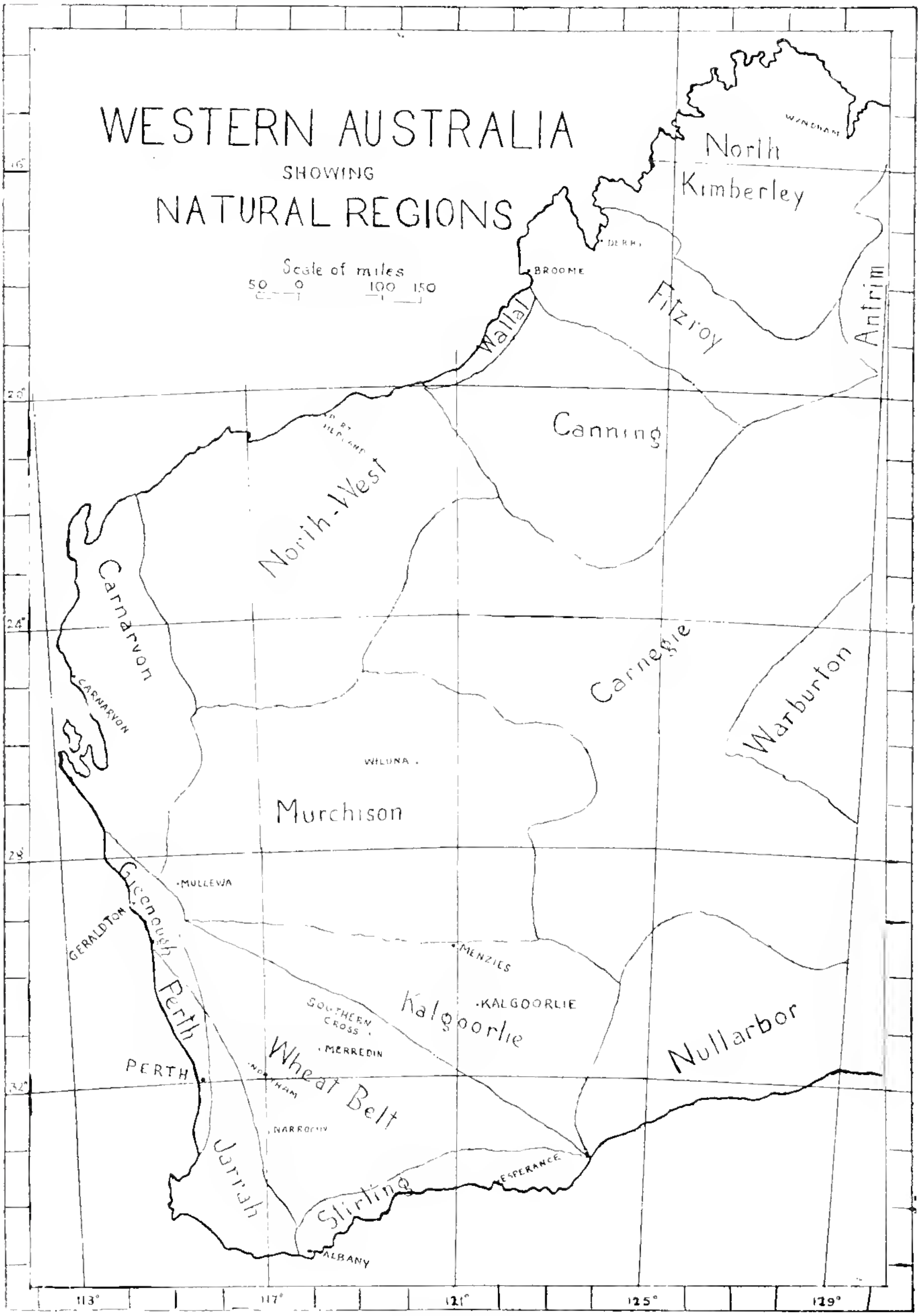

Fig. 1.

—of the water supply difficulties in the two regions, for, if the causes are understood, reasonable ways of overcoming the difficulties are more likely to be found. This has all been written or said before at various times no doubt, but an attempt at a general survey may be of some interest.

This paper, being merely a compilation, owes whatever value it has, in part to published work which is listed in the bibliography, and, to an equal degree, to many who have generously made their special knowledge available. It is a pleasure to record here the willingness with which this invaluable help was given by officers in various Government departments and by others, and also to thank Messrs. J. P. Camm, Surveyor General; G. L. Sutton, Director of Agriculture; S. Bennett, Government Statistician; B. S. Crimp and W. K. Weller, engineers in charge of the Water Supplies to the Agricultural Areas and Goldfields, and E. B. Curlewis, Divisional Meteorologist of the Commonwealth Weather Bureau for permission to use information supplied by themselves and by their officers: to Mr. F. G. Forman, Government Geologist I am indebted for help in many ways. I have also had the benefit of discussing the subject with Mr. P. V. O'Brien, formerly Engineer-in-Charge of Water Supply, with Mr. T. C. Hodgson who was Engineer-in-Charge of the Coolgardie Water Supply at the time of its construction, with Mr. A. Gibb Maitland, who was Government Geologist of this State for 30 years, and with Dr. J. S. Battye, Principal Librarian, Perth Public Library. For the use, or misuse, to which the information supplied by those mentioned, and by many others, has been put in this paper, I am solely responsible.

EXPLORATION OF THE REGIONS.

A good deal of the subject matter of this section is from explorers' journals and maps in the offices of the Lands Department.

A strip of coastal plain, about twenty miles wide, on which the town of Perth stands, ends somewhat abruptly against the Darling Scarp, which is not, however, an obstacle comparable to the Blue Mt. Scarp of Eastern Australia, and, although the first settlement of the Perth Region was only in 1829, yet, by the middle of 1830, Ensign Dale was exploring to the east. The town of York was founded in 1830 and in 1833 the sites of Toodyay and Northam were surveyed. From then until 1860, however, attention was largely diverted from the hinterland to other parts of the Colony, the most notable explorations being those of Grey in the Kimberley in 1837 and from Shark Bay to Perth in 1839, Eyre's crossing from Adelaide in 1841, and the explorations by A. C. Gregory in 1846 and 1848 and by F. T. Gregory in 1861.

In 1843 Landor and Lefroy made an expedition to the S.E. of York. Their reports regarding the possibilities of the country were generally unfavourable. In 1848 J. S. Roe explored to the S.E. of York, discovering Bremer Ra. and Fitzgerald Peaks (Peak Charles).

On July 3, 1861, C. and A. Dempster, B. Clarkson, and C. Harper travelled in a S.S.E. direction from York and discovered and named Lake Grace. In their reports is the first reference which I have seen to the importance of bare granite outcrops as water catchments.

The pioneer explorers of the Kalgoorlie Region were H. M. Lefroy and C. C. Hunt.

Lefroy's expedition was organised by the Colonial Government at the request, and with the aid of the Agricultural Society of the York District, for the purpose of exploring the interior, east of York, with the special object of discovering districts suitable for sheep-farming. The party, consisting of four white men and an aboriginal, left York on May 7th and returned to York on August 1st, 1863. Lefroy's journal is full of interest and shows remarkable appreciation of the peculiarities of this region which was now being traversed for the first time. Thus Lefroy noticed and described the capping which is now known as duricrust or laterite; he also stated that the country as far east as long. 118° consists of "Primitive granite which has been fractured, first and principally along the line of the west face of the Darling Range," the east side of the fracture having been "slightly lifted without tilting to form the barren and elevated tract of country which we call the Darling Range."

Till May 24th Lefroy's party had cloudy weather and a good deal of rain, which accounts for the absence of mention of any water difficulty.

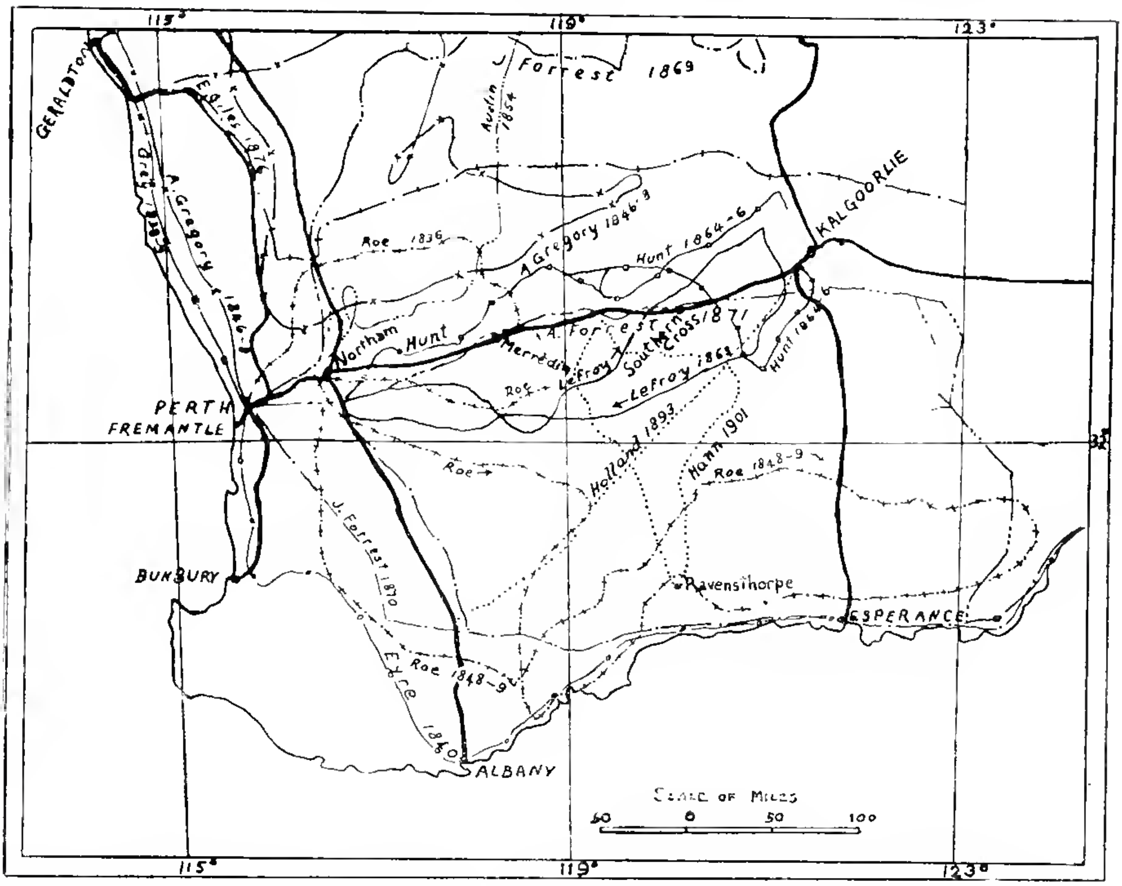

Fig. 2.—Map of Southern Western Australia showing routes of chief explorations. Principal railways also shown. (From information supplied by the Surveyor General.)

East of long. 118° the character of the country altered somewhat, there being no definite lines of drainage. Lefroy noted the importance, in connection with water supply, of the "bald hills" of "granite" and "endeavoured to refer their distribution to some general lines of geographic direction; however, their distribution is so arbitrary, generally being isolated, sometimes forming short ranges whose axes have every variety of bearing, their form is so rounded, the flat valleys which intervene have such a uniform level from which the hills spring up to a very uniform elevation" that he was unable to explain their origin on any theory of hill-making known to him. In the middle of the 19th century the idea that hills have generally been formed by erosion was not, as now, common property.

By June 10th, the party had passed out of the region of "bald hills," were near Mt. Burges, and began to suffer from scarcity of water. On June 15th, the horses having been 72 and the men 24 hours without water, and being six days from any reliable supply of water (the last of the "bald hills"), Lefroy turned back. Fortunately, fresh water which had run over the surface in a rainstorm a few days before and was "surcharged with clay" was found in a claypan.

In the next few days Lefroy realised that ground water in this region is, in the vast majority of cases, salt. He concluded that "future settlers must limit their search for good water to the upper portions of the hills and, having studied the contours of the bare portion of the rock, form the best conjecture which may be possible as to the position of the concavities of the granite buried beneath the soil, and sink wells directly into the computed centre of one of these."

Lefroy was generally optimistic regarding the pastoral possibilities of the region which he had traversed, and thought the water problem by no means insoluble.

On July 9th, 1864, C. C. Hunt's expedition, second only in importance to Lefroy's, left York in search of pastoral country. The party, which had been organised by the "united efforts of the York Agricultural Society and the members of the Exploration Committee with the assistance of the local government," consisted of five white men and two aboriginals. Included in Hunt's party were the police constable, Edwards, and the aboriginal, Kowitch, who had been with Lefroy. Hunt got farther east than his predecessor, discovering and naming Lake Lefroy on August 21st. He returned to York on November 4th.

Hunt again left York on July 9th, 1866, on a second expedition over much the same route. He was accompanied by four white men and three aboriginals, and his equipment included 26 horses and a cart. He found conditions more difficult than on the previous journey and was of opinion that the last three years had been ones of excessive drought. Owing to lack of water he could not penetrate much beyond the Hampton Plains, the western edge of which he had previously reached and named. He concluded that "portions of the country, at certain seasons of the year, are well grassed, but, in the absence of known permanent water I fear it can never be made available for pastoral purposes."

Another, and perhaps the last, expedition that belongs to this period of pioneer effort, was that of A. Forrest, who, with five men and provisions for six months, left York on August 11th, 1871. He followed Hunt's track to "Slate Well," on the border of Hampton Plains, where he made a main camp and explored thence to the E.N.E., east and E.S.E. His farthest east seems to have been 31° S., 123° 37′ E. He then travelled to Esperance, discovering, en route, Fraser Range which he described as splendid grassy country. Forrest appears to have covered even bigger distances than his predecessors without water, at any rate for the horses, and also to have travelled farther in a day—30 miles being not uncommon.

The expeditions of J. Holland in 1893 and of F. H. Hann in 1901, though of much later date, are noteworthy for they added much to our knowledge of the Wheat Belt. Their routes are indicated on Fig. 2. Regarding Hann's expedition I have no information, but Mr. J. Carmody has very kindly supplied the following notes regarding Holland's:—

"There were four of us in the party, John Holland (Leader), Rudolph and Dave Thrackourer (Brothers) and myself; we left Broome Hill on the 10th April, 1893, with two horses in a dray and one saddle horse and provisions for six months. We arrived at Coolgardie about June 21st, 1893. We travelled north-east all the way, touching Mt. Holland and Lake Carmody, which we named after ourselves. Why Mr. Holland chose to go by an unexplored route was (1) because he thought there had never been a white man through the country before, (2) because it shortened the journey by over a hundred miles, and (3) to see if there was any gold bearing country on the route; he did strike Mt. Holland which he thought was gold bearing country, and it proved itself so in later years. On account of travelling in the winter months and striking a lot of granite rock country we were never short of water but we did experience a shortage of horse feed; other than that we did not encounter any difficulties."

It is evident then that no part of the Wheat Belt offers insuperable difficulties in the matter of water supply to experienced men.

THE GOLD RUSH.

In 1854 Surveyor Austin had declared that Mt. Magnet in the Murchison Region was likely to become the centre of one of the richest goldfields in the world. There are well-founded rumours that gold was found in the Kalgoorlie region by Lefroy's and Hunt's parties. It is difficult to believe that these observant men failed to notice the "alluvial" gold that was afterwards found in such quantity in the country over which they had travelled so arduously, and almost equally difficult to believe that, if gold had been found by them, the fact could have been kept a secret merely because the Government dreaded the influx of population and the upset of its conservative methods.

The first authentic discovery of gold in W.A. was made at Peterwangy in 1870 (W.A. Year Book, 1898—9, 1, p. 57). In 1886 came the Kimberley rush. The direct results of this were disappointing, but an indirect effect was to draw attention to the possibilities of this side of the Continent and to bring across many daring prospectors who later tried their luck in other parts of the Colony. In 1887 the finding of a few specks of gold near Toodyay led to the organisation of a party under Colreavy which examined the country between Toodyay and the Yilgarn Hills and led, eventually, to the finding of gold at Southern Cross by Riseley. Finds rapidly followed, chiefly in the country north of the Kalgoorlie Region. The easterly advance had halted, but only for a short time. In April, 1892, Bayley and Ford followed the explorer Hunt's track and found gold at Coolgardie. In June, 1893 Hannan found gold on the present site of Kalgoorlie and the Region was rapidly prospected in all directions with some disappointments but with many striking successes.

Lefroy had noticed that "bald hills"—the early explorers' mainstay for water—are rare in the country which was being ransacked by all sorts and conditions of men. It is difficult now to realise the living conditions on the W.A. goldfields and more particularly in the Kalgoorlie Region in the early 90's. A few inadequate soaks, shallow wells, and water holes were the only natural source of supply for the very large number of men who "rushed" from one find to another generally heeding very little whether or not water was obtainable at the newest Eldorado. It was not uncommon for water to be sold at 2s. 6d. a gallon. The business of condensing water from the brine occurring a foot or two below the salt-caked surfaces of the lakes was lucrative with the price per 100 gallons ranging up to 30s. When rain did fall, the water which ran over the surface was used without any precautions and quite regardless of the total neglect of sanitation. The consequence was a heavy death-roll from typhoid—then a dangerous disease.

It was fortunate that W.A. had, in 1890, become a self-governing colony, freed from the "dominance of Downing Street," and that it had as Premier, John Forrest, whose unshakable confidence and steadfast courage had already been proved in his exploratory work, that in 1891, the post of Engineer-in-Chief and Acting General Manager of Railways was given to C. Y. O'Connor and that the Colony had also secured the services of other able and energetic engineers, of whom, as of O'Connor, it can be said that they "joined with the best engineering knowledge a realistic sense of what answered the economic needs of the time and place" (Shann, 1934).

Forrest and his colleagues boldly embarked on costly undertakings in order to assist the new industry which they realised would bring prosperity to the whole community. Even in 1891, before Coolgardie had been discovered, money was voted for railways, postal and telegraphic communication and search for local water supplies in the eastern goldfields. When the sensational finds were made it was immediately decided to push the railway up to them.* Water was essential for the establishment and maintenance of the railway; but how much was needed and how was it to be got? Before the extension to Southern Cross was completed the traffic was estimated at one train each way per week, but an apparently excessive estimate of one train each way per day should, it was thought, be provided for. When the rush to Coolgardie was at its peak, a minimum of ten and a maximum of twenty locomotives had to be watered daily (Shields 1901). Nothing was known about the water resources of the country east of Southern Cross, though had Lefroy's journal been available, the engineers, new to a land in which there were no water courses, let alone surface water, would have been a trifle reassured. Almost the only available rainfall statistics were for 12 years at Northam (varying from 8 to 20 inches) and Southern Cross for four years (varying from 5 to 15 inches). From the beginning, engineers seem to have concentrated on rock-catchments, strenuous efforts being made to bring them into operation at the earliest possible moment so that no chance shower would be lost.

The position of most of the chief towns along the main railway in the Wheat Belt has been determined by the occurrence of rock catchments from which locomotives could be supplied; in the Kalgoorlie Region their position has been determined by the occurrence of gold-bearing formations.

Equally exacting was the duty which devolved on, or rather, was shouldered, mainly on their own initiative, by such men as P. V. O'Brien and his associates, of supplying water to the communities which sprang up in a day at new finds. Experienced prospectors, pushing out into the unknown, could fend for themselves; not so the mixed assortment, drawn from every walk in life, that followed them wherever they might be, as soon as the whisper went round that someone had "struck it rich" say 90 miles to the north-west. The water hole that held ample supplies for one or two pioneers would not keep "the mob" for more than a day or two. In face of great difficulties the water supply officials succeeded in supplying water—it might indeed, for a time, be only one gallon per man per day—to these mushroom settlements; sometimes condensers were hastily improvised (the Government condensers yielded as much as 2,000 gallons per day), sometimes water was carted by camels (O'Brien was the first to introduce the very efficient method of transport by carts drawn by bullock camels). If the find showed signs of permanence steps were taken to secure a better local supply by well or catchment (O'Brien, 1918).

* In 1892 the railway from Northam to Southern Cross was being constructed, by 1896 it had reached Coolgardie, it was open to Menzies two years later.

It was realised that water was needed, or would be needed, not only for human consumption but also for metallurgical processes. To some extent the saline groundwater, though highly undesirable for boilers, may be employed in ore-treatment, though for some processes (the cyanide for example) its use adds to the expenses very considerably; but, in any case, with the exception of a few centres such as Westonia where, for months, water was pumped from one of the mines at the rate of 60,000 gallons an hour, water of any kind is insufficient in quantity; figures kindly supplied by Mr. R. C. Wilson, State Mining Engineer, show that the mines of the "Golden Mile" do not pump more than 360,000 gallons per day from their workings, whereas their daily water consumption is more than twice that amount (see table of distribution of water from Mundaring Weir below).

From 1891 to 1895 various ways of overcoming the water difficulty, particularly well-sinking (to obtain supplies of ground water), the provision of surface catchments and boring to considerable depths (to tap supposed supplies under artesian pressure) were suggested, deep boring being the most favoured. During this period of "trial and error" the Forrest Government, in spite of advice from various geologists, put down a bore to a total depth of 3,002 feet 6 inches near Coolgardie; the bore entered granite at 16 feet and, except for an interlude of 440 feet of "diorite," continued in granite to the bottom (Maitland, 1897).

In 1895 O'Connor and T. C. Hodgson began to plan the "Coolgardie Water Scheme" by which when completed in January, 1903, water was pumped from a 4,600 million gallon reservoir, in the Darling "Range," to Kalgoorlie, a distance of 351 miles. A well documented account of this great undertaking has been given by Harris (1934) and engineering details will be found in Palmer's (1905) and O'Brien and Parr's (1918) papers. Reynoldson, however (1935), has pointed out that there has not been due recognition of the very important contribution of T. C. Hodgson to the success of the scheme of which, under O'Connor, he had charge from its inception. He searched the Darling Range for a suitable site for the reservoir, surveying about 20 possible sites in the course of the investigation, and finally selecting the valley of the Helena River at Mundaring; his experience led him to recommend an increase in power for pumping by 40 per cent. over that thought necessary by experts in England and to make the weir of a size that some thought unnecessarily great but which later experience has shown was required to meet the variations in rainfall in the catchment; he was largely responsible for the adoption of the locking-bar type of pipes, without which the loss by leakage would have been so great that the whole scheme would probably have been a failure.

The following table shows the distribution of the water pumped from Mundaring Weir during the year ending 30th June, 1935:—

West of Southern Cross (*i.e.*, largely to agriculturists—a use probably unforeseen by both Forrest and O'Connor)	349 million gallons	(340)
East of Southern Cross—		
Towns of Kalgoorlie and Boulder ..	172 million gallons	
Mines in Kalgoorlie and Boulder ..	343 million gallons	
Railways	9 million gallons	
Outside Kalgoorlie and Boulder ..	36 million gallons	
	560 million gallons	(560)
Total ..		900

The area served by the Mundaring scheme is shown on Fig. 3, including the extension, 101 miles long, from Coolgardie to Norseman which is now under construction. Renovations to the main pipe-line, now in progress, will, when completed, make it capable of supplying eight million gallons per day in its western part and five million gallons per day at Kalgoorlie.

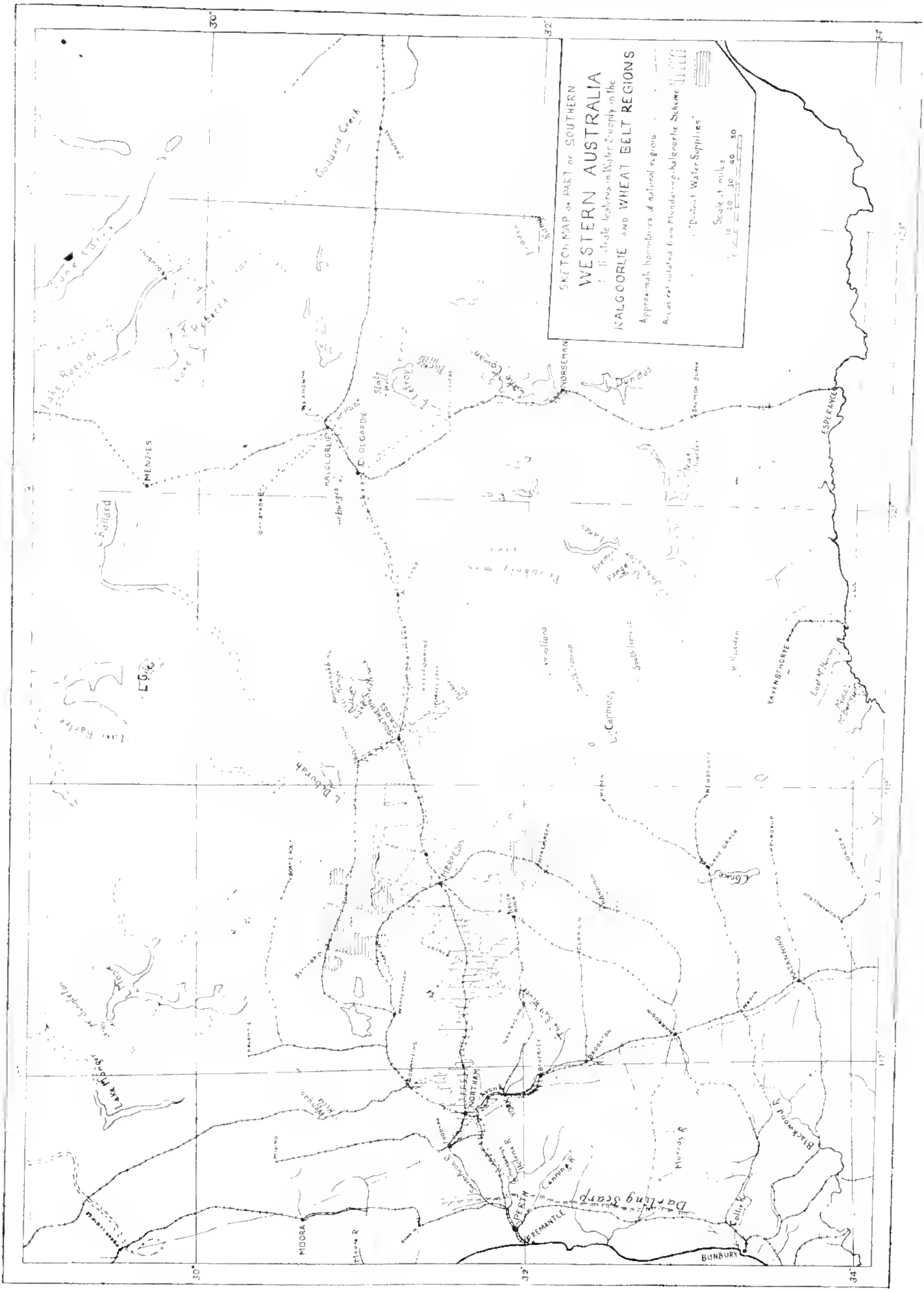

Fig. 3.

Water is supplied to mines in the Kalgoorlie Region and for other industrial purposes at about 7s. per 1,000 gallons, for domestic purposes the price is somewhat lower.

At the present time practically all important mines in the Kalgoorlie Region obtain water for mining purposes from the Mundaring Scheme. The recent addition of branches to Marvel Loch and Yellowdine and the branch to Norseman which is nearing completion, are evidence that the Mundaring water is preferred to the local salt water which, in some of the places cited, would certainly be obtainable in large quantities.

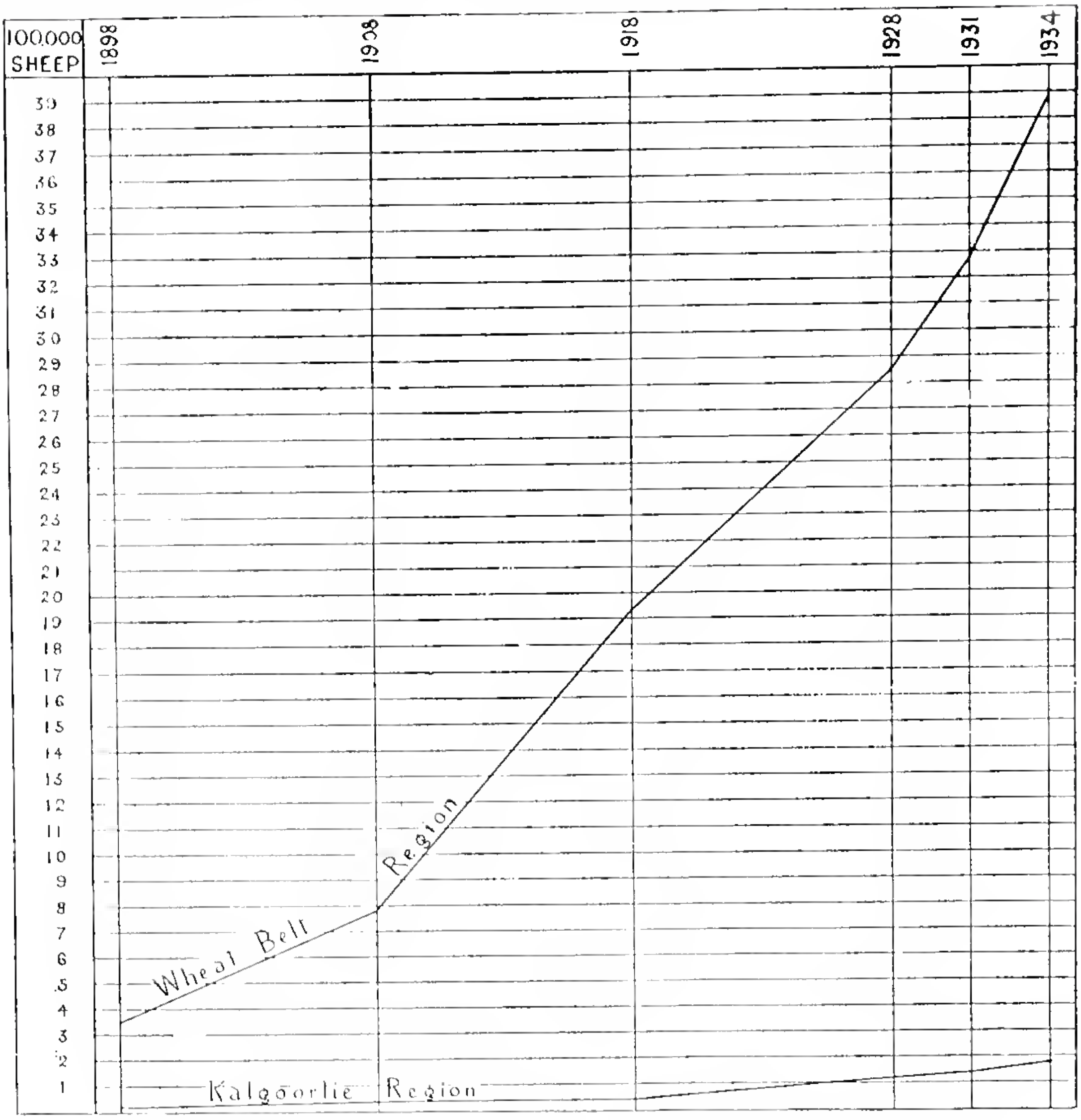

Fig. 5. Diagram showing number of sheep in Wheat Belt and Kalgoorlie regions (from figures supplied by Government Statistician).

DEVELOPMENT OF THE WHEAT BELT REGION.

In the first years of the settlement of the Colony various crops, including wheat, were grown on the Swan coastal plain, but, soon after the York and Toodyay districts had been settled (1831-33), the superiority of the inland regions for wheat became evident. However, not till about 40 years after Lefroy and Hunt had searched eastward for pastoral country, was it realised that wheat can be grown successfully 150 miles east of York.

In 1905 gold production was definitely declining; local secondary industries had to face free competition with the Eastern States, owing to Federation; local revenue was declining owing to increasing diversion of Customs dues to the Commonwealth (Colebatch, 1929). In 1894 the Agricultural Bank had been formed by the Forrest Government to assist the early stages of land development. The Government, now convinced that the future of the country depended on the development of agriculture, made the terms, under which Agricultural Bank assistance could be obtained, progressively more and more liberal. The man who, in his firm conviction that a great primary industry was on the eve of development and in his ceaseless endeavour to foster that development recalls the characteristics of Forrest, was Mr. (now Sir) James Mitchell. The vision of Mitchell and others has materialised to this extent that, whereas in 1905 the State was importing flour, in 1929 wheat to the value of £6,692,000 was exported, and we were "producing more wheat per head of population that almost any other country in the world" (Colebatch). The maps forming Fig. 4, page xlv., for which I am greatly indebted to Mr. R. P. Roberts, B.Sc. (Agric.), of the State Department of Agriculture, show the growth of the area under wheat since 1888.

A wheat farm can be brought through the early stages of development with a water supply sufficient only for men and horses (or engines more commonly at this stage). But, consequent on the catastrophic fall in the price of wheat from 4s. 6½d. per bushel, f.o.b., in the season 1929-30 to 2s. 3¼d. in the season 1930-31, it became very necessary for the farmer to grow sheep as well, and thus there has been a great increase in the demand for water. The growth of the pastoral industry in the Wheat Belt is indicated by Fig. 5.

Further it was realised that, if people are to be induced to regard their farm as their home and not, like a mine, a place to be left as soon as possible after one has amassed sufficient wealth, living conditions must be made as healthy and pleasant as possible, and for this, a sufficiency of water is the first essential (Sutton, 1925). The Government has helped very materially in the following ways to meet the increased demand for water:—

1. By reticulation from the Mundaring-Kalgoorlie pipe-line. By this means about one million acres in the Wheat Belt are supplied at charges determined by distance from the main pipe-line and by other factors, the price varying from 2s. to 4s. per 1,000 gallons. The charges for domestic supplies in towns in the Wheat Belt are somewhat higher than for farms in the same locality.

2. By "District Water Supplies," *i.e.*, reticulation from rock-catchments of which further mention will be made later. The charge for this water is about 4s. per 1,000 gallons. District water supplies at present serve about 700,000 acres.

3. By provision, in areas not included in either of the previous schemes, of wells or of tanks fed from catchments, if possible a rock catchment, but in some places it is perforce of soil and in a few of galvanised iron roofing (Fig. 6). No charge is made for the water from these sources, from which water may be carried. Approximately 480 tanks and 540 wells of this class are in commission.

4. In case of acute water-shortage, by railway transport of water for which the charges are 2s. 6d. per 100 gallons to farmers, 4s. 6d. to others, although these charges do not on the average by any means cover the total expense of rail transport.

An idea of the extent of country in the Wheat Belt, now more or less under cultivation, is obtained from the following figures supplied by the Government Statistician for the season 1934-5:—

Under crops	3,314,078	acres.
Under artificially sown grass	41,357	,,
Under fallow	2,138,888	,,
New ground being prepared for cropping ..	94,285	,,
Previously cropped, used for grazing or lying idle	5,134,360	,,
Ringbarked	724,493	,,

It is evident therefore that, despite the invaluable assistance rendered by the State, private enterprise must in the main be responsible if the region is to increase in population and production.

Sutton (1925) points out how important it is, on the score of economy, that every farmer in non-reticulated areas should have his private supply. He notes that a roof 30 feet by 40 feet will collect more than 3,000 gallons, and that buildings covered with a ton of galvanised iron will collect approximately 5,000 gallons in a year from a five-inch rainfall. Provision of more adequate storage for the run-off from buildings is one rather neglected means of tiding the farmer and perhaps some of his stock over droughts.

Fig. 6.—A roof catchment, about 40 miles west of Kumarl on track to Mt. Holland. (Photo. by Prof. J. A. Prescott.)

DEVELOPMENT OF PASTORAL INDUSTRY IN THE KALGOORLIE REGION.

In 1863 Walter Padbury had laid the foundations of the pastoral industry in the North-West Region—settlement of the Murchison Region followed a few years later, so that, in these more northerly parts, the pastoral industry preceded gold-mining. In the Kalgoorlie Region, on the other hand, in spite of the investigations by Lefroy and Hunt (1863-66), there does not seem to have been any serious attempt at stock-raising until about 1915. Mr. P. V. O'Brien has suggested to me that the fact that stock can not only be kept alive but will also improve in condition on the natural vegetation was first discovered by the butchers of the goldfields towns. In the early stages of the pastoral industry attention was mainly directed to cattle, but it was soon found that they rapidly lose condition in this region in the long dry summer. Sheep, on the other hand, are fairly well suited by the climatic and other conditions, provided, of course, that there is a sufficient water supply. There lies, east of the town of Kalgoorlie, an area, probably of several million acres, excellent for sheep if the requisite water, on the average one gallon per sheep per day, is assured and, since 1925, much of this country has been leased from the State as sheep runs. Unlike the "Mulga Country" which begins about a hundred miles farther north (Clarke, 1926, p. 124) the ground-water, if not deficient in quantity, as it generally is, nearly everywhere is too salt even for sheep. The only solution then of the water problem in this area lies in catchments, which, I am told by Mr. P. V. O'Brien, will have to be mainly on soil-covered country. The following particulars, kindly supplied by Dr. J. E. Nichols, Professor of Agriculture in the University of W.A., may be quoted in support of the statement that, in all but the northernmost part of the Wheat Belt, ground water is of little use pastorally:—

Name of run.	Location.	Area. acres.	Type of water supply.
Pinnacles ...	About 170 miles N.N.W. of Kalgoorlie (in Murchison region)	780,000	79 wells, depth to water-level about 52ft.
Yundamindera	About 100 miles N.N.E. of Kalgoorlie (in Murchison region)	1,000,000	In early stages of development; 2 wells, catchments being installed.
Edjudina ...	About 70 miles N.E. of Kalgoorlie	800,000	38 wells, all rather salt, depth to water-level about 85ft. Catchments now being installed.
Pingin ...	About 50 miles E.N.E. of Kalgoorlie	1,000,000	No wells; water supply entirely from catchments.

CLIMATE, TOPOGRAPHY AND GEOLOGY OF THE REGIONS IN RELATION TO WATER SUPPLY.

INTRODUCTION.

In the two regions under discussion some features of climate, topography and geology affect fundamentally the quantity of available water, as may be seen from the following:—

(1) The regions receive a small quantity of rain—between 15 and 9 inches per annum in the Wheat Belt, less than 10 inches over a great part of the Kalgoorlie Region, which falls mainly between May and August.

(2) The rate of evaporation is considerable.

(3) The regions are part of a great tableland, devoid of perenially flowing streams, and, in its eastern part, almost entirely without defined drainage lines of any length.

(4) (a) In the Wheat Belt Region the soils fall into two main classes:—

(i) Richer soils, occupying the lower ground, which, in its natural state, supports an open forest of Salmon Gum (*Eucalyptus salmonophloia*) and Gimlet (*E. salubris*).

(ii) "Sandplain" which occupies the higher ground and on which the vegetation is more stunted. Descriptions of these two types of vegetation are given by Gardner (1924, pp. 38 and 120).

(b) The Kalgoorlie Region is, of course, from the miner's point of view, divided into auriferous and non-auriferous belts; pastorally it may be divided into:—(i) Hill-country—low, rather sharp ridges which carry little feed. Hill-country makes up a very small part of the total area, (ii) Plain-country which merges imperceptibly in many places into (iii) Lake-country—the "salt lakes" themselves and the samphire and salt-bush flats which border them. Very roughly, lake-country comprises 30, plant-country 60, and hill-country 10 per cent. of the whole area.

(5) The geological structure of both regions precludes the possibility that artesian water can exist in the sense of copious supplies which will rise to the surface, possibly from depths of several thousand feet, if the water-

bearing strata are pierced by a bore. The fact that, in isolated instances, water has risen to the surface from bores in these regions, does not invalidate the statement that, from the practical point of view, artesian water does not exist in the Kalgoorlie and Wheat Belt regions.

On the lower-lying land, which is the better for crops and stock in years of average rainfall, ground-water is nearly everywhere too saline to be of use. On the higher country ground-water is, in perhaps half the places that have been tried, usable or good, but its quantity is generally small.

Some of these features will now be discussed.

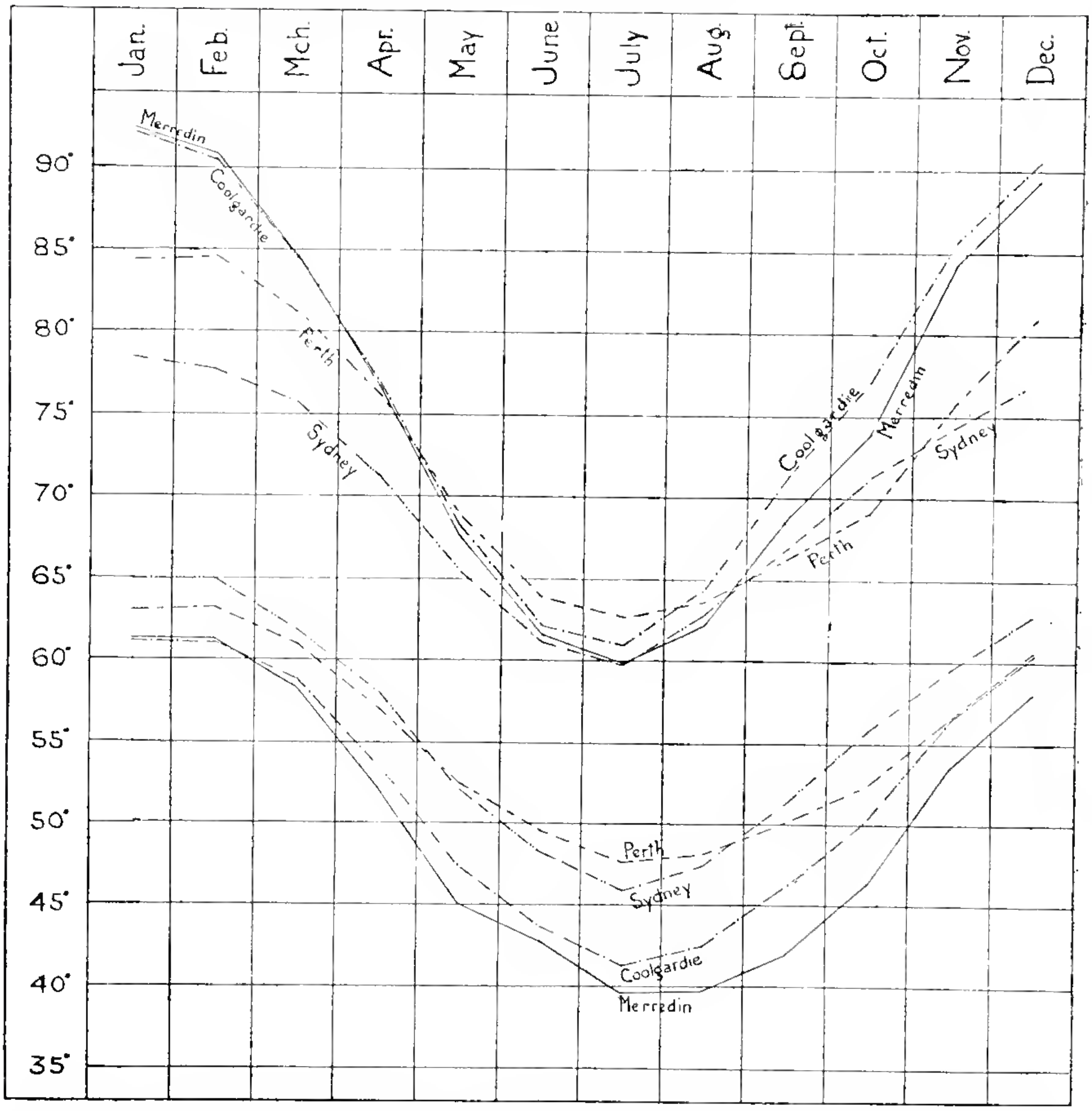

Fig. 7.—Range of temperature in Wheat Belt (Merredin) and Kalgoorlie (Coolgardie) regions compared with Perth and Sydney. (From figures supplied by Commonwealth Weather Bureau.)

CLIMATE.

Taylor has described the climate of Western Australia in various publications, some of which are cited in the bibliography at the end of this address. The following aspects of the climate bear directly on the matter of water-supply:—

The Kalgoorlie and Wheat Belt Regions lie in an area in which rainfall ranges from about 15 inches to less than 10 inches per annum. Most of the rain comes in winter, being brought by east-moving "lows." In summer the path of these depressions moves to the south and so misses the regions under discussion. There are very occasional rains in summer, brought by aberrant tropical disturbances, but they are of small importance.

Rather characteristic of the rainfall is the lightness of the individual falls. This is illustrated by statistics for a number of stations in the Wheat Belt which give an average annual rainfall of 13.2 inches and an average number of rainy days per annum of 73, whence the rainfall for an average "wet" day is only .18 inches.

The Wheat Belt Region is also characterised by the regularity with which the rains come in the winter and by the consistency of their amount, in fact Taylor (1920, p. 156) considers it to be an area of most "reliable"

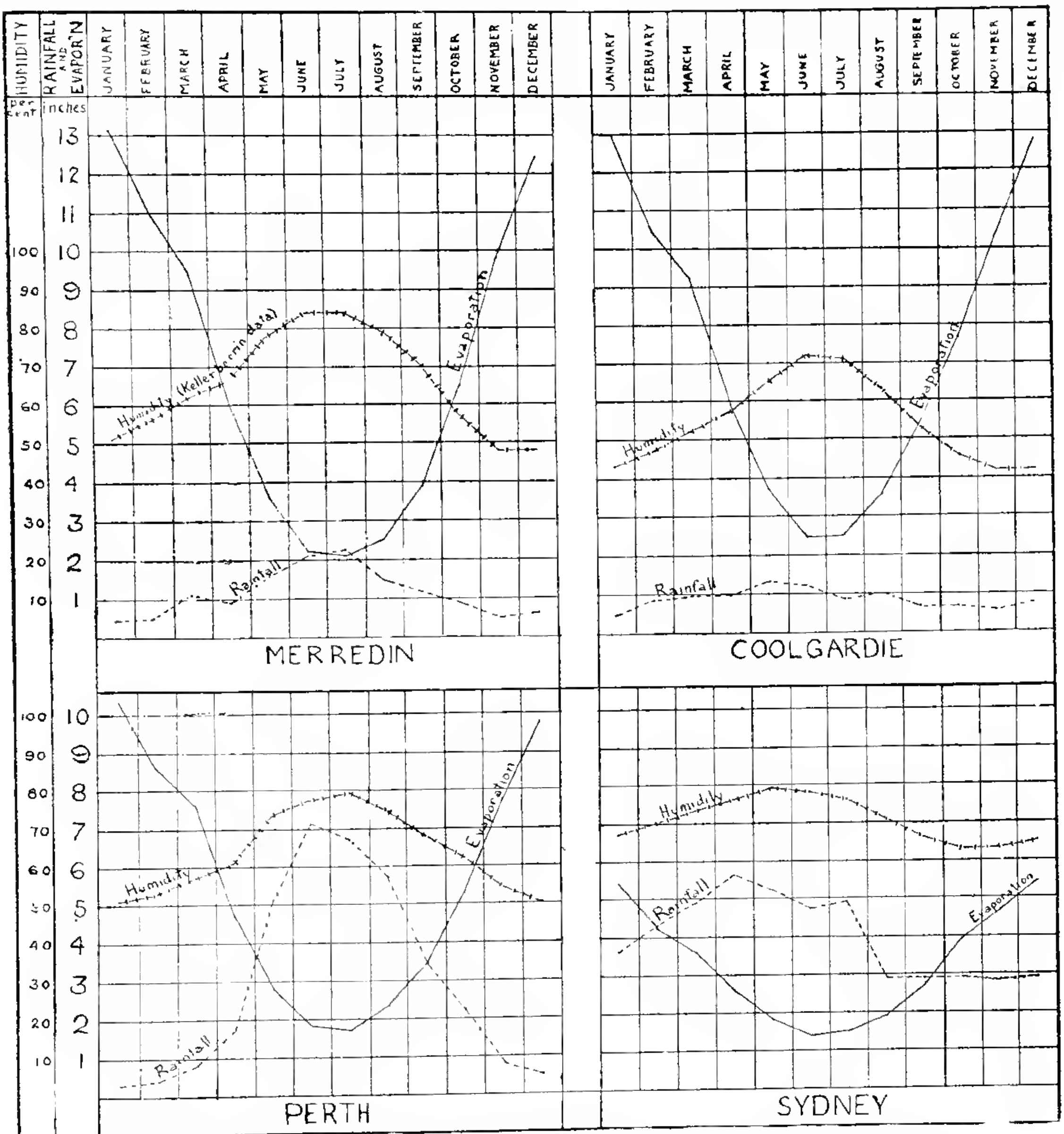

Fig. 8.—Mean monthly rainfall, evaporation, and humidity in Kalgoorlie and Wheat Belt regions and at Perth and Sydney. Annual means are:—

	Rainfall. inches.	Evaporation. inches.	Humidity. per cent.
Coolgardie	10.19 (38)*	87.32 (16)	54 (33)
Merredin	13.24 (27)	82.53 (21)	65 (16)†
Perth	34.92 (59)	66.22 (36)	62 (38)
Sydney	47.54 (76)	39.21 (55)	70 (76)

* Number of years over which data have been collected is in parentheses.
† Humidity data for Merredin not available; those quoted are for Kellerberrin.
(From information supplied by Commonwealth Weather Bureau.)

rainfall. This reliability, though valuable, may, as pointed out by Sutton (1925) encourage improvidence in the matter of water conservation on individual farms.

The latitude and inland position of the regions result in a considerable temperature range (Fig. 7).

Humidity is low but, as shown by Fig. 8, not as markedly so as might be expected in comparison with a coastal station like Perth.

The amount of wind is, taking available figures, rather small. Southern Cross and Wyndham are the least windy meteorological stations in the State; 22 per cent. of the mornings and 19 per cent. of the afternoons at Southern Cross are recorded as "calm."

High ratio of evaporation to precipitation (Fig. 8) follows naturally on the factors just mentioned and is, of course, an important factor in problems of water-supply, but it is interesting to note that the total annual evaporation at Coolgardie (7 feet) is not strikingly different from that at Perth (5 feet 6 inches).

The rain in these regions brings an appreciable quantity of sea-derived salt. Bleazby (1917) and Wood (1924) drew attention to the increasing salinity of many reservoirs used by the railways, and Wood suggested that though the immediate cause was the removal of native vegetation, most of the salt had been brought by wind and rain from the sea. A committee was formed by the Royal Society of W.A. to investigate the matter further (Wilsmore, 1929). Particulars concerning the salt-content of rain at various meteorological stations were collected. The conclusion was reached that rain does bring with it a certain amount of the various oceanic salts; that the amount is much greater at coastal stations, such as Perth, than inland, *e.g.*, at Coolgardie. that rain brought by a wind blowing directly from the sea contains a higher salt percentage than rain brought by a wind which had blown for some distance over the land. It was concluded, therefore, that a portion at least of the saline matter found in ground-water in these regions is of recent oceanic origin.

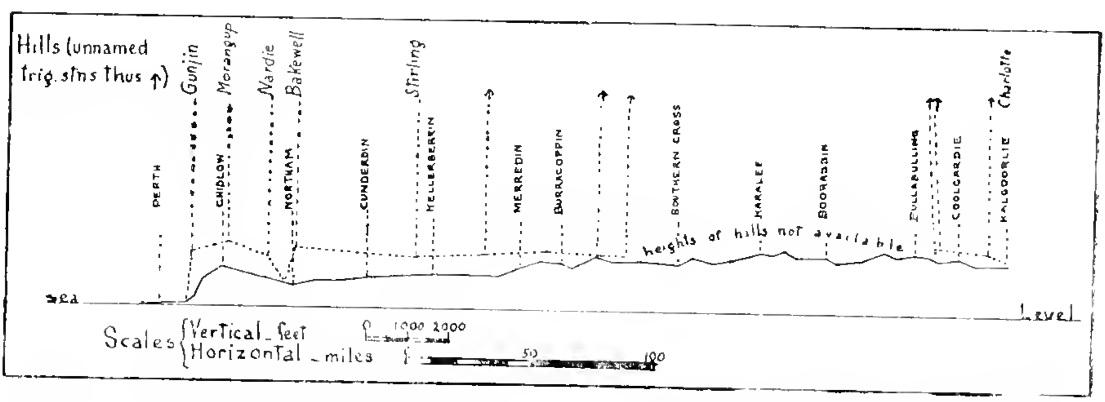

Fig. 9.—Profiles from Perth to Kalgoorlie; broken line connecting hills of known height, continuous line connecting stations on railway.

TOPOGRAPHY.

Eastwards from the edge of the Darling Scarp extends a tableland which rises very gradually eastwards. There is also a very gentle slope southwards to the south coast. The apparent downward slope to the west as shown by railway levels is, however, slightly misleading. The western portion of the Wheat Belt is grooved by many watercourses in wide valleys with very gently sloping sides (Fig. 10). Such valleys do not occur in the eastern part of the Wheat Belt (Figs. 11 and 12) nor in the Kalgoorlie Region (Figs. 16-18), except where represented by lines of salt "lakes" (described later). The railway lines lie mainly in the valleys in the western part and profiles drawn from railway heights somewhat exaggerate the slope (see Fig. 9).

Fig. 10.—Near Muresk Agricultural College, showing moderate relief of western Wheat Belt. The country has been almost entirely cleared of bush.
(Govt. Printer Neg. B763.)

Fig. 11.—Eastern Wheat Belt country near Merredin; portion of "granite rock" in foreground, higher level country in background and lower in middle distance, but relief very subdued.
(Govt. Printer Neg. B2242.)

Systematic discussion of the physiography of the Kalgoorlie and Wheat Belt regions will be found in Jutson (1934). It is proposed here merely to describe briefly some surface or sub-surface features which are important in the matter of water supply.

Rock Catchments in the Wheat Belt Region.—The tableland is dotted with hills which rise above the surrounding country by 200 feet or less. In the western part of the Wheat Belt they are obviously residuals of erosion, which owe their existence to the stream-pattern. In the eastern part of the Wheat Belt and in the Kalgoorlie Region they are also residuals formed mainly by a river-system which is now all but obliterated, but further modified in the present cycle of more arid erosion. Lefroy, in his pioneering exploration eastwards, quickly appreciated the value of these hills as water-catchments, particularly in the eastern part of the Wheat Belt. Nearly all of them are composed of granitic rocks (Fig. 13), though how many of them are granites and how many are granite-like gneisses remains to be proved. (It should be noted that only a few of these rocks are indicated on Fig. 3.)

Rock-catchments from the engineering standpoint are discussed by Fernie (1930). Perhaps the chief advantage of these hills (generally called "rocks" in articles on the subject) for water-supply purposes is that 60 per cent. to 90 per cent. of the total rain that falls on them runs over the surface and therefore may be collected by contour drains and conserved. Consequently "rocks," as experience shows, yield considerable quantities to the reservoirs from light summer rains, such, for example, as those recorded at Merredin, a fairly typical Wheat Belt centre, where summer rain over a period of 21 years averages January 41 points, February 47, March 76, October 85, November 48, December 63, nearly all of which seems to have fallen as light showers which would have produced no run-off from earth-catchments.

Again, rock catchments are relatively small areas, useless for any purpose other than water-conservation, and can be securely fenced and so protected from contamination. Further, most "rocks" stand above the general level of the surrounding country, making reticulation by gravity possible.

The reservoirs connected with rock-catchments are in some instances tanks excavated in the soil at the foot of the "rock," sometimes dams across gullies in the "rock" (Fig. 14); for smaller supplies it is sometimes found most economical to erect a circular, concrete tank.

In the Wheat Belt there are many "rocks" which will ultimately be used for catchments. Definite plans for the "harnessing" of at least five such "rocks" have been prepared by engineers of the Public Works Department.

Rock-Catchments in the Kalgoorlie Region.—As Lefroy, in 1863, approached the region in which the towns of Coolgardie and Kalgoorlie were later to arise, he noticed the disappearance of the "bald hills" which he had found so useful for water. It is characteristic of the Kalgoorlie Region, much of which is composed of basic igneous rocks and sediments, most of them more or less metamorphosed, that prominent granite hills are rare. Their place is taken by lines of low hills. A few of these have been sketched in on Fig. 3. Most of the ridges are built of the metamorphic rocks just mentioned, which, because of their dominant colour, are generally called "greenstones." Many of the "greenstones" have persistent planes of parting such as cleavage, bedding or schistosity, and therefore form very poor catchments and are seldom important in connection with water

Fig. 12.—Sand-plain near Bremer Range.
(Photo. Dr. L. J. H. Teakle.)

Fig. 13.—Yilliminning Rock, 11 miles east of Narrogin.
(Photo. R. T. Prider.)

supply. Another form of higher ground in the Kalgoorlie Region but much more prominent in the Murchison Region consists of long lines of low cliff (Figs. 19 and 20), leading down, over steep talus slopes, to level ground. The low cliff is, in many places, undercut, and regression by undercutting is in progress to-day. This type of high ground is known throughout the State as a "breakaway." Discussion of breakaways and of their origin will be found in Jutson (1934, p. 235). No attempt has been made to indicate them on Fig. 3. They are referred to here because on their upper surface, near the edge, "gnamma holes" may occur, and in the short streams which drain from them, "rock holes" (Fig. 21) are not infrequent. Both these natural sources of water are referred to later.

Earth-Catchments.—Reticulation from the Mundaring-Kalgoorlie pipeline and from rock-catchments cannot, even when much more developed, supply economically all the needs of the Wheat Belt; there are wide expanses of good country beyond the reach of either scheme. Unless such areas are exceptionally fortunate in having large supplies of usable underground water, resort must be had to catchments on earth or sand-covered ground. The inferiority of such "earth-catchments" to rock-catchments is very obvious; most of the rain sinks in and is lost, therefore a large area of good land must be reserved for water-catchment and cannot be cultivated; the run-off water carries a large amount of undissolved matter, the finest of which remains in suspension for a long time and discolours the water, while the coarser will quickly silt up the dam unless a silt pit is provided; on the lower-lying country, where the need for such catchments is generally greatest, the shallowness of the saline ground-water makes it impracticable to excavate any but a shallow tank from which loss by evaporation will be very serious, unless the expense of roofing is faced. The amount that is lost by evaporation from an unroofed tank, taking annual evaporation at the very conservative figure of five feet, can be appreciated from the following figures:—*

Reservoir.	Capacity (million gallons).	Depth (feet).	Amount held by upper 5ft. of reservoir (million gallons).
Narrogin	77	21	37
Barbalin	41	22.7	21

It has been proved that, by roofing, evaporation is reduced to a tenth of its amount in an uncovered reservoir—in short that, if the initial outlay can be met, roofing always pays.

Water-supply engineers of the Public Works Department have recently been experimenting with bitumen-coating of earth-catchments, the first step in the process being treatment of the area with crude oil to kill vegetation. Tests are not complete, but it is permitted to state that results so far are encouraging.

"Salt Lakes" are fully discussed by Jutson (1934). They are rather conspicuous physiographic features of the Wheat Belt, and in the Kalgoorlie Region are so important that Jutson uses the name "Salt Lake Physiographic Division" for a part of the State which includes the Kalgoorlie Region. (It should be noted that Fig. 3 gives an inadequate idea of the area covered by "lakes.") They are shallow depressions, generally greatly elongated, whose level floors are, in most places, covered with mud and glistening with a coating of various salts, amongst which sodium chloride is very prominent; in

* Information supplied by Mr. C. M. Dimond, B.E.

Fig. 14.—Gully in Yorkrakine Rock near Westonia.
(Photo. Geol. Surv. of W.A.)

Fig. 15.—Gnamma Hole at Jumannia, about 80 miles east of Kalgoorlie.
(Photo. Geol. Surv., W.A.)

places, however, the floor of the lake is a "billiard table" surface of rock. The shores of the "lakes" are in most places sand, or sandy clay, but some are low rocky cliffs. The water-table is only a few feet or inches below the surface, and the groundwater is intensely salt. Nevertheless "lakes" have, in the past, been the site of many "condensers." The following are analyses of "lake" waters (Simpson, 1916 and 1926), results being in parts per million:—

	Well, Hannan's Lake.	Lake Cowan.	Lake Monger.	Reward Lake, Lake Brown System
$CaCO_3$	52	76	40	...
$Al_2(SO_4)_3$	...	...	...	2,460
$CaSO_4$	3,984	2,238	1,360	1,468
$MgSO_4$	4,921	11,324	27,650	...
$NaNO_3$	...	...	Nil	12
$CaCl_2$	...	...	...	1,440
$MgCl_2$	19,260	31,905	43.740	9,078
$NaCl$	128,371	188,806	242,510	70,455
KCl	...	738	9,700	505
$NaBr$	...	...	230	...
$Al_2O_3Fe_2O_3$	38	44	20	...
SiO_2	47	...	30	122
H_2SO_4	...	...	...	19

Duricrust or laterite.—A hard capping, at, or just below the surface, is of wide occurrence throughout these regions, but has yet to be studied thoroughly in its various aspects. In some places it appears to be, in the main, ferruginous, in others it resembles an impure porcelain, in others it is calcareous, in others silicious, but, except in the extreme west of the Wheat Belt, there is no record of the occurrence of aluminous (bauxitic) varieties. The term "laterite," though appropriate enough for the bauxite capping which occurs near the Darling Scarp, does not seem applicable to the capping which occurs in the interior, and "duricrust," proposed by Woolnough (1927) is preferable, for the name does not suggest similarity to the Indian laterite.

Considering the variety of its composition, duricrust probably has a variety of origins. Much has, no doubt, been formed during the present cycle of arid erosion, but some may have been formed under the more humid conditions immediately following the Miocene submergence of southern W.A. (Clarke & Jutson, 1935, pp. 467-8). Leaving this question we have here to note that although duricrust cappings are not, to my knowledge, used in any water supply scheme in the Wheat Belt or Kalgoorlie Regions, yet they are the catchments for some natural tanks. Moreover, the process of "case-hardening," *i.e.*, incipient formation of duricrust, has taken place and is taking place in all parts of the area under discussion, and has a most important bearing on the efficiency of rock catchments. Generally in these regions the outside six inches or more of a granite "rock" is compact and coherent, whereas the rock immediately below this skin is less coherent and more porous and it is only after sinking to a depth of several feet that comparatively fresh, compact granite is entered. It is this surface hardening, due to climatic conditions, that has made the "granite rocks" so impervious that they form excellent catchments, so that there is a run-off even from light showers.

Gnamma Holes.—The typical gnamma hole (Fig. 15) has a capacity varying from a few gallons to several hundred and is a deep, water-tight cleft in a "rock" or in a duricrust surface, so situated that it collects water from the surrounding few acres or perhaps only square yards. Some gnamma holes are more or less flask-shaped, so that perhaps a hole little more than a foot in diameter opens out below into quite a capacious cavity, but in any case the area of water exposed to evaporation is small in comparison with the capacity of the hole. Where gnamma holes occur in

Fig. 16. Typical Kalgoorlie region country—near Ora Banda. (Photo, Geol. Surv., W.A.)

"granite" they are at the intersection of two or more well-marked joints, or along pegmatite veins, or in some other place where the rock is unusually susceptible to weathering; in duricrust the reason for their location is not obvious. Their formation is begun by weathering which removes material more rapidly from the weak spot than elsewhere. The only explanation offered for the depth of the typical gnamma holes is that animals, such as kangaroos and emus, in getting the last drops of water from what was then a shallow depression, have enlarged the hole by scraping out disintegrated material. Aboriginals have, no doubt, done most of the later enlargement, scooping out the softer rock underlying either duricrust or "case-hardened" rock. Without such assistance from man and beast it seems likely that such weak spots in the rock would merely have become soil-patches (as in Fig. 14). More than once in the course of clearing rock-catchments, such patches have been cleaned out and have been found to conceal large depressions; an example is the King Rock reservoir, due east of Kondinin, which has a capacity of 1½ million gallons.

Rock Holes.—This term is best reserved for holes formed by erosion in watercourses and holding water for a considerable time after rain, they thus contrast with gnamma holes which have no connection with watercourses.

Watercourses in the western part of the Wheat Belt are too flat in grade to form rock holes, but short channels, of fairly steep grade, drain off the hills and breakaways of the Kalgoorlie region, disappearing in a short distance when they enter the lower lying country, and, in them, rock holes are not uncommon (Fig. 21). Rock holes are generally shallower in comparison with their water-content than are gnamma holes and so suffer more from evaporation. Like gnamma holes they are only of much value in the exploratory and pioneering stages of development.

Ground Water.—Hundreds of bores and wells have been sunk to the water table in the regions with which we are concerned, but, until the relative heights of the various bore-sights, as well as their positions on the map and the character of the rocks in which they were sunk are known, none but tentative conclusions can be drawn from the resulting information.

In the Wheat Belt region the water-table, as ascertained in wells, averages 60 feet below the surface in the Dowerin Agricultural Area, 58 feet in the Hines Hill Area, 55 feet in the Wickepin Area, and 73 feet in the Dumbleyung Area.

Regarding the composition of this ground-water, there is general agreement amongst those most familiar with the subject—farmers, water-supply engineers and chemists—that wells in the lower-lying richer tracts produce considerable supplies but are, as a rule, too salt even for stock. On the other hand, wells sunk in the higher ground may encounter water suitable even for human consumption, although the supply is generally small, and it has been found that in many instances, after having been drawn on for a number of years, the water becomes too salt.

The following data concerning ground waters examined by the Department of Agriculture, and made available by the Director of Agriculture (Mr. G. L. Sutton), support this statement; all samples were collected in low-lying ground—the shallowness of the water-table is noticeable:—

District	Depth to water (feet).	Chloride as sodium chloride (grains per gall.).
Salmon Gums	6	4,144
Salmon Gums	12	2,695
Salmon Gums	?	298
Boodarockin	14	3,507
Campion	11	3,689
Corrigin	3¼	1,505
Moulyinning	—	238
Moulyinning	2½	763
Moulyinning	3	1,981
Moulyinning	5	2,254
Wyalkatchem	?	1,064

The greatest amount of total solids in grains per gallon that is generally regarded as allowable for different purposes in this State is (Simpson, 1926):—For cities 70, for small towns 105, for individual farms 210, for horses 450, for cattle 700, for sheep 900. It may be noted that, in South Australia, a calculation based on the relative harmfulness of various salts is used (Jack, 1930, p. 6).

Fig. 17. Kalgoorlie region country; greenstone ridge near Ora Banda. (Photo, Geol. Surv., W.A.)

The main body of ground water throughout the Wheat Belt and Kalgoorlie regions is probably strongly saline, approaching in composition the water of the "salt lakes." The salts are thought to be partly connate—the dregs of the Miocene sea which covered the two regions at least as far north as lat. 29° (Clarke and Jutson, 1935, p. 467); partly they are sea salts brought, in geologically recent times, by wind and rain from the ocean and from the "salt lakes." That part of each season's rain which sinks into the soil

Fig 18.—Typical low ridge in "greenstone" country (now denuded of vegetation) formed by outcrop of a "jasper bar": Wimmera Hill, Southern Cross, site of first discovery of gold in the district by Riseley and party.
(Photo. Geol. Surv., W.A.)

reaches the water-table and forms a layer of comparatively fresh water, overlying the salter and very slowly mixing with it. The contours of the water-table follow the surface contours, in a subdued way, and therefore the yearly quota of absorbed rainwater will move slowly down towards the lower ground.

In the Wheat Belt Region the land forms may, as already mentioned, be divided into:—(a) "granite" outcrops, (b) sand-plain, (c) lower-lying flats of heavier soil. Rain falling on such country will drain off the "rocks" and soak into the porous soils round them, giving "soaks," *i.e.*, short-lived

Fig. 19.- Breakaway S.W. of Bindulli. (Photo. Geol. Surv., W.A.)

springs, and, in places where the water is held in shallow basins in the rock underlying this shallow soil, giving a moderate supply of good well-water. Farther down the slope the water will be somewhat nearer the surface, and, if places can be found where the underlying unweathered rock surface is of favourable contour, a large supply of fairly good water may be obtained from wells (Fig. 23). It is interesting to note that H. M. Lefroy's words quoted earlier show that he fully realised this, so that, regarding this aspect of water supply, nearly all that is known was known 70 years ago.

Below a certain optimum level, which is generally about half way down the slope, the amount of comparatively fresh rainwater that has moved down underground, along the gently sloping water-table from the higher ground, has become smaller—not sufficient to freshen, appreciably, the saline ground-

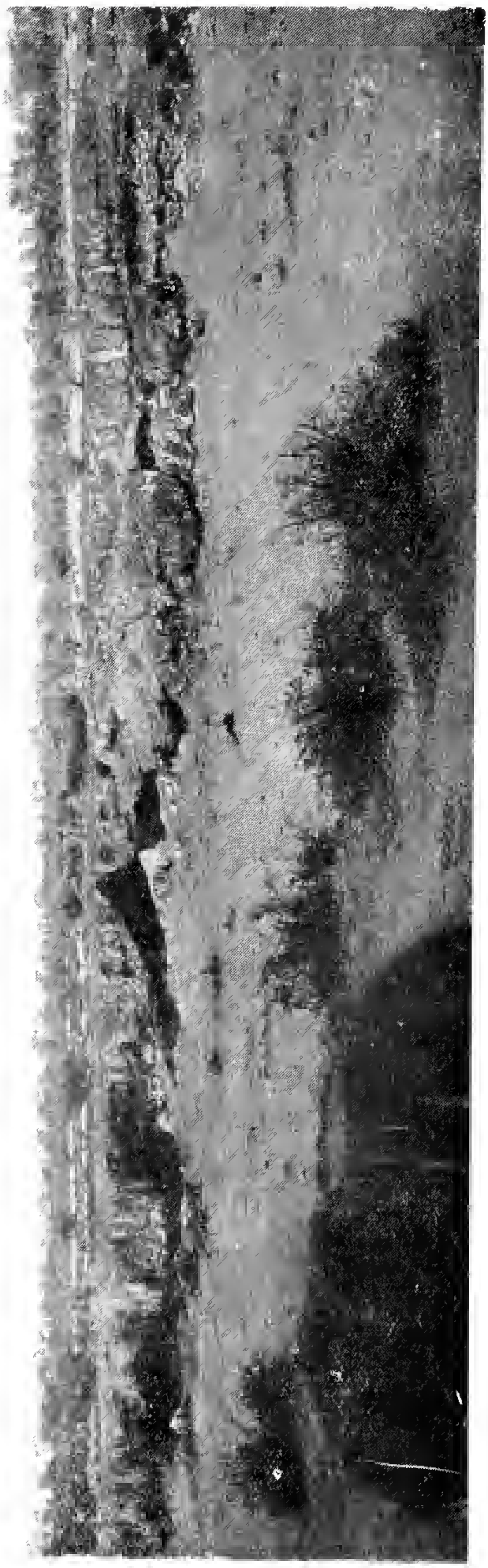

Fig. 20.—Breakaway on north shore of Lake Koorkoordine, near Southern Cross. (Photo. Geol. Surv., W.A.)

water. In the Kalgoorlie and Wheat Belt Regions, in their native state, the annual increment to the ground-water from rain must have been balanced by the amount returned to the air by the transpiration of the trees and shrubs together with that ultimately returned southward or westward to the sea by very slow movement of the ground-water along the strings of lakes, otherwise it is hard to understand why the salinity is not even greater than it is.

The effect of clearing the lower, more fertile ground has been to destroy this balance and to bring the saline water nearer, or actually to the surface. Under cultivation, therefore, not only must a certain amount, and, according to some well qualified to express an opinion, an alarming amount, of good land cease to be cultivable, but also, owing to the nearness to the surface of the saline ground-water, it must become increasingly difficult to excavate successful tanks on the lower ground.

On the other hand, clearing and cultivation of the higher, lighter ground will increase the absorption of rain and therefore increase the supply of useful underground water.

Fig. 21.—Rock Holes—the "Chain of Water-holes" about 20 miles north of Leonora, Murchison region.

GEOLOGY.

The Kalgoorlie and Wheat Belt Regions are believed to be underlain everywhere by rocks of Pre-Cambrian age. Until the last three or four years the usual interpretation of the geology was that a huge granite bathylith had in Pre-Cambrian times invaded a system of sediments and acid and basic lavas and tuffs. Erosion has laid bare the bathylith, but numerous roof pendants of the invaded rocks have been left, particularly in the Kalgoorlie Region. These roof pendants are, according to this interpretation, the "greenstone islands" or "rafts" in which are found gold-ores. These islands are generally very much longer than wide, their long axes run N.N.W. and their area varies from a few square yards to many hundreds of square miles.

As the result of recent investigations by geologists connected with mining companies and by the State Geological Survey, it now appears that the whole area is made up of a folded complex of Pre-Cambrian age, which consisted, in the first place, of a great succession of sediments interbedded with flow and fragmental volcanic rocks. This complex has been metamorphosed in varying degree, partly by earth-movement and partly by later intrusions. The earliest and most important of the intrusions was of an acid magma which, by granitization, converted a large portion of the quartzites into gneisses, a later intrusion was by a basic magma which produced a widely distributed system of dykes, sills and stocks of dolerite, epidiorite and gabbro. Some consider that there was a second injection by acid magma of a type different from the earlier acid invasion. Maitland (1919, p. 14) agrees with the earlier view in so far as the great importance of the granite bathylith is concerned, but judging from his "generalised section" (p. 9) evidently considers that schists and other metamorphic rocks bulk very largely in the Wheat Belt region. The differences in the structure of the country implied by the three interpretations are illustrated in Fig. 22, for the information contained in (3), of which I am indebted to Mr. F. G. Forman, Government Geologist.

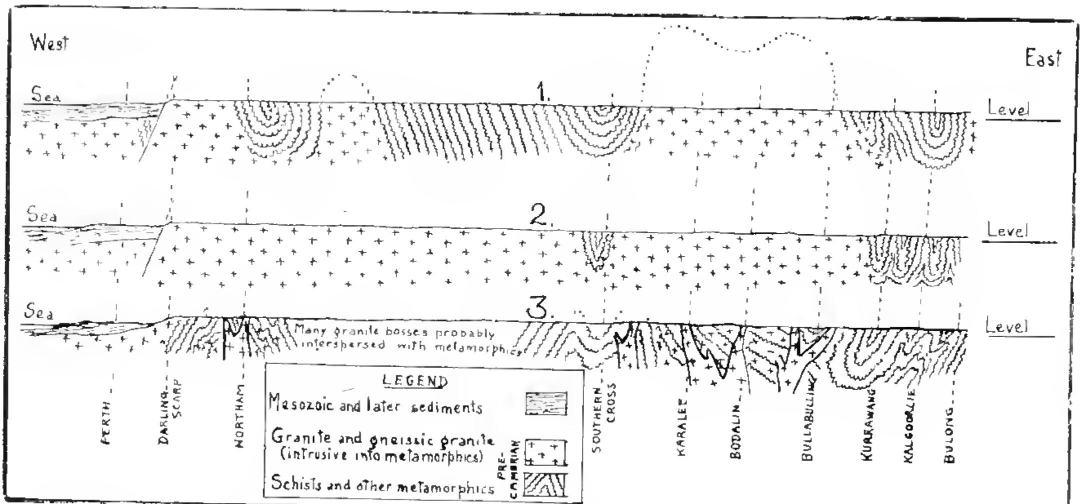

Fig. 22.—Diagrammatic sections from Perth to Kalgoorlie, illustrating three conceptions of its geological structure. 1. After Maitland (1919). 2. The generally accepted conception a few years ago. 3. The present conception (after Forman).

According to the usual conception (Fig. 22, 2), nearly all of the Wheat Belt and the non-gold-bearing parts of the Kalgoorlie Region are underlain by a solid basement of granite, and the "granite rocks" of the Wheat Belt Region are parts of the granite bathylith, which because of some difference in composition or structure, have resisted erosion better than the rest of the granite. In particular, the sand-plain country is regarded as underlain by granite, from the waste of which the sand has been derived.

According to the later conception (Fig. 22, 3) the greater part of the Wheat Belt and Kalgoorlie Regions has a much more complex structure and is composed throughout of a far greater variety of rocks than is implied by the earlier interpretations. The "granite rocks" are, in part, granite stocks; many of them may, however, prove to be gneiss formed by granitization or some other type of metamorphism of the sediments; sand-plain country represents, in the main, disintegrated quartzites and quartz schists; the lower-lying expanses of richer soil may be weathered basic metamorphics, such as hornblende schist.

On the second theory, which is now generally regarded as more nearly the correct interpretation, the fate of rainwater which runs off a "granite rock" into surrounding sandy country depends to a certain extent on the types of metamorphic rocks of which the area is composed and on their arrangement.

On neither theory of course can there be any chance of getting artesian water. Some people still cherish the hope that inspired the 3,000-foot bore at Coolgardie, that good water will yet be found under the salt water, in

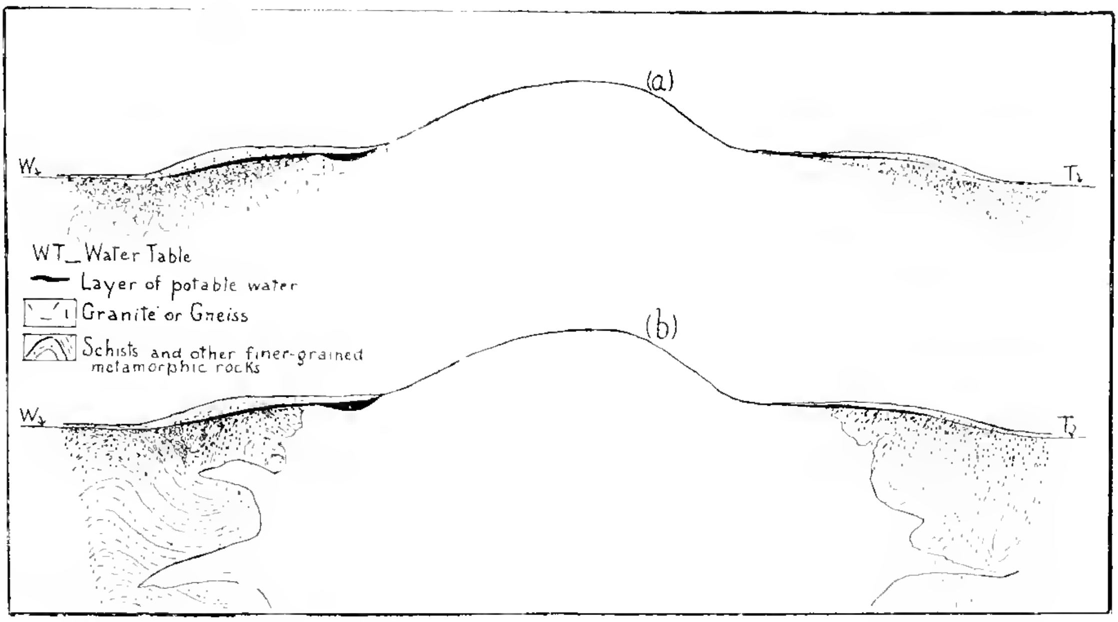

Fig. 23.—Diagrammatic sections across a granite rock as might be expected under two of the interpretations of the geological structure of the Wheat Belt.

other words, that artesian conditions do exist in these regions. Small supplies, under pressure, might indeed be tapped in restricted, shallow basins on the surface of the old rocks, in which recent deposits of sand, etc., have accumulated. Also small amounts under pressure would be obtained from the old rocks themselves, if by chance a bore were put down where there is a fortunate combination of joints or other partings, but the position for such a bore could not be predicted.

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APPROXIMATE POSITIONS OF PLACES MENTIONED IN TEXT.

(Figures given are approximate longitude E. followed by latitude S.)

Barbalin 118° 10′, 30° 50′.
Binduli 121° 25′, 30° 50′.
Boodarockin 118° 45′, 31°.
Bremer Range 120° 40′, 32° 35′.
Broome Hill 117° 40′, 33° 50′.
Brown, Lake 118°, 31° 05′.
Burges, Mt. 121° 05′, 30° 50′.
Campion 118° 30′, 1°.
Carmody, Lake 119° 20′, 32° 30′.
Charles, Peak, *see* Fitzgerald Peaks.
Coolgardie 121° 10′, 31°.
Corrigin 117° 50′, 32° 20′.
Cowan, Lake 122°, 32°.
Darling Range *or* Scarp 116°, 30° 50′, to 33° 40′.
Dowerin 117°, 31° 10′.
Dumbleyung 117° 50′, 33° 20′.
Edjudina sheep run 123°, 29° 30′.
Esperance 122°, 33° 50′.
Fitzgerald Peaks 121° 10′, 33°.
Fraser Range 123°, 32°.
Grace, Lake 118° 20′, 33° 10′.
Hampton Plains 122°, 31°.
Hannan's Lake 121° 30, 30° 40′.
Hine's Hill 118° 10′, 31° 30′.
Holland, Mt. 119° 50′, 32° 10′.
Jumannia 122° 50′, 30° 50′.
Kellerberrin 117° 50′, 31° 40′.
Koudinin 118° 10′, 32° 30′.
Kumarl 121° 35′, 32° 45′.
Lefroy, Lake 121° 50′, 31° 15′.
Leonora 121° 30′, 29°.
Magnet, Mt. 117° 45′, 28° 05′.
Menzies 121° 15′, 29° 40′.
Merredin 118° 20′, 31° 30′.
Monger, Lake 117° 10′, 29° 20′.
Moulyinning 118°, 33° ′.
Mundaring 116° 15′, 31° 50′.
Muresk 116° 40′, 31° 45′.
Narrogin 117° 15′, 32° 50′.
Northam 116° 40′, 31° 40′.
Perth 115° 50′, 32°.
Peterwangy Hill 115° 40′, 28° 50′.
Pingin sheep run 122° 30′, 30° 30′.
Pinnacles sheep run 120°, 28° . 0′.
Salmon Gums 121° 40′, 33°.
Shark Bay 113°, 25°.
Slate Well 121° 45′, 31° 15′.
Southern Cross 119° 20′, 31° 15′.
Toodyay 116° 30′, 31° 30′.
Westonia 118° 40′, 31° 20′.
Wickepin 117° 30′, 32° 45′.
Wyalkatchem 117° 20′, 31° 10′.
Wyndham 127° 55′, 15° 20′.
York 116° 50′, 31° 50′.
Yundamindera sheep run 122°, 29° 30′.

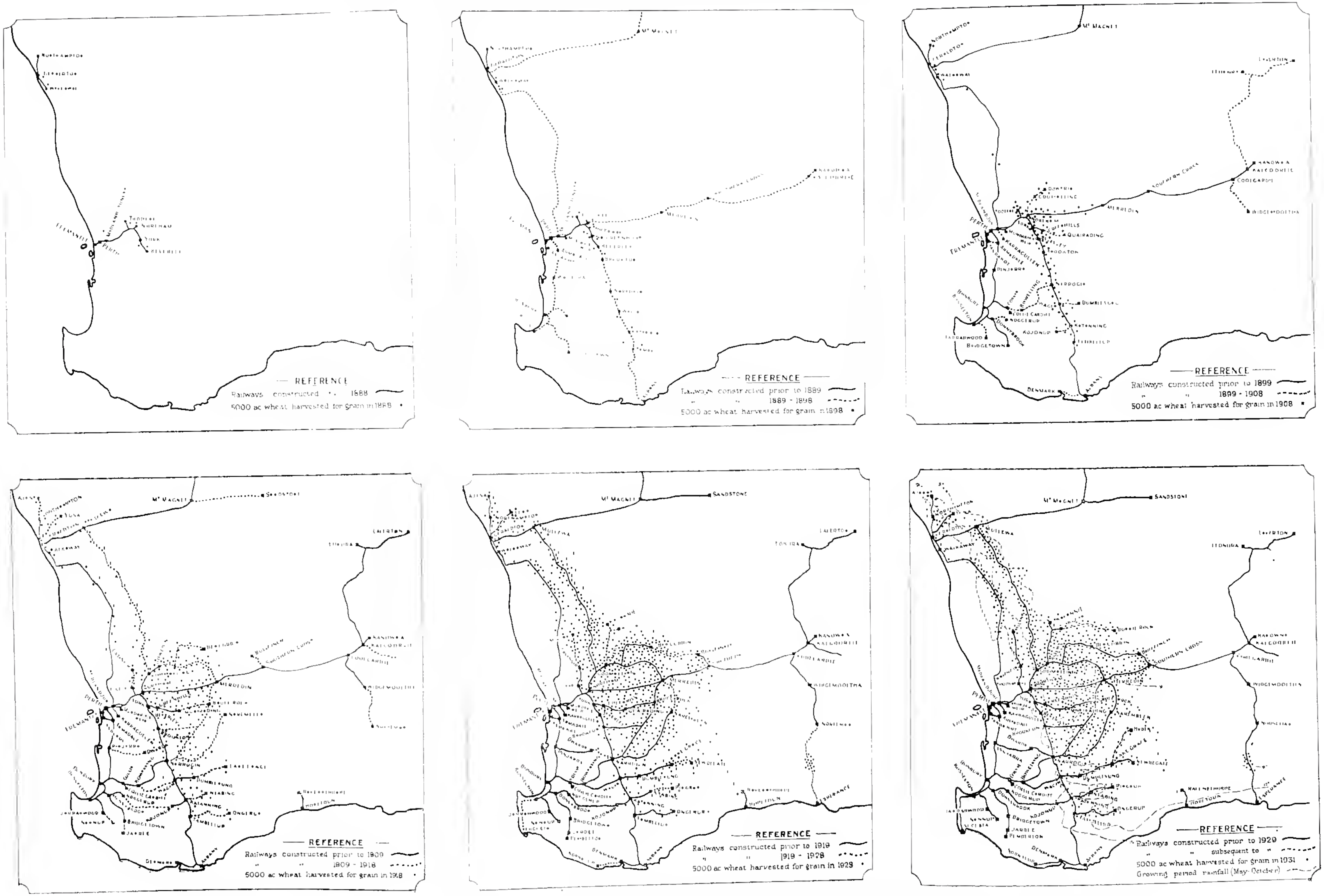

Fig. 4.—Maps showing extension of area under cultivation for wheat in Western Australia between the years 1888 and 1931. (Compiled by R. P. Roberts, B.Sc. (Agric.), of the State Agricultural Department in collaboration with the Government Statistician and the Surveyor General.)

JOURNAL OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

VOLUME XXII.

1.—CONTRIBUTIONS TO THE MINERALOGY OF WESTERN AUSTRALIA. SERIES IX.

By EDWARD S. SIMPSON, D.Sc., B.E., F.A.C.I.

Read: 13th August, 1935; Published: 16th March, 1936.

CONTENTS.

With one text figure.

(1) ACTINOLITE, COMET VALE, CEN.

Between the town of Comet Vale and the shore of Lake Goongarrie the rock formation consists of Precambrian serpentine, succeeded to the east by amphibolite. In the steep gully of Tunnel Creek running down into the lake, the latter rock is traversed by quartz veins and shear and crush zones, all of which are auriferous, and many scheelite-bearing. The amphibole of the main rock mass is the dark green, strongly pleochroic, variety typical of the goldfields amphibolites. In the crush zones which have been impregnated with gold and scheelite, irregular patches of it have been altered into a variety of a pale grey-green colour. Small inclusions of the latter are to be seen in places in the auriferous reefs. Neither of these two amphiboles has been examined in detail.

On a dump on G.M.L. 4739 near the Lake View G.M., and close to the original source of the new mineral goongarrite, the Writer in 1933 found a third amphibole to be plentiful in hard satiny films in all the cracks in the quartz. It is characterised by an unusual bluish-grey colour (Ridgway 33'f to 45'd). The microscope shows that the masses are composed of roughly parallel groups of microscopic needles, which are practically colourless. They have a maximum extinction angle of 15°, which proves to be the angle between c and Z. The extreme refractive indices were found to be Ng 1.651, Np 1.629. The specific gravity was 3.04.

In outward appearance the mineral resembles glaucophane ($H_2Na_2Mg_3Al_2Si_8O_{24}$) or abriachanite ($H_2Na_2Mg_3\overset{'''}{Fe_2}Si_8O_{24}$), but analysis shows it to be an actinolite with only minor proportions of those molecules. The results obtained were:—

Actinolite, Comet Vale.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO
Per cent. ...	56·80	·62	1·45	6·71	·23	19·75	11·24
Mols. ...	9457	61	91	934	32	4898	2004

	Na_2O	K_2O	H_2O+	H_2O-	TiO_2	Total.
Per cent. ...	·71	·12	2·58	·15	·12	100·48
Mols. ...	115	13	1432	—	15	

Analyst: D. G. Murray.

From the analysis the following molecular percentages were calculated to be present in the "mixed crystal":—

Actinolite, $H_2Ca_2(Mg, Fe)_5Si_8O_{24}$ ... ... 89·5 per cent.
Abriachanite, $H_2Na_2Mg_3\overset{'''}{Fe_2}Si_8O_{24}$ ... ... 6·3 ,,
Glaucophane, $H_2Na_2Mg_3Al_2Si_8O_{24}$ ... ... 4·2 ,,

(2) CHLORITE, HOLLETON AND NINGHANBOUN HILLS, S.W., AND RANDALLS, CEN.

The Chlorite Group embraces a number of mineral species having the general formula $H_4\overset{''}{R_3}Si_2O_9 + H_4\overset{''}{R_2}\overset{'''}{R_2}SiO_9$. In this formula, with certain rare exceptions,* R″ is Mg or Fe″, and R‴ is Fe‴ or Al, and six end members are therefore theoretically possible, viz.:—

Antigorite, $H_4Mg_3Si_2O_9$	Ferroantigorite, $H_4\overset{''}{Fe_3}Si_2O_9$
Amesite, $H_4Mg_2Al_2SiO_9$	Daphnite, $H_4\overset{''}{Fe_2}Al_2SiO_9$
Magnesiocronstedtite, $H_4Mg_2\overset{'''}{Fe_2}SiO_9$	Cronstedtite, $H_4\overset{''}{Fe_2}\overset{'''}{Fe_2}SiO_9$

Intermediate cocrystallisations are only varieties of these six species, with chemical and physical properties following continuous smooth curves between the end members. In spite of these fundamental facts various authors, mainly petrologists, have burdened the literature with well over seventy unrelated names of chlorites, mainly on the strength of minute dif-

* In Kaemmererite R‴ is partly Cr. and in Nepouite R″ is mainly Ni.

ferences in optical properties, due, as in so many other isomorphous series, to varying degrees of isomorphous replacement, which in the majority of cases, are certainly not specific, nor even sub-specific. Winchell shows for example that the slightly positive optical character of certain chlorites changes by slow gradations through zero point to slightly negative with increase in proportion of iron-bearing molecules, and that the crossing point is not quite coincident with the chemically critical point, viz., the 50/50 per cent. proportions of the two end components([1]). It follows that a least fifty of the names now appearing in the literature are redundant.

Up to the present, except for brief petrological descriptions in the publications of the Geological Survey, no details have been available regarding any West Australian chlorites. The following data have been elucidated recently.

Corundophilite, Holleton.

The Holleton chlorite is a slate green (near Ridgway 33'k) mineral, forming lenses of very coarse plates up to 1 cm. in diameter, partly in radiating groups, in a massive chlorite rock of finer grain. The rock is part of the Archaean greenstone complex. No corundum is associated with it. The analysis given is that of the coarse platy mineral, which, when carefully handpicked, was entirely free from intergrowths or signs of weathering. The laminae are somewhat brittle, and under the microscope give a biaxial figure with 2E about 30°, and positive sign. Ng, 1.590, Np, 1.582. X and Y, bottle green: Z, colourless. The properties determined are all typical of this variety of amesite.

Analyses of West Australian Chlorites.

Species	Amesite	Amesite	Daphnite
Variety	Corundophilite	Clinochlore	Normal
Locality	Holleton	Ninghanboun	Randalls
SiO_2	28·08	32·40	23·43
Al_2O_3	22·16	19·17	18·21
Fe_2O_3	1·46	2·36	4·49
FeO	9·56	4·04	36·30
MnO	·04	*Nil*	trace
NiO	*Nil*	·32	*Nil*
MgO	26·54	27·62	5·41
CaO, Na_2O	*Nil*	*Nil*	*Nil*
K_2O	·04	*Nil*	*Nil*
H_2O+	12·66	12·21	12·15
H_2O—	·26	1·56	trace
TiO_2	*Nil*	·17	*Nil*
Total	100·80	99·85	99·99
G	2·80	2·69	3·14
Analysts	D. G. Murray	D. G. Murray	E. S. Simpson

The varietal names, in the case of the first two, were arrived at by determining the approximate proportions present of the pure molecules antigorite, amesite, ferroantigorite and daphnite or cronstedtite, and comparing them with the table and graph given by Winchell([2]).

Clinochlore, Ninghanboun Hills.

This mineral, collected at the extreme eastern end of Ninghanboun Hills, is in bunches of large plates in the outcrop of talkicised amphibolite. The hexagonal crystals are 1 to 5 cm. in diameter, and are mostly arranged in radiating spherulitic aggregates. It is slightly weathered in places. Some of the freshest mineral of 3 cm. diameter was analysed; it was of a dark greyish-green colour.

Incipient weathering, involving a change of FeO to Fe_2O_3, is indicated by a yellowish tinge in some other specimens. The colours are impossible to match with certainty against Ridgway's standards owing to the bright micaceous lustre of the mineral, but they are near 29^4i for the fresh mineral, and 25^4k for that which is slightly weathered.

The results of the analysis are given in the table. A second specimen of the slightly smaller plates (1.5 cm. diameter) was found to contain FeO, 4.46 and total H_2O 13.78, as against 4.04 and 13.77 for the large plates.

Under the microscope the analysed mineral was almost colourless and biaxial, with a rather small optic axial angle, and positive sign. The composition and physical properties agree with those recorded for clinochlore.

Daphnite, Randalls.

In the Santa Clause G.M. at Randalls there are dense masses of greenish-black (R.$33^4$1) microscaly chlorite, impregnated with crystals of arsenopyrite, the whole being slightly auriferous. Sufficient of the chlorite was separated cleanly with CH_2I_2 to enable an analysis to be made with the results given in the table. This shows the species to be daphnite, with slightly more magnesia than in the type mineral from Cornwall, which also is associated with arsenopyrite. Under the microscope it is appreciably birefringent, and negative in optical sign. Ng 1.661, Np 1.656. X, greenish yellow, Y and Z, dark bottle green. The mineral is therefore typical in optical properties as well as in specific gravity and chemical composition.

References: (1) Winchell, *Elements of Optical Mineralogy, Part II., 2nd Edit.*, p. 284.
(2) *Idem*, pp. 279, 280.

(3) COBALTITE AND ERYTHRITE, RAVENSTHORPE, S.W.

During a hurried visit to Ravensthorpe in 1934 it was found that these two minerals are plentiful in two gold mines not far from the town.

On the Golden Contact Prospecting Area, 1½ miles N.W. of the town, masses of small grains and imperfect octahedra of cobaltite are plentiful in quartz and chalcedony, together with thin films and stains of pale pink erythrite, and an undetermined yellowish ferric arsenate. A bulk sample of such ore taken from a depth of 30ft. and forming a 30-inch band on the wall of a clean quartz reef, assayed: Cobalt, 2.43 per cent; nickel, traces; gold, 28.88 dwts. per ton; silver, 8.5 dwts. per ton. Some of this ore was concentrated to yield as clean cobaltite as possible, and the concentrate then analysed. After deducting 40 per cent. of insoluble quartz, and under one per cent. of $FeAsO_4$, soluble in dilute HCl, the results recalculated to 100 per cent., were:—

Cobaltite, Ravensthorpe.

Co	Ni	Fe	As	S	Total
30·64	1·03	3·61	45·73	18·99	100·00

Analyst: H. P. Rowledge.

The molecular percentages of the concomitant molecules are:—

CoAsS	NiAsS	FeAsS	$CoAs_2$
84·6	2·9	10·7	1·82

At the Bulldog G.M., also known as the Plantagenet G.M., about two miles N.E. of the town, beautiful specimens of erythrite were to be found in abundance in shallow workings on an auriferous vein consisting largely of quartz and chalcedony. The mineral is in broad films up to 2 mm. in thickness, on the many fracture planes in the vein. It is earthy in texture, and of a striking pink colour ranging from Ridgways 1'd, alizarine pink, to 71d, deep rose pink, rarely much darker, about 67i, aster purple.

In some specimens the origin of the erythrite can be traced to small granular bunches or scattered grains of cobaltite, which have been protected from oxidation by the dense siliceous matrix.

In both mines the matrix of the lodes appears to be a complex of Precambrian amphibolites of different types.

(4) FUCHSITE, MILOSCHITE AND ALEXANDROLITE, MEEKATHARRA, MUR.

Fuchsite is the emerald green chromiferous variety of muscovite having the formula $H_2K(Al,Cr)_3Si_3O_{12}$. Miloschite is the corresponding blue-green variety of kaolin $H_4(Al,Cr)_2Si_2O_9$, and alexandrolite the similar bright green variety of halloysite, $H_4(Al,Cr)_2Si_2O_9.2H_2O$. The three minerals are often found in close association.

The most casual visitor to Meekatharra must be struck with the long line of bright green dumps stretching southward from the Wiluna railway line north-east of the town, past the State Battery to the summit of the ridge to the east of the town. An examination of the dumps, which are on still working or abandoned gold mines, shows that the strong colour is due to miloschite, alexandrolite and fuchsite, the first predominating. The material appears in every case to have been obtained in kaolinised rocks at depths down to about 100 feet. Below water level in the mine workings neither miloschite nor alexandrolite has been encountered, but in several mines there are bands of quartz-mesitite-fuchsite rock, which are highly carbonated phases of a large peridotite or pyroxenite intrusion, flanked by amphibolites and related rocks and intruded by ceratophyre dykes([1]). All of these are Precambrian in age.

Typical specimens were collected by the Writer in 1932 from a number of the green dumps, and examined in the Laboratory with the following results:—

Fuchsite, Miloschite and Alexandrolite, Meekatharra.

No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Undecomposed by fuming sulphuric acid: Per cent. of whole sample.									
Quartz	43·43	14·76	22·94	17·29	20·67	31·34	44·80	35·88	16·69
Other insol. ...	1·07	·36	·51	·44	·42	1·63	1·42	1·11	·79
Decomposed by fuming sulphuric acid: Per cent. of decomposable material.*									
K_2O	6·09	2·69	·07	·08	·05	·06	·15	·98	·86
Na_2O	·90	·13	·14	·01	·01	·10	·11	·76	·63
H_2O+	7·84	9·08	13·00	13·25	12·95	14·41	11·97	11·71	11·21
H_2O-	1·94	1·96	·57	3·29	5·09	5·49	5·87	9·71	10·76
Cr_2O_3	1·05	·82	·68	·92	·87	1·37	1·60	1·46	1·15
Principal constituent	Fuchs.	Milosch.	Milosch.	Milosch.	Milosch.	Milosch.	Alexan. / Milosch.	Alexan.	Alexan.
Second constituent ...	Milosch.	Fuchs.	—	Alexan.	Alexan.	Alexan.	Milosch. / Alexan.	Milosch. / Fuchs.	—
Colour (Ridgways Standards).									
Dry	41²d	39³e	39²f	39²g	41²f	41²d	37³f†	38²d‡	38²d‡
Wet	41²b	41²c	39²d	41²d	41²c	41²b	41²b		

* Including separated silica.
† With inclusions of pale cream, nonchromiferous, clay and quartz.
‡ Two levigated moities of one specimen which in mass is 39″b both dry and wet.

The following are descriptions of the samples analysed, each being taken from a different mine dump. The mineral compositions given are those of the remnants after deducting quartz and insoluble:—

(1) Halcyon Group of mines. Granular, firmly coherent, slightly gneissic. Evidently leached quartz-fuchsite-mesitite rock. About 65 per cent. fuchsite, 30 per cent. miloschite.

(2) Pioneer Group. Dense, tough, fine grained. About 27 per cent. fuchsite, 58 per cent. miloschite, 15 per cent. alexandrolite.

(3) Pioneer Group. Fine soft homogeneous clay, slightly foliated. About 1 per cent. fuchsite, 95 per cent. miloschite.

(4) Halcyon Group. Slightly hard but brittle clay, somewhat foliated, many small ironstains. About 1 per cent. fuchsite, 74 per cent. miloschite, 25 per cent. alexandrolite.

(5) Halcyon Group. Similar to (4) but a little softer. Traces only of fuchsite. About 58 per cent. miloschite, 42 per cent. alexandrolite.

(6) Just N. of Wiluna Railway near 2m. post. Similar to (4). About 1 per cent. fuchsite, 55 per cent. miloschite, 45 per cent. alexandrolite.

(7) Halcyon Group. Anastomosing bands of blue-green clay in creamy white, porous, quartz rock. Probably leached quartz-fuchsite-mesitite rock. About 2 per cent. fuchsite, balance equal parts of miloschite and alexandrolite.

(8) (9) Halcyon Group. Rich green, much cracked, mass of waxy consistency, with embedded quartz fragments. The mass was crushed and levigated, all which sank through 5 inches of water in half a minute being rejected. The balance was divided into two grades, viz. (8) which sank in one minute, (9) which did not sink in one minute. Of these (9) is practically pure alexandrolite, contaminated only by about 1.5 per cent. fuchsite. (8) contains small percentages of both miloschite and fuchsite.

The approximate relative proportions of the three minerals present may be calculated from the analytical figures. Every one per cent of K_2O (including any relatively small proportion of Na_2O) represents 10 per cent. of fuchsite. Fuchsite contains 4% of H_2O+; miloschite, 14% H_2O+ and usually about 0.5% H_2O-, whilst alexandrolite contains 12% of H_2O+ and the same amount of H_2O-. After calculating from the alkalis the fuchsite present, the relative proportions of miloschite and alexandrolite can be calculated approximately from the figures for H_2O+ and H_2O-. The miloschite in (3) had G 2.67 and Nm 1.555, and was cryptocrystalline.

As to the origin of the minerals, the fuchsite is a metasomatic product of the basic igneous rock, due to invasion of the rock by magmatic potassium solutions charged with carbonic acid, a phenomenon often associated on our goldfields with the introduction of porphyry dykes and of gold into the Precambrian complex. From the frequent occurrence of this mineral with miloschite and alexandrolite at Meekatharra, and the occurrence of the three minerals along belts mapped by E. de C. Clarke [2] as occupied by carbonated amphibolites, pyroxenites and peridotites, the conclusion is drawn that fuchsite is the parent of the other two minerals. From the known occurrence in several places throughout the State (e.g. Toodyay and Menzies) of perfectly fresh fuchsite right at the surface, it appears that ordinary atmospheric weathering would not effect its transformation into clay minerals. In the Meekatharra area, however, many of the rocks, including some parts at least of the carbonated peridotite, are impregnated with pyrite and arsenopyrite, the weathering of which would give rise to sulphuric acid.

This would effect the leaching out of the mesitite, and also attack the fuchsite, dissolving out the alkali and transforming the chromiferous mica into the two chromiferous clays.

Reference: ([1]) 1916, E. de C. Clarke, *Geol. Surv. Bull 68*. Text and maps.

(5) MONTEBRASITE, RAVENSTHORPE, S.W. AND UBINI, CEN.

Amblygonite ($LiAlFPO_4$), Montebrasite ($LiAlOHPO_4$), and Fremontite ($NaAlFPO_4$) are very similar minerals, which occur under identical conditions, viz. in veins of granite pegmatite. They are completely isomorphous and capable of cocrystallising with one another in all proportions. In addition the molecule $KAlFPO_4$ is also isomorphous, but is unknown as an independent mineral, and is never present in more than small proportions in any known mineral. The correct name to be applied to any member of the group depends upon the relative atomic proportions of Li to Na, and of F to (OH), as determined by analysis.

Ravensthorpe.—As far back as 1911 the author detected a member of the group in material collected from the large pegmatite vein which crosses Cattlin Creek a little north-west of the town of Ravensthorpe. It has been referred to on several occasions ([2]) ([3]) under the provisional title of amblygonite, pending the necessary analysis to fix its classification definitely. The following figures have now been obtained on a representative specimen of the freshest material obtainable:—

Montebrasite, Ravensthorpe.

P_2O_5	F	H_2O	Li_2O	Na_2O	K_2O	G	Ng	Np
47·44	2·72	4·57*	8·76	·60	·32	2·95	1·628	1·599

* By calculation.

The figures indicate the presence of the following molecules:—

$LiAl(OH)PO_4$	...	...	...	76·7 per cent.
$LiAlFPO_4$	...	...	...	19·1 ,,
$NaAlFPO_4$	...	...	...	3·1 ,,
$KAlFPO_4$	...	...	...	1·1 ,,

The correct name, therefore, for the mineral is Montebrasite, the pure molecule of which preponderates over all others.

The largest specimen of it seen as yet is a mass about 9 x 5 x 5 cm. ($3\frac{1}{2}$ x 2 x 2 inches) associated with quartz, albite and bicoloured (green and pink) elbaite. On several sides this large mass is altered to a depth of several millimetres into a dull white, almost opaque, mineral, possibly variscite.

The clean mineral is greyish white in colour, with a pronounced basal cleavage reaching across the whole mass, and showing one twinning plane (101 ?) crossing it. A second cleavage (100) is less pronounced. Flakes under the microscope show a variable translucency, small areas being completely colourless and transparent; whilst the balance is more or less thickly crowded with minute grey inclusions, having no distinctive form. The clearest parts have a specific gravity of 2.98 to 3.01, but various other fragments yielded figures down to below 2.90 due probably to the presence of fluid inclusions. The material analysed was floated between 2.92 and 2.98. A refractive index determination on the clearest mineral yielded the figures Ng, 1.628; Np, 1.599.

Ubini.—Large masses of amblygonite were found here in a pegmatite vein many years ago, and have already been described ([1]) ([5]). The published analyses, one of which is quoted below, leave no doubt as to its specific identity.

In 1928 when the Writer visited the deposit he observed, in close association with the amblygonite, a few large masses resembling it in many ways but differing appreciably in colour and transparency. This second mineral resembled amblygonite in having one very pronounced cleavage, on the face of which traces of multiple twinning with irregular boundaries were to be seen. Furthermore it was translucent, had nearly the same density, and some of the masses were surrounded by an opaque white decomposition product similar to that seen at Ravensthorpe on montebrasite, and occasionally at Ubini on amblygonite. The observed differences were that it was distinctly yellowish in tinge as compared with the pure white amblygonite, and it had a mottled appearance on the cleavage, due to a variation in translucency. The clearest parts were much more translucent than the amblygonite, the cloudy parts about the same as it.

Some of the freshest looking material was chosen from the centre of one of the masses for analysis. The figures are given below against "Montebrasite?" with those of the amblygonite from the same vein for comparison.

	Al_2O_3	Fe_2O_3	Li_2O	Na_2O	K_2O	MgO	P_2O_5
(1) *Montebrasite?* ...	35·90	·22	5·89	1·38	tr.	·02	44·36
(2) *Amblygonite* ...	34·71	·07	9·31	·78	*Nil*	*Nil*	48·01

	F	H_2O+	H_2O-	SiO_2	Total	$-O.F_2$	G
(1) *Montebrasite?* ...	4·04	8·93	·12	1·04*	101·90	1·70	2·90
(2) *Amblygonite* ...	6·95	2·70	tr.	*Nil*	102·53	2·92	3·02

* Includes combined SiO_2 0·41. No Ca, Mn, Be, Ce or Y were detected in either.

Analysts: (1) D. G. Murray; (2) E. S. Simpson.

A determination of the Sp.gr. of a small fragment of the clearest portion of (1) gave 2.92. Much of the analysed material was less transparent and slightly lower in specific gravity.

The calculated molecules present are:—

$LiAl(OH)PO_4$	23·25	Montebrasite.
$LiAlFPO_4$	17·30	
$NaAlFPO_4$	4·57	
$AlPO_4$	19·12	Ceruleolactite ?
$Al(OH)_3$	8·20	
H_2O	27·56	
	100·00	

These figures are difficult to interpret. If the mineral is practically homogeneous, as the persistent cleavage and twinning suggest, it is an hitherto undescribed species having the complex formula $H_3Li_5Al_8(OH)_9F_2(PO_4)_7$.

If, however, the slight blotchiness in transparency and colour indicates an association of an alteration product, devoid of alkalis, with an original mineral of the Amblygonite Group, then the results may be interpreted as a mixture of original Montebrasite, constituting 66% by weight, with Ceruleolactite, 34%. The latter mineral is credited with the formula $4AlPO_4.2Al(OH)_3.7H_2O$, whilst the residue of the Ubini material, after subtracting montebrasite, gives the ratios:—

$$4\tfrac{3}{4}AlPO_4.2Al(OH)_3.7H_2O.$$

References: (1) 1911, E. S. Simpson, *Geol. Surv. W.A. An. Rept.*, 1910, p. 6.

(2) 1912, E. S. Simpson, *Geol. Surv. W.A. An. Rept.*, 1911, p. 10.

(3) 1919, E. S. Simpson, *Mining Handbook of W.A. Rare Metals*, p. 3.

(6) MUSCOVITE, WODGINA, N.W.

A very unusual type of muscovite has been found four miles S.E. of the township of Wodgina amongst the Archaean greenstone hills. It occurs on the surface in large angular boulders up to 6 inches (15 cm.) in diameter. Nothing is known of its immediate associations or genesis.

The mineral is devoid of all visible trace of scaly structure, being very dense, tough and subvitreous, and so compact that it carves well, takes an excellent polish, and when a dye solution is allowed to dry on a polished surface, it can be rubbed off quite easily, leaving no stain. Except for slight surface oxidation of the contained ferrous iron, it is perfectly homogeneous in texture and almost so in colour, the latter being between Ridgways 29'i, pois green, and 25'k, lincoln green. It is translucent in layers up to 1 cm. thick. The hardness is 3½, distinctly higher than that of normal muscovite. It can be conveniently sawn with a hacksaw into firm blocks with sharp arrises, which show no tendency to chip. The various physical properties of the mineral make it admirably suited for carving into various small ornamental articles.

Under the microscope the homogeneity and unusual texture is confirmed. The masses appear to be of uniformly finely granular structure, with no trace of scaliness except along the disrupted edges of the section, where minute highly birefringent flakes are discernible.

Chemically the mineral is a typical muscovite. An analysis made for me by Mr. D. G. Murray shows:

Muscovite, Wodgina.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO
Per cent. ...	46·01	37·08	·18	·16	·05	·16	·22
Mols.	7661	3637	11	22	7	40	39

	Na_2O	K_2O	H_2O+	H_2O-	TiO_2	Total	G
Per cent. ...	·54	10·79	4·58	·12	*Nil*	99·89	2·84
Mols.	87	1145	2542	—	—	—	—

If the small amount of protoxides are calculated in turn to the two possible isomorphous molecules (1), $H_2MgAl_4Si_2O_{12}$ and (2), $H_2Mg_2Al_2Si_3O_{12}$, the ratios of the balance of the constituents are:

	H	K	Al	Si	O
(1) ...	2·01	1·02	2·84	3·08	11·94
(2) ...	2·02	1·00	2·92	3·04	11·97

Both of these are very close to the accepted formula for muscovite, viz. $H_2KAl_3Si_3O_{12}$.

Several types of compact cryptocrystalline muscovite have been described and given independent names. In the absence of type specimens of them it is impossible to correlate the Wodgina mineral with any of them with certainty. "Oncosine" is perhaps the nearest type. Some "Agalmatolite" also is of this nature.

(7) SILLIMANITE, TOODYAY AND CLACKLINE, S.W., AND KYANITE, CLACKLINE.

The first impression one gains of the Darling Range massif, and one supported by the maps and writings of earlier geologists, is that it consists entirely of massive and gneissic granite, with occasional greenstone dykes.

It is now certain, however, that there are considerable areas of Precambrian sediments included in it. The Writer has already recorded their occurrence throughout the length of the Chittering Valley (3) (8), and with Mr. J. E. Wells was the first to draw attention to them in the Jimperding Valley near Toodyay (5). The latter occurrence was later mapped in detail by Prof. E. de C. Clarke and his students, and described in brief by Clarke (7), and later in more detail by R. T. Prider (9).

Toodyay. No published record can be found of the occurrence of sillimanite in any of the metasediments in the vicinity of this town. Neither Clarke (7) nor Prider (9) makes any reference to its presence in the Jimperding Valley schists.

In the Writer's collection, however, are specimens illustrating its occurrence in six places in the district, three of them in the Jimperding Valley. The specimens are (1) A white kaolinised quartz-mica schist with many porphyroblasts of andalusite, and innumerable interbedded films composed of microscopic needles of sillimanite. Locality, 2 miles W.N.W. of Jimperding Hill.

(2) An ironstained quartz-muscovite-biotite schist with large porphyroblasts of andalusite, between two of which is a thick flake of white fibrous sillimanite, 50 x 30 x 5 mm. Locality, Block 3204, Jimperding Valley, South of Kowalyu-Katta.

(3) Quartz-biotite-muscovite schist, one specimen with a few large slabs of fibrous sillimanite, another with innumerable thin interbedded films of the same. Locality, North of Block 195, Jimperding Valley.

(4) Quartz-biotite-muscovite schist with a broad (3 cm.) plate of white fibrous sillimanite lying parallel to the foliation plane and enclosing small scales of biotite. Locality, collected by J. E. Wells 20 chains west of Key Farm, 2 m. S. of Toodyay.

(5) Biotite schist with thin plates of white fibrous sillimanite. Locality, 3 miles north-east of Toodyay.

(6) Small much weathered specimen of mica (biotite?) schist with silky appearance on cross fracture. This yields abundant micro-spicular sillimanite, 0.01 to 0.10 mm. in diameter, when treated with hydrofluoric acid. Locality, Perrin's prospecting area, Wongamine, 10 miles N.E. of Toodyay.

In each of these cases the identity of the mineral has been established by optical properties, supported when possible by chemical reactions and specific gravity determinations in methylene iodide.

Clackline. For over 30 years firebricks have been made at Clackline. The clay comes mostly from a large pit in what has been considered by most authorities to be an area of massive granite and granite gneiss, traversed by greenstone dykes, all the rock being completely kaolinised to a depth of at least 30 ft. in the clay pit. See for example F. R. Feldtmann (2) and A. G. D. Esson (4). E. de C. Clarke, however, published in 1930 (7) a sketch map showing a continuation of the Jimperding schists south-eastward through Clackline, but has no corresponding description in the text.

Last year two specimens of different clays from the brickworks were brought to me by Mr. C. S. Hunter (the proprietor) and Mr. J. E. Wells, and these appeared as if they might contain sillimanite. Laboratory tests by the Writer proved that in each case that mineral was indeed present to the extent of about 5 per cent. of the whole. In consequence of this, and the fact that Mr. H. Bowley had picked up a loose crystal of kyanite a little to the north of the brickpit, the Writer visited the place early this year and carefully examined it for the presence of sillimanite and kyanite. None of the latter could be detected by eye though afterwards seen occasionally under the microscope. Sillimanite on the other hand was found to exist plentifully both in the main clay pit and within a radius of half a mile of it. This pit it should be noted is only 11 miles S.E. of the first find of andalusite schist at Jimperding, and approximately on the line of strike of the quartzites and andalusite-sillimanite schists existing there.

Careful examination of the faces of the main pit discloses that at least two-thirds of the kaolinised rock is distinctly foliated with vertical bedding, the remainder being massive. The latter appears to consist largely of kaolinised greenstone, but small tongues and veins of undoubted kaolinised pegmatite are visible in the foliated mass. The former consists of a mixture of kaolin, finely granular quartz, mica and sillimanite, with one band in which limonite pseudomorphs after almandine are easily recognisable. Typical specimens taken from the east side, centre, and west side of the main north face are distinctly seamed with thin plates and small lenticular "eyes" of almost pure sillimanite, which mineral constitutes from 5 to 10 per cent. of the whole mass.

The mineral was concentrated for detailed examination either by (1) puddling the coarsely broken ($^1/_4$ inch) clay until nothing but small fibrous lenses of sillimanite and associated quartz grains were left, or (2) treating a few grams of the finely powdered (60 mesh) clay with strong hydrofluoric acid, followed by strong hydrochloric or sulphuric acid, and then distilled water. The residue in both cases was examined under the microscope.

The mineral in every case occurs in fibrous lenses and thin silky plates of a pure white or pale buff colour, with the fibres parallel to the foliation of the rock. These aggregates easily break up into individual fibres ranging from 0.005 up to 0.100 mm. in diameter. The smaller ones are invariably perfectly straight, transparent, colourless rods. The larger ones often striated in the prism zone, and sometimes show a basal parting. No terminal prisms could be seen. Optically they are characterised by straight extinction, positive elongation, Ng. 1.680, Np. 1.659. Chemically they are typically resistant to hot strong HCl and HF. The specific gravity, when tested, was over 3.03.

A few small prisms of schorl and deep brown rutile, and rarely a small tabular crystal of kyanite, with typical extinction angle, cleavage, etc., were found in the sillimanite concentrates from one of the clays of the main pit.

On the west side of this pit a rather hard, but porous, and completely weathered, rock was found which appeared to be a local silicification of a softer rock. It was crowded with a network of thin films of finely fibrous, white sillimanite.

A concentrate from a single specimen of a strongly foliated micaceous clay in the small No. 2 Pit contained a few microscopic rods of sillimanite and tablets of kyanite. This pit is about 20 chains N. of the main pit.

In a costeen a little further to the north-west is a very soft, highly micaceous clay with innumerable microscopic spicules of sillimanite (.005 – .01 mm. diam.) and occasional larger prisms up to several millimetres in length and 0.05 to 0.20 mm. diameter. Many of the flakes of bleached biotite are penetrated by needles of sillimanite. This frequent association of sillimanite with mica inclines one to believe that the so-called spicular mica, said to be responsible for so many cases of silicosis, is in reality not mica but sillimanite.

A little to the west of the clay pit, the sediments are much more sandy, with bands in which small and large plates of white fibrous sillimanite are plainly visible. The chief constituents of these rocks are quartz, biotite, muscovite and sillimanite, some specimens being identical in macroscopic and microscopic appearance with certain rocks of the Chittering Valley. A sometimes partial, sometimes complete sericitisation of some of the sillimanite masses indicates a later stage of retrograde metamorphism.

This alteration of sillimanite into muscovite is brought about almost certainly in the zone of katamorphism by the invasion of the meta-sediments by hot alkaline potash solutions from intrusive pegmatite or granite. It is not widely recognised in mineralogical literature, but has been observed on a large scale in India and recorded by J. A. Dunn [6], and again by A. Lacroix in Algeria [1]. Very perfect examples of it have been observed by the Writer in several places in the Chittering Valley close to intrusive granite.* At Clackline the evidence of this pseudomorphism is indisputable, the typical fibrous appearance, situation and form of the original sillimanite masses being perfectly retained.

From these observations it becomes clear that the greater part of the clay used in making firebrick at Clackline is a highly kaolinised biotite-sillimanite schist of the Chittering Precambrian series. Originally this rock was probably a highly glauconitic shale. That the kaolinised schist still carries some unaltered mica is indicated by the alkali contents of a sample from the east side of the pit, viz. K_2O, 1.80 per cent., Na_2O, 0.29 per cent.† Instrusive into it, and used with it in the brickworks, are at least three types of completely kaolinised igneous rocks. These are (1) granite pegmatite, (2) dolerite or epidiorite, (3) a chromium-bearing rock with little or no quartz, now a miloschite-bearing clay with occasional nodules of opal, but probably originally a hypersthenite or serpentine, both of which species of rock are known as unweathered dykes within a radius of 15 miles of Clackline.

Probably from (2) is derived the vanadium which forms such conspicuous bright yellow films of potassium vanadate on the new bricks after they have been exposed to their first shower of rain. This often changes to a greenish-black vanado-vanadate by contact with organic dust.

References: (1) 1910, A. Lacroix, *Min. de la France*, 4, p. 679.

(2) 1920, F. R. Feldtmann, *Geol. Surv. An. Rept.* for 1919, pp. 29, 30.

(3) 1926, E. S. Simpson, *J. Roy. Soc. W.A.*, 12, pp. 62-66.

(4) 1927, E. C. D. Esson, *Geol. Surv. An. Rept.* for 1926, pp. 13, 14.

(5) 1928, E. S. Simpson, *J. Roy. Soc. W.A.*, 14, pp. 50, 51.

(6) 1929, J. A. Dunn, *Mem. Geol. Surv. India*, 52, Pt. 2, pp 150, 182, 201-2, 205, 207-9.

(7) 1930, E. de C. Clarke, *Rept. Aust. and N.Z. Ass. Adv. Sci.*, 20, p. 167.

(8) 1932, E. S Simpson, *J. Roy. Soc. W.A.*, 18, pp. 66 7, pp. 75-82.

(9) 1934, R. T. Prider, *J. Roy. Soc. W.A.*, 20, pp. 3-16.

* For example, near Block 780, Middle Chittering Valley.

† In addition there was 1·21 per cent. of NaCl, all the clays in the pit carrying a notable quantity of salt ranging from 0·5 per cent. upwards.

(8) STIBIOTANTALITE, GREENBUSHES, S.W.

Stibiotantalite is the name which was applied to a new mineral found at Greenbushes in 1893 by J. J. East and G. A. Goyder and described by them in the same and following years ([1]) ([2]). The essential composition is $SbTaO_4$. Stibiocolumbite, $SbNbO_4$, and bismutotantalite, $BiTaO_4$, are isomorphous compounds and, as well as existing as independent minerals, occur as cocrystallisations in stibiotantalite, the former in all proportions, the latter only in small amounts. Many descriptions have been given of the Greenbushes mineral, but most of them are only repetitions of the information published by East and Goyder, and of the further details published by the present Writer in 1907 ([3]).

The exense for this note is an unpublished analysis and a description of a single crystal now available, with a few additional details regarding its occurrence.

The main source of the Greenbushes mineral has been the Enterprise M.L. 369, on the saddle between Floyds and Bunbury gullies, about a mile S.E. of the town, and the alluvium in these gullies below this lease. A little has also been found in Boronia gully near the Boronia M.L. 361, 2 miles N.W. of the town. Some has been found with tantalite and cassiterite in the Enterprise lode, a greisenised pegmatite, but the major quantity in the tin bearing alluvium. In all probably well under one hundredweight of the mineral has been obtained, and most of it shipped away in parcels of tin ore or tantalum ore.

All the specimens obtained from the lode, and many of those from the alluvium, have been in the form of replacements of, or fissure fillings in, comparatively large pieces of tantalite. It thus appears that the genesis of the tantalite has preceded that of the stibiotantalite, the latter being formed by interaction between antimonial solutions and pre-existing tantalite in the later stages of pegmatite history. Veinlets are rare, and consist of honey-coloured translucent mineral, usually 1 mm. or less in thickness. Replacements are quite common and usually proceed from one side of the tantalite to an extent ranging from a thin shell only 1 mm. thick to an almost complete replacement of a mass several centimeteres across. The advancing face of the antimony replacement is always uneven, and often ragged, whilst completely isolated inclusions of unaltered tantalite have frequently been observed in the stibiotantalite. This pseudomorphous stibiotantalite is usually very finely granular, dull grey or yellow in colour, and of low translucency.

In addition to the large alluvial pebbles of intergrowths of the iron and antimony compounds, the alluvial ground carries smaller pebbles, usually not over 5 mm. in diameter, of pure stibiotantalite. Many of these have the appearance of the replacing mineral just described, others are more or less translucent, and apparently consist of a single crystal individual. Owing to its comparative softness and brittleness, crystal faces are not preserved, only one crystal capable of orientation and measurement being known. Cleavage faces are more often apparent, and occasionally two adjacent crystal faces with worn boundaries.

Much of the alluvial mineral is translucent in thicknesses up to 4 or 5 mm. and some of it quite transparent when 1 mm. or rarely 2 mm. thick. The colour is usually some tint of pale yellow, sulphur, honey or lemon. Darker fragments grade towards cement grey on the one hand, and dark brown on the other. The mineral is anisotropic. In some pieces a distinct cleavage is to be seen, probably (001).

Specific gravities determined on a number of pebbles by the Writer were as follow:—

6·41, 6·75, 7·05, 7·05, 7·14, 7·17, 7·18, 7·26, 7·27, 7·29, 7·34, 7·35, 7·36, 7·41, 7·46, 7·48.

Goyder gave the range of specific gravity as 6.47 to 7.37. The highest figure must represent that of almost pure $SbTaO_4$, the lower ones indicate increasing association with $SbNbO_4$. The lighter specimens in some cases carry quartz inclusions. There does not appear to be any correlation between specific gravity and depth of colour. The heaviest fragment (G 7.48) was dark yellow, but two dark brown ones gave 7.26 and 7.35, and a pale sulphur yellow 7.41.

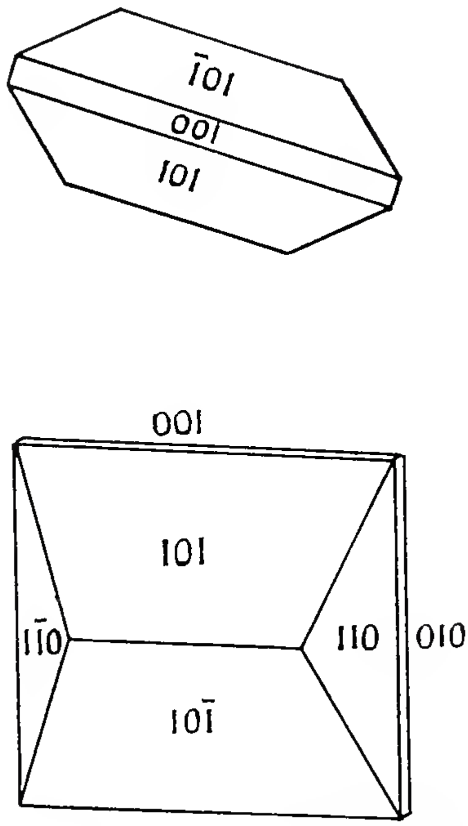

Fig. 1.—Crystal of Stibiotantalite, Greenbushes.

A broken crystal, the only large one seen, which measured 13 x 12 x 6 mm. had the form shown in the Fig. It was a combination of (010), (001), (110), (101). A number of smaller crystals, 1 to 3 mm. in diameter, were too imperfectly developed for their forms to be determined in the absence of complete crystallographic data for the mineral. The one which has been measured confirms the grouping of stibiotantalite with pucherite ($BiVO_4$).

In composition the Greenbushes mineral is found to consist mainly of $SbTaO_4$, with minor variable amounts of $SbNbO_4$, and usually under 2 per cent. of $BiTaO_4$. The two analyses that have been made on pure mineral are:—

Stibiotantalite, Greenbushes.

Ta_2O_5	51·13	57·29
Nb_2O_5	7·56	1·79
Sb_2O_3	40·23	40·64
Bi_2O_3	·82	·30
NiO	·08	*Nil*
Fe_2O_3	trace	*Nil*
	99·82	100·12
G	7·37	7·345

Analysts: G. A. Goyder E. S. Simpson.

The colour of the pebble analysed by the Writer was rather dark brown.

Mawson and Laby in 1904 examined specimens of the mineral for radioactivity, but found none. In 1911 W. G. Giles, an English chemist with considerable experience of the rare metals, wrote me that he had found in Greenbushes stibiotantalite decided traces of germanium.

References: (1) 1893-4, J. J. East, *Aust. Mining Stand. 9, No. 233. Trans. Aust. Inst. Min. Eng. 1*, pp. 139-142.
(2) 1894, G. A. Goyder, *Trans. Roy. Soc. So. Aust. 17*, p. 127. *Rept. So. Aust. School of Mines*, pp. 163-5.
(3) 1907, E. S. Simpson, *Aust. Ass. Adv. Sci. 11*, p. 452-5.

(9)—ZOISITE, JIMBLEBAH, N.W., NINGHANBOUN HILLS, AND WONGONG BROOK, S.W.

Only one analysis of a West Australian zoisite is on record, made by the Writer many years ago on specimens of saussuritised plagioclase collected at Sir Samuel(1).

Analyses of three other specimens are now available, one from Ninghanboun Hills being of unusual purity.

Jimblebah, N.W.—In 1927 the Writer found a number of small white angular boulders lying loose on the northern slope of the main eastern spur of the Hamersley Ranges between Jimblebah and Skeleton Creek. The rock formation here consists of Precambrian amphibolites intruded by large masses of serpentine. The boulders were not traced to their original matrix, which is probably some form of hornblende rock.

The boulders themselves are homogeneous and almost pure white in colour, except where ironstained on the surface from contact with the soil. They are hard and dense, and micro-granular in structure. Some of the cleanest material from the centre was taken for analysis, the results obtained being shown in the table. Microscopic examination reveals a finely granular (0.02 — 0.05 mm.) mixture of zoisite and albite with a little quartz and mica, the first predominating and in many cases exhibiting an anomalous bright "Prussian blue" interference colour, which according to Weinschenk is characteristic of clinozoisite. This blue colour is only to be seen in about one half of the grains, and is apparently only exhibited by sections of the mineral which are close to the optic axial plane. No prismatic sections were available to determine whether extinction was straight (zoisite) or oblique (clinozoisite). Calculation from the analysis given below indicates the presence of approximately—

Ferriferous zoisite ...	81·1	per cent.
Albite	15·3	,,
Quartz	2·1	,,
Muscovite	1·5	,,

Ninghanboun Hills, S.W.—In 1930 the writer found a large pale pink and grey inclusion in the outcrop of a Precambrian hornblende rock near the eastern end of these hills. This inclusion, or segregation, which was several feet in length, was very hard and tough, with a microgranular structure. The pure pink parts of it graded imperceptibly into the greyer parts, whose colour appeared under the microscope to be due to a slight intergrowth of a darker coloured amphibole with preponderant zoisite. The pale pink masses were practically pure zoisite, having G 3.32 and 3.28. A fragment partly pink, partly grey, had G 3.27, one mostly grey, 3.14.

An analysis was made of the purest material with the results shown in the table. The figures taken as a whole show the following atomic ratios:—

	H	Ca	Al	Si	O
Theory for Zoisite ...	1	2	3	3	13
Ninghanboun mineral...	1·13	2·00	2·90	3·05	13·02

The material analysed was well over 95 per cent. pure, with small inclusions of felspar, amphibole, sphene (with occasional remnants of ilmenite), and zircon. Blue interference colours, not quite as bright as those oberved in the Jimblebah mineral, were noticeable, but every grain showing a definite cleavage yielded a straight extinction, indicating zoisite and not clinozoisite. The granules were about double the size of those in the Jimblebah specimens.

Wongong Brook, S.W.—In sinking some trial shafts to test a proposed dam site in the valley of the Wongong Brook in the Darling Range, one of the many epidiorite dykes in the main granite mass was found to be studded with large porphyritic crystals and groups of crystals of a saussuritised plagioclase. These being light cream to greyish white in colour stand out most prominently against the almost black mass of the rock. In cross section they have mostly a fortification-like outline, conisting of straight lines joining a series of projecting and reentrant angles. They reach up to 10 cm. (4 inches) in diameter.

Microscopic examination of a thin slice of one of the masses reveals a typical saussurite, probably an altered labradorite, consisting of zoisite, albite, epidote, muscovite, quartz, chlorite and biotite. Those portions of the masses which are palest in colour are practically devoid of the last two, which are more abundant in the greyer portions. The zoisite in the section shows mostly bluish-grey interference tints, rarely brightening to greyish-blue.

An analysis was made of some of the lightest coloured portions, with the results given in the table. From this the mineral constitution is calculated to be—

	Zoisite	Epidote	Albite	Muscovite	Quartz	Chlorite Biotite
Per cent. ...	54	12	14	17	3	traces

Impure Zoisite.

No.	1	2	3
Locality ...	*Jimblebah*	*Ninghanboun*	*Wongong.*
SiO_2	45·59	39·69	45·66
Al_2O_3	29·29	29·95	29·65
Fe_2O_3	2·57	3·23	2·75
FeO	trace	·23	·59
MnO	*Nil*	·08	·07
MgO	*Nil*	·16	·65
CaO	18·66	23·88	15·15
Na_2O	1·82	·03	1·73
K_2O	·18	·22	2·01
H_2O+	1·88	2·21	2·04
H_2O-	*Nil*	·05	·08
TiO_2	n.d.	·08	·06
CO_2	*Nil*	·03	*Nil*
Total	99·99	99·84	100·44
G	3·14	3·32	3·02
Analysts ...	D. G. Murray	H. P. Rowledge	W. W. Saw
Calcd. Zoisite ...	81%	99%	54%

Reference: (1) 1907, E. S. Simpson, *Geol. Surv. Bull. 28*, p. 47.

ACKNOWLEDGMENTS.

The writer desires to express his thanks to Messrs. D. G. Murray, H. P. Rowledge and W. W. Saw, of the Staff of the Government Laboratory, for the valuable assistance they have rendered him by making analyses of several of the minerals described in this paper, and to Mr. J. E. Wells for specimens and field information.

Government Laboratory, Perth,
5th August, 1935.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

2.—THOLEIITE BASALTS FROM CAPE GOSSELIN, WESTERN AUSTRALIA.

By A. B. EDWARDS, Ph.D.

Read: 13th September, 1935; Published: 20th May, 1936.

CONTENTS.

With one plate.

INTRODUCTION.

The following petrographical description of the Cape Gosselin basalts is based upon collections made in that area by Professor E. de C. Clarke, who generously placed them at the writer's disposal. The specimens are preserved in the collections of the Geology Department of the University of Western Australia (Reg. Nos. 5539-5547, 5552, 5555, 10338-10342, 10351-10354).

Cape Gosselin, or Black Point as it is called locally, is about 20 miles east of Cape Leeuwin. The outcrops of basalt at Cape Gosselin are residuals of flows which were possibly of much wider extent. The residuals probably mark the position of the vents or fissures about which extrusion occurred, since there seems to be evidence that the surrounding sediments have been metamorphosed. One specimen of the collection, No. 5543, is a dense black chert, of extremely fine grain size, with thin elongated lenticles of chalcedony between the bedding (?) planes. It has an appearance suggesting that it might have been fused: but it has not been found in situ. A second specimen, No. 5545, is a metamorphosed limestone, and consists of small equigranular crystals of calcite, with thin bands of hematite, more or less parallel to one another, at intervals. The hematite bands may mark original bedding planes.

PETROGRAPHY.

The basalts, as represented in the collection, are olivine-free labrodorite basals, generally similar in character, and with the textures and compositions of tholeiites. In the hand specimen they are grey, crystalline rocks, showing small glassy prisms of plagioclase and occasional dark spots of ferromagnesian minerals, without any suggestion of flow structure.

Under the microscope (Plate 1, Fig. 1-4) they are seen to be microporphyritic, the phenocrysts consisting of stout prisms of plagioclase, about 1 to 2 mms. long, and often strongly zoned. The inner zones have a maximum extinction angle of about 38° in the zone at right angles to (010), indicating labradorite about Ab_{35}, while the outer zones are considerably more acid, and in some instances appear to be andesine, about Ab_{65}. They carry numerous rounded inclusions of apatite. Occasional larger crystals about 3 mms. in diameter possess well marked idiomorphic outlines, but show inclusions of pyroxene and green glass along their cleavage planes. In the specimens with a fine-grained groundmass the plagioclase phenocrysts show a tendency to clot together (Plate 1, Fig. 1).

The pyroxene also tends to microporphyritic, especially in the finer-grained rocks, when it shows twinning parallel to (100); but it rarely shows idiomorphic outline in the coarser-grained rocks, unless adjacent to a patch of glass. Sometimes it forms locally ophitic intergrowths with the plagioclase, but more generally it is moulded about the felspar laths, or intersertal to them. It is lightly brownish to colourless, with $Z \wedge \underline{c} = 40°$ approximately, and has a very low optic axial angle ($2V = 5°$ approximately), so that it is a pigeonite or enstatite-augite. The composition of the pyroxene is variable, as occasional measurements of 2V indicate a more diopsidic character ($2V = 50°$). The pigeonite is the dominant species, however.

The lavas are characterised by the absence of olivine. Only in one slide have small remnants of olivine been seen occasionally.

The textures of the groundmass vary, and the collection might be divided into two groups on a textural basis—dolerites and basalts—but there is a gradation between them. The texture is sub-hyaline and doleritic to intergranular (Plate 1, Figs. 1-4). The minerals of the base are plagioclase (labradorite Ab_{45}), pyroxene (pigeonite), magnetite and glass. The labradorite occurs in small prisms, which grade in size into the microphenocrysts, and the pyroxene is intersertal to it. The glass may appear in one of three forms:—(i) as a brown isotropic glass, which consists of a felspathic material crowded with minute grains of iron-ores, and is the common type; (ii) as a green chloritic, and weakly birefringent material, filling cavities; and (iii) occasionally as a clear yellow material. Iron ore forms fairly coarse crystals throughout the groundmass, and is sometimes skeletal in a curious pattern (Plate 1, Fig. 4), the diagonals and the rim of the crystals having developed, while the intermediate parts of the crystals remain unfilled.

The collection includes a vein of calcite through the basalt, but the rocks themselves are free from zeolites or calcitic material. The calcite is probably derived from the metamorphosed limestone referred to previously.

An analysis of a typical tholeiite gives the following composition:—

	1.	2.	3.	4.
SiO_2	51·14	49·42	47·88	50
Al_2O_3	14·56	14·95	14·22	13
Fe_2O_3	4·05	1·38	1·73	} 13
FeO	7·04	10·76	12·36	
MgO	6·25	6·16	6·35	5
CaO	10·15	9·85	10·23	10
Na_2O	3·96	2·70	2·47	2·8
K_2O	0·58	0·72	0·51	1·2
H_2O + 110 ...	0·54	0·77	0·23	
H_2O — 110 ...	1·35	0·09	0·07	
CO_2	0·05	*nil*	*nil*	
TiO_2	0·01	1·95	2·95	
MnO	0·16	0·47	...	
Cl	*nil*	...	0·08	
S	*nil*	0·26*	0·08*	
BaO	*nil*	...	tr.	
Total	99·86	100·03	99·71	

* FeS_2.

1. Tholeiite, from columns at the western end of the outcrops, Cape Gosselin (No. 10353). (Analyst—A. B. Edwards).

2. Quartz-dolerite, sill or flow, Irregully Creek, Upper Ashburton River, N.W. Division (*Bull. No. 67 Geol. Surv. Western Australia*, p. 32, Analysed Specimen No. 7728). (Analyst—H. Bowley.)

3. Amphibolite, Bunker Bay, near Cape Naturaliste (*Proc. Lin. Soc. N.S.W.*, *li.*, (4), p. 625, 1926).

4. Composition of Tholeiite Magma Type, after W. Q. Kennedy, *Amer. Journ. Sci. vol. 25*, 1933.

Norms.

	1.	2.
Q	...	...
Or	3·45	4·45
Ab	31·65	23·06
An	19·12	26·41
Ne	...	...
di	25·26	15·65
hy	2·34	18·64
ol	9·65	3·86
mg	5·88	2·09
il	0·03	3·65
ap	0·03	1·28
cal	0·10	...
pyr	...	0·26

The analysis is remarkable for its low titania content, but otherwise approximates closely in composition to the tholeiite magma, as defined by Kennedy.(8). It is quite distinct from the olivine-basalts of the Eastern States, and from the much older Antrim Plateau basalts of the Kimberley District, which are fine-grained felspathic rocks, possibly related to the mugearites. The nearest approach to it chemically among the analyses of Western Australian rocks is a quartz-dolerite from the Ashburton River(3) but this carries quartz, orthoclase, hornblende and biotite in addition to labradorite and augite. Also similar in bulk composition is an amphibolite dyke from Bunker Bay, near Cape Naturaliste(5), which consists of brown hornblende, rhombic pyroxenes, basic plagioclase and ilmenite. It is thought, however, by Saint-Smith(2) to be a derivative of the ancient granites of the Cape Naturaliste region.

On account of the relatively high soda content recorded in the analysis, the Cape Gosselin basalt appears undersaturated in the norm, rather than tholeiitic (saturated). The large amount of soda leaves less silica available in the calculations. This increases the amount of albite and diopside in the norms, at the expense of the anorthite and hypersthene. Magnesia, which with a lower soda content would appear as hypersthene, has to be calculated as olivine. With a somewhat lower soda content the norm would indicate the typical tholeiitic characters which the rock itself possesses. Such a norm is provided by the quartz-dolerite (Analysis 2), in which the only outstanding chemical differences from the Cape Gosselin analysis are the titania and soda percentages.

Tholeiites are rare among the records of Australian basalts. The only occurrence known to the author is a tholeiite dyke from Kangaroo Island, South Australia, which has been described by Tilley(7), and is regarded by him as associated with the enstatite-basalts of that island(1). Olivine-free basalts have been described from Queensland by Richards(16), but they do not appear to be true tholeiites.

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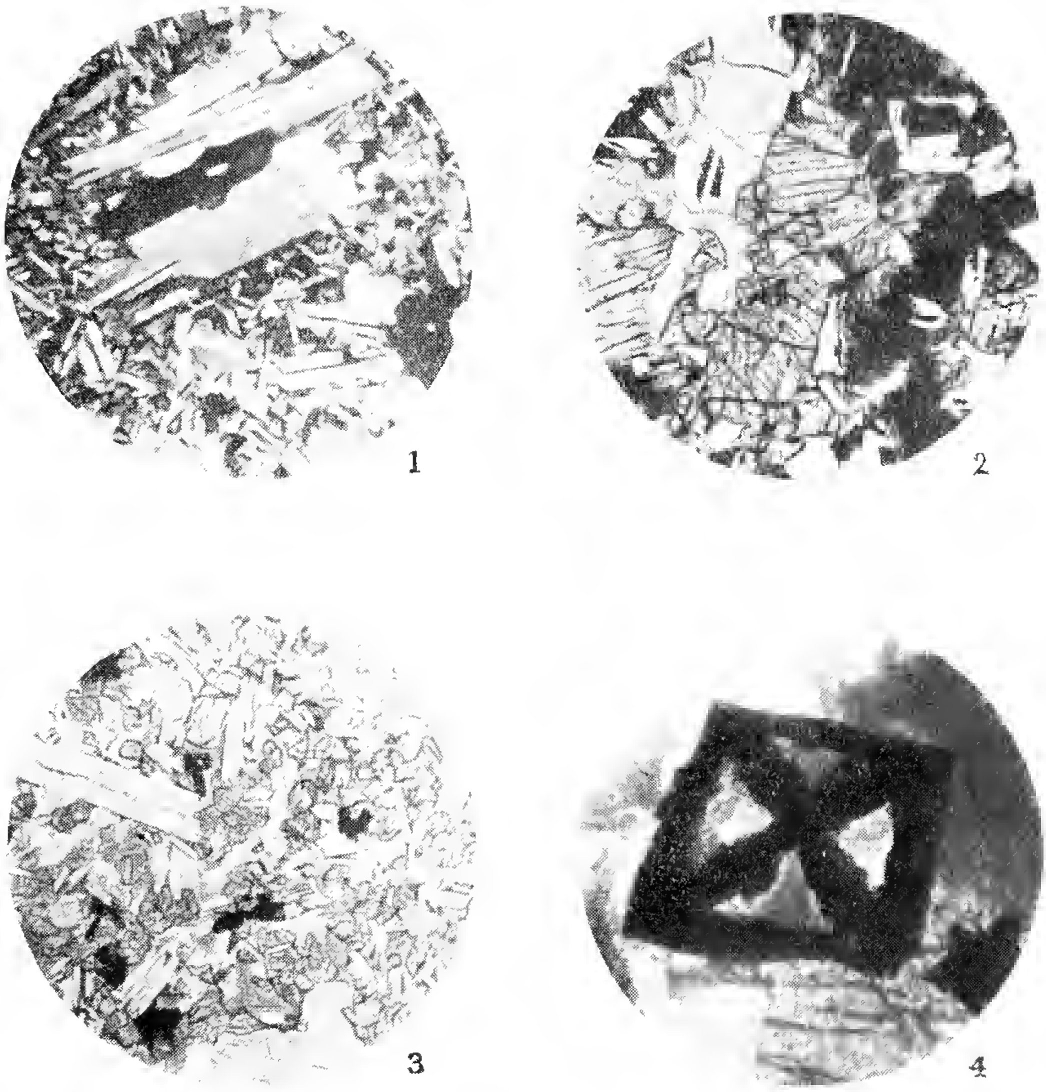


PLATE I.

1. Clot of zoned plagioclase phenocrysts in a fine-grained, sub-hyaline groundmass. Crossed nicols, X 20.
2. Doleritic textured tholeiite, showing intergrowth of plagioclase and pigeonite, with dark intersertal glass. Ordinary light, X 65.
3. Groundmass of intergranular tholeiite. Ordinary light, X 67.
4. Skeletal crystal of magnetite, from groundmass of tholeiite. Ordinary light, X 300.

3.—UPPER DEVONIAN CORALS FROM WESTERN AUSTRALIA.

By Dorothy Hill, Ph.D.,
Associate of Newnham College, Cambridge.

Read: 10th March, 1936; Published: 10th July, 1936.

With one plate and eight text figures.

INTRODUCTION.

This paper revises those species of corals already described from Western Australia, adds some new species, indicates that with one exception the age of the coralliferous beds is probably Frasnian (*i.e.*, the lower part of the Upper Devonian), and describes the arrangement of the calcareous fibres in the Tabulate genera *Alveolites* Lamarck and *Syringopora* Goldfuss.

The Rugose Corals here described belong with one exception to the group of corals related to *Disphyllum* de Fromentel, a group recently studied by Lang and Smith (1935). The group is characteristic of the Devonian of Europe and America; it is important in the Middle Devonian, and dominant in the Upper Devonian, and it is but natural that the earliest collections of Rugose Corals from the Upper Devonian of Western Australia should consist almost entirely of its representatives. The Tabulate corals described here also belong to genera dominant in the European Upper Devonian.

The specimens are from collections made by E. T. Hardman in 1880, H. P. Woodward in 1906, A. Wade in 1920 and J. E. Wells in 1922, and are in the British Museum (Catalogue Letters B.M.R.), the Geological Survey of Western Australia (Catalogue Numbers beginning 100........), the Perth Museum (Catalogue Letter △), and the University of Western Australia (Catalogue Number......).

The localities and the species found at each are shown in the accompanying table:—

	Price's Ck., Rough Range, Kimberley.	Price's Ck., Rough Range, Kimberley (N. of Borehole).	Opp. Mt. Krauss, Rough Range, Kimberley.	Barker Gorge, Napier Range, Kimberley.	Gascoyne R. (locality challenged).	Mt. Pierre, Kimberley. (Famennian).
"*Cystiphyllum*" *kimberleyense* sp. nov.	...	...	...	...	...	×
Disphyllum depressum (Hinde) ...	...	×	×	...	×	
D. virgatum (Hinde)	...	...	×	...	×	
Phillipsastraea delicatula sp. nov. ...	...	...	...	×		
Prismatophyllum brevilamellatum sp. nov.	×					
Alveolites aff. *multiperforatus* Salée	...	...	?	...	?	
A. tumida (Hinde)	...	...	×			
Aulopora repens Knorr & Walch; Hinde	...	...	×			
Syringopora patula Hinde	...	...	...	...	×	

Of these species, "*Cystiphyllum*" *kimberleyense* was collected from the red Goniatite limestone of Mt. Pierre, shown by Delépine (1935) to be Famennian. Of the others, *D. virgatum* is close to *D. aequiseptatum* Edwards and Haime from the Upper Givetian or Lower Frasnian of Ilfracombe. *D. depressum* is close to *D. goldfussi* (Geinitz), from the Givetian and Frasnian of Europe. *P. brevilamellatum* is unlike any of the described forms of this genus, which is characteristic of the Middle and Upper Devonian of Europe and America. *P. delicatula* is like the Upper Devonian *P. hennahi* Edwards and Haime. *Syringopora patula* is comparable with the Givetian *S. caespitosa* Goldfuss. *A. tumida* may possibly be related to the Upper Middle Devonian genus *Plagiopora* Gurich. *A. multiperforatus* is a characteristic Frasnian coral. *A. repens* ranges through Eifelian, Givetian and Frasnian.

The ages of the coralliferous localities which these species indicate are as follows. "Opposite Mt. Krauss" (where also, for reasons given in the next paragraph, the specimens said to be from the Gascoyne River are believed to have been collected) is either Upper Givetian or Lower Frasnian, and the absence of all the cyathophylloid genera so characteristic of the Middle Devonian makes a Lower Frasnian horizon more likely. The cream-coloured limestone from Price's Creek north of the Bore-hole is also probably Lower Frasnian. The white crystalline limestone of Price's Creek is either Middle or Upper Devonian, and the only coral species collected from there might well be Frasnian. The Barker Gorge limestone is Upper Devonian, and probably Frasnian.

I doubt that the specimens of *D. virgatum, D. depressum, S. patula,* and *A.* aff. *multiperforatus* from the Hardman collection, labelled as from the Gascoyne River, actually came from this locality. So far as I can discover from David's Geological Map of Australia, there is no outcrop of Devonian rocks along the Gascoyne River. The "Gascoyne" specimens of *D. virgatum* and *D. depressum* are identical in matrix and preservation with those from opposite Mt. Krauss, even to the crushing of *D. virgatum. D. depressum* "from Gascoyne River" is encrusted with *Stromatoporella eifeliensis*, known from opposite Mt. Krauss. The lower half of the holotype of *D. depressum* is labelled as from opposite Mt. Krauss, and the calical half is labelled "Gascoyne River." In this case there is proof that the labels have been mixed; and I think that probably all the corals mentioned in this paper as from the Gascoyne River were really collected opposite Mt. Krauss. No Devonian brachiopods were described from the Gascoyne River in the series of articles on Western Australian Palaeontology which accompanied Hinde's paper on the corals. *Amplexus pustulosus* and *Plerophyllum australe*, described by Hinde as from the Gascoyne River, are Permian corals, and are probably correctly labelled.

The relations of the Kimberley Upper Palaeozoic limestones (Wade, 1923-24; Hosking, 1933) may be summarised as follows:—

PERMO-CARBONIFEROUS	sandstones with tillites
unconformity	
LOWER CARBONIFEROUS	Upper grey limestones (Wade) 600 feet +
FAMENNIAN Smith, 1933.	Red goniatite limestone of Mt. Pierre (Wade) with "*Cystiphyllum*" *kimberleyense*, 200 ft. +
FRASNIAN	(a) White or cream-coloured *Atrypa* limestone, with *Pugnax pugnus*, *Wilsonia cuboides* and *Spirifer* cf. *disjuncta*, of Margaret River - Christmas Creek area.
All other coral localities mentioned in this paper.	(b) White crystalline limestone of Price's Creek. (c) Red and red-white limestone of Barker Gap. The relations of a, b, c to one another are not known.

DESCRIPTION OF CORALS.

"**Cystiphyllum**" **kimberleyense** sp. nov.

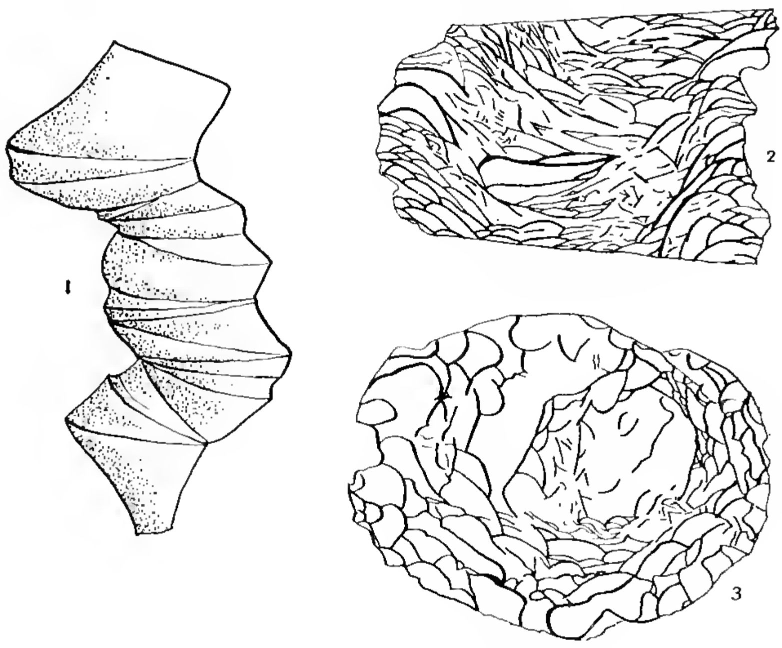
(Text figures 1-3.)

Cystiphyllum sp. Wade, 1924, p. 13.

Holotype. B.M.R. 29066, Upper Devonian (Famennian), Mt. Pierre, Kimberley. This is the only specimen examined.

Diagnosis.—Simple Rugose coral of irregular growth, with large dissepiments, flat or sagging tabulae and no septa or vestiges of septa.

Description.—The corallum is simple, 45 mm. tall, with a maximum diameter of 20 mm. The apical portion is trochoid, but after attaining a height of 10 mm. the corallum becomes very irregular in diameter and in direction of growth. Rejuvenescence of the type causing gradual decrease in diameter of the corallum, alternates with periods of normal growth, each segment differing from the preceding in direction. (Text fig. 1.) The calice is not known. The epitheca is rugose, and does not show longitudinal striation.



Text-figs. 1-3. "**Cystiphyllum**" **kimberleyense** sp. nov.
B.M.R. 29066. Holotype.
1. Diagram of corallum (natural size).
2. Median vertical section. x 2. B.M.R. 31072.
3. Transverse section. x 2. B.M.R. 31071.

No septa or vestiges of septa are present. The dissepiments are large plates convex distally, and slope gently down towards the tabularium, which occupies half the width of the corallum, and has flat, complete, and closely placed tabulae. The skeletal tissue is damaged by crushing. The vertical section is not unlike that of *Omphyma.*

Remarks.—Pending a revision of the cystiphylloid corals of the Devonian, this species is temporarily referred to *Cystiphyllum* Lonsdale, which is a Silurian genus. The Devonian cystiphylloids are unrelated homeomorphs.

DISPHYLLUM.

Disphyllum de Fromentel, 1861, p. 303.

Disphyllum Lang and Smith, 1934, p. 80; 1935, p. 544.

Genolectotype: *Disphyllum goldfussi* (Geinitz), of which the lectotype is *Cyathophyllum caespitosum Goldfuss*, 1926, p. 60, Pl. XIX., fig. 2b only, see Lang and Smith *Loc cit.*

Diagnosis.—"Phaceloid Rugose corals in which increase may be lateral or calicular; the septa rarely reach the axis, but are usually long, and typically thin; the tabulae are sometimes complete, though generally incomplete and differentiated into a transverse axial, and an inclined periaxial, series; with dissepiments typically small, strongly arched, sometimes of one, but frequently of two, kinds: an inner, single series of globose, distally directed dissepiments, and an outer series of flat or arched dissepiments." Lang and Smith, 1935, p. 545.

Remarks.—This very variable genus is widespread in the Middle and Upper Devonian. It has recently been described and analysed by Lang and Smith, 1935, together with its genomorph (*Phacellophyllum*) Gurich, and the related genera *Prismatophyllum* Simpson, *Phillipsastraea* d'Orbigny and *Macgeea* Webster. The group possesses distinctive horizontal skeletal elements. In what is probably the fundamental arrangement, the tabulae are complete and flat or sagging, and the dissepiments are more or less globose. In some members of the group a single vertical series of horse-shoe dissepiments may be differentiated, with series of globose and highly inclined dissepiments on either side, or with a series of flat dissepiments on the peripheral side. The tabulae may be replaced by tabellae, or be differentiated into two series. Lang and Smith have considered that those Disphyllids in which the dissepiments consist of a single series of flat plates and a single series of horse-shoe plates, and in which the tabulae are in two series, form a genomorphic group, (*Phacellophyllum*) Gurich. The West Australian forms are typical *Disphyllum.*

Disphyllum depressum (Hinde)

(Plate I., figs. 4-8).

Cyathophyllum depressum Hinde, 1890, p. 195, Pl. viii., figs. 2a, 2b, from the Devonian opposite Mt. Krauss, Kimberley District; and the Gascoyne River [locality challenged].

Cyathophyllum depressum Hinde; Glauert, 1910, pp. 78, 82; 1925, p. 41.

Cyathophyllum depressum Hinde; Hosking, 1933, p. 68.

Syntypes: R. 2269 with figured slide R. 13981 (fig. 2b) in British Museum is the upper part of 10039 in the Western Australian Geological Survey Collection. The label for 10039 reads Gascoyne River, but the B.M. specimen is said to be from opposite Mt. Krauss, Kimberley District, W.A. This latter is probably right. (Plate I., figs 6 and 7.)

R. 13982, opposite Mt. Krauss, Kimberley. A vertical section has been cut from the apical part of this. (Plate I., figs. 4 and 5.)

R. 2270, Gascoyne River, encrusted with *Stromatoporella eifeliensis* Nicholson.

Lectotype: (here chosen) R. 2269, with slide R. 13981 in British Museum, and its lower part 10039 in the Geological Survey of Western Australia Collection, from the Devonian (Frasnian, or ? Givetian) opposite Mt. Krauss, Kimberley District, W.A. (Plate I., figs 6 and 7).

Other specimens: 2753, 2754, in the Collection of the University of Western Australia, from the Devonian (Frasnian, or possibly Givetian) of Price's Creek, north of bore, Rough Range, Kimberley; (Plate I., fig. 8).

Diagnosis.—Dendroid *Disphyllum* with trochoid corallites; and with dissepimentarium forming an almost complete peripheral stereozone.

Description.—The corallum is dendroid, offsets arising by lateral increase. The individual corallites are trochoid, and erect or slightly curved, attaining an average diameter of 15 mm., in a length of 20 mm. The largest corallite had a diameter of 16 mm. Calical and epithecal characters were not observed.

The septa are of 2 series, about 26 of each. They are neither wavy nor carinate. The major septa may extend to the axis, where their axial ends rotate slightly, but typically they leave an axial space devoid of septa. They are dilated and usually in contact with the dilated minor septa in the dissepimentarium, thus forming a wide stereozone, but in the tabularium they are attenuate. The minor septa are one-third to one-half as long as the major septa. In some specimens dilatation is confined to those parts of the septa at the periphery and at the inner border of the dissepimentarium, so that the transverse sections resemble *D. virgatum.* The septa consist of compound trabeculae, laterally contiguous, but unfortunately the preservation of the material is not good enough to allow detailed description.

The dissepiments are small, globose and distally convex, and are not often seen, being developed only where interseptal loculi are left between the dilated septa. The tabulae are in two series, an outer series of steeply inclined plates, and an inner series which are usually complete, and may be either domed or horizontal. The tabulae are not dilated.

Remarks.—The holotype shows a less perfectly developed stereozone than the other specimens. The species is easily separable from *D. virgatum*, which occurs at the same horizon and locality, by the trochoid shape of the hysterocorallites. Except for its trochoid hysterocorallites and the great dilatation of its septa, *D. depressum* resembles *D. goldfussi* (Geinitz) the type of the genus, which is common in the Givetian and Frasnian of Europe.

Disphyllum virgatum (Hinde).

(Plate I., figs. 1-3.)

Cyathophyllum virgatum Hinde, 1890, p. 194, Pl. viii., figs. 1a, 1b, from the Devonian opposite Mt. Krauss, Kimberley District; and the Gascoyne River [?].

Cyathophyllum virgatum Hinde; Glauert, 1910, pp. 78-82; 1925, p. 41.

Cyathophyllum virgatum Hinde; Hosking, 1933, p. 68.

Syntypes: R. 2268, R. 13980, British Museum, and △ 4, Western Australian Museum, from the Frasnian (or ? Givetian) opposite Mt. Krauss, Kimberley. R.2272, British Museum and 10038, Geological Survey of Western Australia, Gascoyne River (locality challenged, see introduction).

Lectotype (here chosen). B.M.R. 2268, figured Hinde pl. 8, fig. 1, and our Plate I., fig. 1.

Diagnosis.—Large *Disphyllum* with globose dissepiments, with sagging tabulae replaced by tabellae, and with stereozones at the inner and outer margins of the dissepimentarium.

Description.—The corallum is probably phaceloid, but only fragments of corallites are known; these are cylindrical, and straight or gently curved, the largest being 7 cm. in length, by about 11 mm. in average diameter. The maximum diameter observed was 15 mm. They are all somewhat crushed. The type of increase of the corallum, and the nature of the calice are not known. The epitheca is weathered off. There are 50-56 septa arranged in two series. They are dilated in the dissepimentarium, where there are two zones of greatest thickening—at the epitheca, and at the innermost series of dissepiments, so that two stereozones are formed which may merge in places. They are neither waved not carinate, and recrystallisation has masked their structure. The minor septa are only one-third to one-half as long as the major septa, which may extend to the axis, but usually are slightly withdrawn from it.

The dissepiments are small and globose, distally convex near the epitheca, but steeply inclined near the tabularium, developed in two, three, or even four series, dilated at the epitheca and near the tabularium.

The tabulae are represented by tabellae, varying in size, but larger than the dissepiments. The axial tabellae are convex distally; those near the dissepiments are steeply inclined, but not regularly enough developed to form a distinct periaxial series. The tabulae which they replace are sagging.

Remarks.—There can be little doubt that the fragmentary corallites found are parts of phaceloid coralla. They are close to *D. aequiseptatum* Edwards and Haime from the Lower Frasnian or Upper Givetian of Ilfracombe, showing the replacement of tabulae by tabellae characteristic of the latter, but having septa less withdrawn from the axis.

PHILLIPSASTRAEA.

Phillipsastraea d'Orbigny, 1849, p. 12.

Phillipsastraea Lang and Smith, 1935, p. 556.

Genolectotype: *Astraea hennahi* Lonsdale; see Edwards and Haime, 1850, p. lxxi.

Diagnosis.—"Plocoid or sub-cerioid Rugose corals . . . . . . Typically, the septa are dilated at the margin of the tabularium, and there the minor septa terminate, though the major septa may extend to the axis. They are usually carinate, sometimes very strongly so. There is no columella, and the tabulae are transverse, but may be complete or incomplete. Dissepimental tissue is strongly developed, and the dissepiments forming the wall of the tabularium are often smaller and more globose than the rest, corresponding to the horse-shoe shaped dissepiments of *Disphyllum* (*Phacellophyllum*), *Macgeea*, and other allied genera." Lang and Smith, 1935, p. 556.

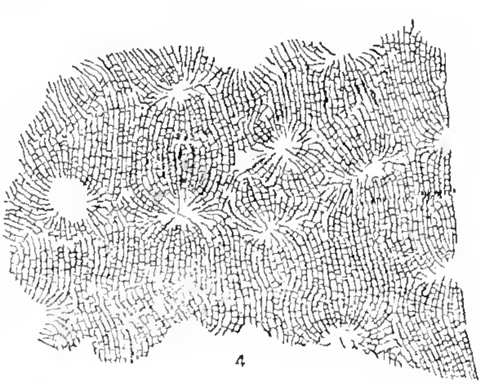
Remarks.—The genus is highly characteristic of the Upper Devonian, and is very widespread.

Phillipsastraea delicatula sp. nov.

(Text figures 4 and 5.)

Holotype: F. 326 [catalogued as F. 328] = 6924 in the collection of the Geological Survey of Western Australia (text-fig. 4); mentioned Glauert, 1910, pp. 78, 112; 1925, p. 41; and Hosking, 1933, p. 68; Barker Gorge, Napier Range, Kimberley, Upper Devonian. Other specimens are W.A. Museum Nos. 4435-6, Coll. J. E. Wells 1922, mentioned Hosking 1933, p. 69, from the same locality.

Diagnosis.—Thamnastraeoid *Phillipsastraea* of extremely fine texture, with no horse-shoe dissepiments.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Text-figs. 4-5. **Phillipsastraea delicatula** sp. nov.
4. Transverse section. x 2. 6924, Geol. Surv. W.A. Holotype.
5. Median vertical section. x 2. 4435, W.A. Museum.

Description.—The corallum is spreading, the holotype being $4\frac{1}{2}$ x $3\frac{1}{2}$ inches x $1\frac{1}{4}$ inch tall, and thamnastraeoid, the septa of neighbouring corallites being confluent and arranged between the individual tabularia like lines of force between poles in a magnetic field. The distance between tabularia varies between 4 mm. and 15 mm., and each tabularium is about 2 mm. in diameter. There are 30 to 40 septa in each corallite. They are attenuated, and waved in short waves parallel to their upper edges; thin trabeculae form noticeable carinae. They are not dilated at the wall of the tabularium. The interseptal loculi are only 0.25 mm. wide. The minor septa are of unequal lengths and extend into the tabularium, sometimes almost to the axis. The tabulae are transverse, about 0.25 mm. apart, and usually complete; they may be gently bowed or sagging. The dissepiments are very small and crowded. Those near the tabularia are steeply inclined, but the inclination decreases towards the line of junction with a neighbouring corallite, where they are horizontal and rather longer.

Remarks.—Only three specimens are known. In its delicacy of structure the species approaches the genotype, *P. hennahi* (Lonsdale), and *P. verneuli* Edwards and Haime, from which it differs in the absence of any dilation of the septa at the tabularium, and in the more irregular spacing of the tabularia. It indicates an Upper Devonian horizon.

PRISMATOPHYLLUM.

Prismatophyllum Simpson, 1900, p. 218.

Prismatophyllum Lang and Smith, 1935, p. 558.

Genotype: *Prismatophyllum prisma* = *Cyathophyllum rugosum* (Hall), Edwards and Haime, p. 387, pl. xii., figs. 1, 1a-b only, (Lower Middle) Devonian, [Onondaga ("Jeffersonville")] Limestone, Falls of Ohio, etc. The specimen figured by Edwards and Haime was named by Simpson as genotype, who pointed out that it was not conspecific with *Astraea rugosum* Hall, 1843, Lang and Smith, 1935, p. 558.

Diagnosis.—"Cerioid Rugose corals with septa which may, or may not, reach the axis; tabulae typically differentiated into a horizontally disposed axial series and an axially inclined periaxial series; and typically numerous, small, globose, dissepiments." Lang and Smith, 1935.

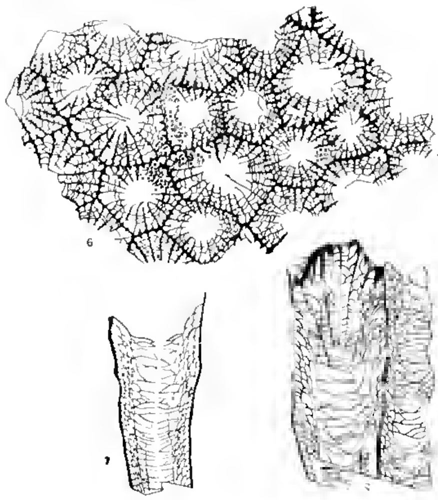
Remarks.—Lang and Smith, 1935, p. 559, state that "the genus is widespread and very typical of the Middle and Upper Devonian rocks. The type species agrees in internal structures with *Disphyllum goldfussi*, but is cerioid. The septa are often more or less dilated peripherally, attenuated axially, and are typically, though not always, carinate. The dissepiments are fine and globose . . . . The species vary in their internal structure, from forms with transverse tabulae all of one kind, to others, more typical . . . . with two . . . . In some forms the major septa not only reach the axis, but become more or less involved with each other; in others, they are very short, and alternate with the minor septa at the border of the tabularium."

The genus passes into *Phillipsastraea* on the one hand, and *Disphyllum* on the other.

Prismatophyllum brevilamellatum sp. nov.

(Text-figures 6-8.)

Holotype: No. 2515, University of Western Australia; a fragment 2½ × 1½ × 1½ inches in pure, white and coarsely crystalline limestone, from Price's Creek, Rough Range, Kimberley; recorded as *Lonsdaleia* aff. *floriformis* in the Annual Report for 1923 of the Geological Survey of Western Australia p. 35, and as *Lonsdaleia* sp. cf. *L. floriformis* Mart. by Glauert, 1925, p. 45, Upper Devonian.



Text-figs. 6-8. **Prismatophyllum brevilamellatum** sp. nov.
2515, University of Western Australia, Holotype.
6. Transverse section. x 1.
7 and 8. Median vertical sections. x 1.

Diagnosis.—*Prismatophyllum* with short major septa, and with minor septa reduced to septal ridges.

Description.—The corallum is cerioid, and the corallites sub-equal and straight, of average diameter 0.8 mm. The largest corallite is 10 mm. in diameter. The type of increase of the corallum was not observed.

The septa are of two series, average number 18 of each, straight and not carinate; re-crystallisation masks the septal structure. The major septa are one-half to two-thirds the length of the radius, and are continuous plates, but the minor septa are reduced to mere septal ridges on the epitheca. The septa of neighbouring corallites tend to be placed opposite one another, usually major to major and minor to minor; and the wall between corallites thus has a serrated appearance.

The tabulae are complete, supplemented near the dissepimentarium by a few tabellae. They are shallowly concave, and on the average are 0.75 mm. apart, though this distance varies from 1.5 mm. to 8.3 mm.

The dissepimentarium extends half-way towards the axis. Dissepiments are in three or four irregular vertical series, are steeply inclined and rather shallow. Occasionally they show angular intersections in transverse section. There is no axial structure, and the skeletal elements are not dilated.

Remarks.—Only the holotype is known, and this is incomplete. The reduction of the minor septa to septal ridges, and the shallow concavity of the tabulae seem diagnostic structurally. It would seem to bear the same relation to *Prismatophyllum* as *Cylindrophyllum* Simpson does to *Disphyllum*.

ALVEOLITES.

Alveolites Lamarck, 1801, p. 375.

Alveolites; Smith, 1933, p. 135.

Alveolites; Lecompte, 1933, p. 7.

Genotype (Genolectotype): *Alveolites suborbicularis* Lamarck, 1801, p. 376, Upper Devonian, Frasnian. Near Dusseldorf, Germany. Chosen Edwards and Haime (1850), p. lxi. See also Smith, 1933, p. 135.

Diagnosis (translated from the French of S. Smith, 1933, p. 135).—Massive Tabulate corals, growing in superposed layers. The corallites grow out horizontally or obliquely from one or more centres, the lower surface resting on the support. Usually the corallites are small, semilunar or subtriangular in section; they are more or less compressed, and open to the surface by oblique calices each with lower lip projecting. The wall may be thin or thickened; the septa when present are represented by spines. The tabulae are complete and thin, and the mural pores are wide and distant.

Remarks.—The genus has also recently been discussed by M. Lecompte, in a paper containing much valuable detail. He describes fully the variation possible in each species, and indicates the interpretation to be placed on sections taken along different directions in the corallum. He also compares the genus with *Favosites*, *Coenites*, and *Pachypora*.

Arrangement of the calcareous fibres in the sclerenchyme.—The walls of the corallites consist of fibres. They are arranged on either side of the median or sub-median planes of each wall, the plane appearing in thin section as the "median dark line." The fibres are slightly curved, being directed distally and towards the axes of the corallites. The plane is usually median in the more erect or polygonal corallites, and sub-median, nearer to the lower surface of the wall, in reclined and depressed corallites. If one considers the fibres of one corallite, *i.e.*, those on one side only of the median planes of the walls, it is seen that at certain points a small group of fibres is produced further in to the lumen of the corallite, forming a spine; such a spine may have its fibres radiating from its axis, as in the monacanths and holacanths of Rugose corals. The spines tend to be arranged in vertical series, each series thus being similar to the septum of a Rugose coral. Sometimes in the walls the growth lamination, which cuts the fibres at right angles, is more obvious than the fibres, owing to re-crystallisation, as in *Pachypora lamellicornis* Lindström.

Presumably the common walls of corallites were laid down in vertical invaginations in the base of the polypary, deposition of fibres being influenced by very shallow secondary invaginations (septal invaginations), on each side of the wall invagination. See diagram of the relation of the soft parts of a corralum to the hard parts, Hill (1936).

Alveolites multiperforatus Salée.

Alveolites multiperforatus: Salée ms. 1915-16; Lecompte, 1933, pp. 39, 42, pl. iii., figs. 1, 1a, 1b; from the Middle Frasnian (F_2), Assize de Frasnes, à *Hypothiridina cuboides*, on the southern border of the Dinant basin, the northern border of the Namur basin, and the flanks of the Condroz ridge.

Diagnosis.—Massive or encrusting Alveolites frequently of irregular growth; where growth is regular the corallites may be only 40-20° from the vertical; the calicinal diameters are usually equal and polygonal corallites are predominant; locally in the corallum the walls are thickened; mural pores are abundant and not limited to the two side walls; spines may be present, variable; tabulae are straight and thin.

Remarks on the Belgian specimens.—The corallites have a diameter of approximately 1 mm.; compressed corallites occur locally. The common walls may be 0.5 mm. thick. Thickening of the wall does not exceed 0.25 mm., and the corners of the polygon may be rounded. The pores are usually 0.2 mm. in diameter, and about 0.66 mm. apart. Spines are occasionally present; there may be one only, median and strong, or numerous small radial ones, usually short and swollen, rarely long and thread-like, with sometimes one or two predominating.

Description of a West Australian specimen, Alveolites aff. multiperforatus Salée. (Plate I, figs. 9 and 10).—This is a worn fragment, 1½ x 1½ x 1½ inches, △ 43 in the Collection of the West Australian Museum, labelled *Favosites goldfussi* M. Edwards and Haime from (?) Champion Bay (? Gascoyne River). So far as is known there is no outcrop of Devonian rocks in Champion Bay, or along the Gascoyne River; but the lithology suggests that the specimen is from the Devonian opposite Mt. Krauss, in the Rough Range, Kimberley District. It is worn so that the calices and the shape of the corallum are not discernible.

The corallites of the fragment show at least one axis of divergence near which they are almost vertical; more distant corallites are increasingly more oblique (Plate I, fig. 10). Nearly all the corallites are polygonal, with a diameter of just under 1 mm.; rarely, very slightly compressed corallites are seen. The common walls are regularly about 0.4 mm. thick, usually a little more at the angles; their structure is that described above for the genus. The "dark line" is median. The walls are pinnately fibrous, with the fibres directed upwards and inwards. Mural pores are about 0.2 mm. in diameter, and about 0.7 mm. apart, and very numerous. They are not confined to the two side walls, but occur with equal frequency on all walls. Spines are seen in nearly all corallites, partly masked by re-crystallisation, in irregular vertical series, on any side of the corallite, or sometimes in the angles. They are of equal size, and about 0·17 mm. long. The maximum number observed in the transverse section of any one corallite was 8. The tabulae are thin, complete, straight or slightly arched, and there are usually 25 in the space of 10 mm.

Remarks on the Australian fragment.—The similarity of this fragment to *A. multiperforatus* was pointed out to the author by M. Lecompte. It shows constant thickening of the walls. This is a localised character in *A. multiperforatus*, but the Australian fragment may well be such a localisation in a large corallum. M. Lecompte also stated that Dr. Stanley Smith had shown him a specimen from the Frasnian of Canada which might well be called *A. multiperforatus,* so that the group would seem to have a wide geographical range. It is unfortunate that the locality of the West Australian specimen is so obscure.

Alveolites tumida Hinde.

(Plate I, figs. 11-14.)

Pachypora tumida Hinde, 1890, p. 197, pl. viii., fig. 3, Devonian, opposite Mt. Krauss, Kimberley District.

Pachypora tumida Hinde; Glauert, 1910, pp. 78, 83; 1925, p. 48.

Pachypora tumida Hinde; Hosking, 1933, p. 68.

Holotype (by monotypy): R. 2271 and 2 slides, British Museum; Devonian, opposite Mt. Krauss, Kimberley District.

Description.—The holotype is a fragment, 4 cm. long, 1.5-3.5 cm. wide and 1.3 cm. deep, from a tuberose corallum. It looks like a fork between two branches; but growth was very irregular, for one "branch" grows downwards in relation to the corallites of the other (Plate I, fig. 11). In the "branch" which has been sectioned the corallites are arranged about one axis of divergence; the oblique calices suggest that at least at its periphery the branch is made up of sheaths of corallites arranged like the tobacco leaves in a cigar. The calices (Plate I, fig. 12) are oblique to the surface (not perpendicular thereto, as in *Pachypora* and *Striatopora*) and variable in outline. They are sometimes elongate with the lower lip projecting, when they may be semilunar, or nearly rhomboid when the corallite edges of the upper lip lie along the tops of the domed upper lips of the two underlying corallites. They are more usually irregularly polygonal or almost circular.

The corallites are about 1 mm. along their largest diameter (Plate I, figs. 13-14); they are usually hexagonal or almost circular in section, but, near the calices, may be depressed, semilunar or rhomboid; in the more cylindrical parts of the corallum they are arranged about axes of divergence: they leave the axis at an angle of 30 ° and curve gently towards the periphery, where they open obliquely. The walls between corallites are much dilated—0.03 mm.; they are pinnately fibrous, as described above for the genus, the fibres being directed upwards towards the axis of the corallites from a sub-median "dark line"; mural pores are rare and large (0.02 mm.). Occasional spines are present, and thin complete tabulae are developed.

Aulopora repens (Knorr & Walch): Hinde.

Aulopora repens (Knorr & Walch); Hinde, 1890, p. 199, from Rough Range, Mt. Krauss, Kimberley District, Western Australia. The specimen figured by Hinde is R. 2267 in British Museum.

Nothing can be added to Hinde's description, p. 199. "There is a single example of this species growing on the surface of *Cyathophyllum virgatum*, which, as far as its outward characters are concerned, cannot be distinguished from the type forms of the species from the Eifel. The corallites range from 2.5 to 4.5 mm. in length, and from 1 to 1.25 mm. in thickness. The oval or elliptical apertures are between .75 mm. and 1 mm. in width."

SYRINGOPORA.

Syringopora Goldfuss, 1826, pp. 75-76.

Genotype: (Genolectotype, see Edwards and Haime (1850) = *Syringopora ramulosa* Goldfuss, from the Carboniferous of Olne in Limburg, Germany. "Edwards and Haime give *Syringopora* as a synonym of *Harmodites* Fisher, 1828 (which however was published two years later), and take *S. ramulosa* as the genotype of *Harmodites*, thereby implying that they consider it the genotype of *Syringopora*" (Lang and Smith MS).

Diagnosis.—Fasciculate tabulate corals with long, thin, parallel to remotely diverging tubular corallites, connected by small approximately horizontal tubules containing extensions of the tabulae. The septa are holacanthine. The tabulae are infundibuliform and axially connected to form an axial tube which may be crossed by horizontal plates. Increase is lateral.

Arrangement of the calcareous fibres.—The corallites of *Syringopora* have a peripheral stereozone which, in thin section often appears to be divisible into outer and inner zones, which, however, merge into one another. The outer zone is seen to consist of fibres directed inwards and slightly upwards. The inner zone is of wavy laminae very steeply inclined from the periphery down towards the axis, at right angles to the fibres of the outer zone. Set in this inner zone are vertical series of spines which are fibrous; the fibres are directed distally and outwards from the axes. The laminae arch up about the spines, and altogether this inner zone is similar to the stereozone of *Tryplasma rugosum*, which has been already described in detail (Hill, 1936). The spines are holacanths; and the lamellar appearance of the sclerenchyme surrounding them is due to re-crystallisation having emphasised its growth lamination at the expense of its fibrosity. Each lamina really consists of fibres at right angles to its surfaces, and represents horizontal tissue laid down between the septa. Probably the fibres of the outer zone are merely the peripheral extensions of these fibres, but are not affected by re-crystallistion in the same way.

Thus the septa of *Syringopora* are holacanthine.

Syringopora patula Hinde.

(Plate I., figs 15 and 16.)

Syringopora reticulata var, *patula* Hinde, 1890, p. 198, pl. viii., fig. 4, from the Gascoyne River (locality challenged). ? Devonian.

Syntypes: 10054, Geological Survey Collection, Western Australia, figured Hinde, 1890, pl. viii., fig. 4. This has a green paper spot, similar to those used in the British Museum to indicate figured specimens (Plate I., figs. 15 and 16). R. 2265, British Museum, from the Gascoyne River.

Lectotype: (here chosen), 10054, Geological Survey Collection, Western Australia (Plate I., figs. 15 and 16).

Diagnosis.—*Syringopora* with slightly diverging corallites of average diameter 2 mm., unevenly spaced and connected at irregular intervals chiefly by lateral contact of the walls, but also by connecting processes; lateral increase is frequent; spinules are short, and there is a persistent axial tube.

Description.—The corallum is fasciculate, in low bushy masses of slightly divergent flexuous corallites. The largest specimen examined was 5 cm. high by 11 mm. wide. The corallites range in diameter from 1.6 to 2.15 mm., and are at irregular distances apart, varying from 0.5 to 3 mm. Distally they diverge gently. Neighbouring corallites may come into contact laterally by their walls touching, or are connected by rather rare irregularly spaced connecting tubules. New corallites arise by frequent lateral increase. At their point of issue they are very narrow and are almost perpendicular to the parent corallite; then they quickly swell to the adult diameter and grow almost parallel to the proto-corallite; the narrow tube connecting the new corallite to the parent corallite is thus different in origin from the rarer connecting tubules.

The corallites have uniformly peripheral stereozones about 0.25 mm. thick consisting of "lamellar" sclerenchyme; the septal spinules, which are holacanths, are very irregularly developed as small, conical projections from the inner surface of the stereozones. The tabulae are dissepiment-like plates, flat at the periphery, but becoming steeply inclined towards the axis, where they meet to form rather persistent axial tubes about 0.4 mm. in diameter.

Remarks.—Hinde erected this species as a vaiety of *S. reticulata* Goldfuss, from the Carboniferous. In its slightly diverging corallites and frequent lateral increase, however, it resembles more closely the Eifelian *S. caespitosa* Goldfuss, and I think that most probably it is Devonian in age. In matrix and preservation it resembles the corals from opposite Mt. Krauss, Rough Range, Kimberley, and in all probability it was really collected from that locality.

ACKNOWLEDGMENTS.

The Author is much indebted to Miss Lucy Hosking, Prof. E. de C. Clarke and Mr. L. Glauert for the loan of specimens in their charge; to Dr. Stanley Smith for help in deciding the affinities of some of the species; to M. Lecompte for his remarks on *Alveolites multiperforatus* Salée; to Miss G. L. Elles and Dr. W. D. Lang for advice at all times, and to Dr. W. D. Lang and Dr. H. Dighton Thomas for facilities at the British Museum and for photographs of *A. tumida* Hinde. The work was begun during the tenure of the Old Students' Research Fellowship of Newnham College, and completed during a Senior Studentship of the Royal Commission for the Exhibition of 1851.

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1936—Hill, Dorothy:

EXPLANATION TO PLATE I.

All figures (except figs. 11-14) x 2 diameters.

Fig. 1. *Disphyllum virgatum* (Hinde), median vertical section of lectotype.
Fig. 2. The same, transverse section of syntype △ 4.
Fig. 3. The same, vertical section of syntype △ 4.
Fig. 4. *Disphyllum depressum* (Hinde), median vertical section of syntype R. 13982.
Fig. 5. The same, transverse section of syntype R. 13982.
Fig. 6. The same, transverse section, part of holotype 10039.
Fig. 7. The same, median vertical section, part of holotype 10039.
Fig. 8. The same, median vertical section of 2754, University of Western Australia.
Fig. 9. *Alveolites* aff. *multiperforatus* Salée, transverse section △ 43.
Fig. 10. The same, vertical section, △ 43.
Fig. 11. *Alveolites tumida* Hinde, external of holotype, natural size.
Fig. 12. The same, x 2½.
Fig. 13. The same, transverse section, natural size.
Fig. 14. The same, tangential section, natural size.
Fig. 15. *Syringopora patula* Hinde, transverse section of the holotype.
Fig. 16. The same, vertical section.

I am indebted to the British Museum of Natural History for the photographs figs. 11-14.

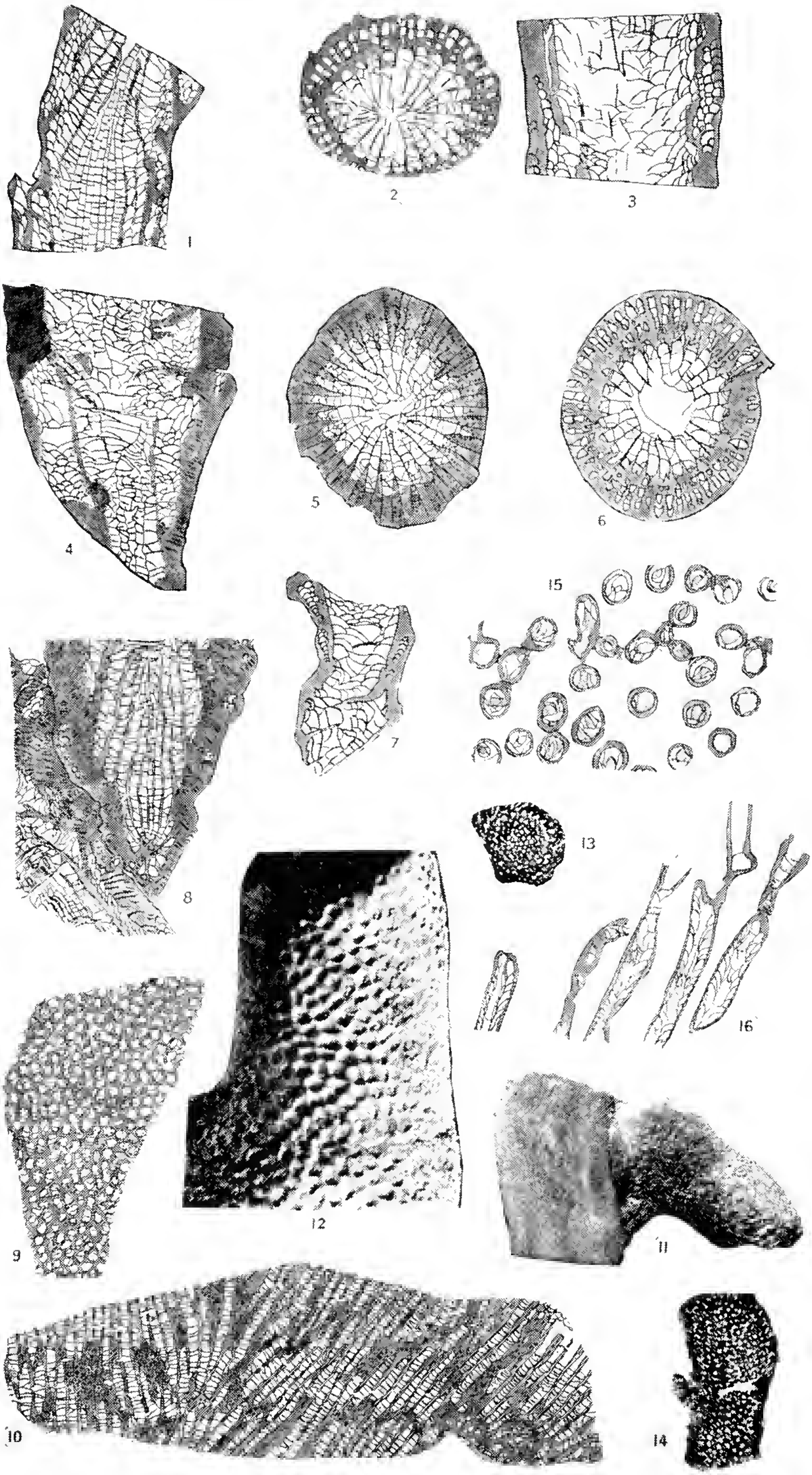

Plate I.

4.—DESCRIPTION AND LIFE-HISTORY OF A NEW WESTERN AUSTRALIAN PSYLLID.*

By M. E. SOLOMON.

Read : 10th March, 1936 ; Published : 15th July, 1936.

CONTENTS.

(with two plates.)

I. INTRODUCTION.

Most of our knowledge of the Australian Psyllidae is due to the work of W. W. Froggatt (3), published in the years 1900 to 1903. His revision included 73 species, of which 64 were new. All were from the eastern parts of Australia, including Tasmania. The same author described another species in 1923 (6).

Psyllidae are fairly common in Western Australia, but until a systematic revision of the family is carried out, it is unlikely that much useful work on the local forms will be possible. The family includes at present about 150 genera, many of which were established without reference to any general scheme of classification for the family ; and a good deal of the literature is not available to Australian workers. However, there are among the Australian forms a few well-defined genera to which species may be referred without fear of confusion.

One such genus is *Spondyliaspis*, to which belongs the species about to be described.

II. SYSTEMATICS.

According to Froggatt (3), who gives a full definition of the genus, it was established in 1879 by Signoret and later redefined by Schwarz (1896). In the system used by Froggatt, *Spondyliaspis* was placed in the subfamily Aphalarinae, but in Crawford's system (5) this genus falls into the Triozinae. At present it includes five species, all from the eastern Australian region.

The new species agrees with the definition of *Spondyliaspis* in almost every particular, and certainly in all of the chief points. Of these may be mentioned the long cylindrical face lobes (genal cones), the flattened surface

* This work was carried out in the Department of Biology, University of Western Australia, during the tenure of a Hackett Research Studentship, for which the Writer wishes to record his indebtedness.

of the head, the dilated apex of the posterior tibia with a strong mucro at the outer angle, the enlargement of the first segment of the posterior tarsus into a cushion-like pad, and the venational characters—although Crawford considers that venation is of little value in the classification of the family.

In the following description the measurements refer to the type specimens only, and their exact values are of no specific significance.

Genus **SPONDYLIASPIS** Signoret (1879)

re-defined Schwarz (1896)

Spondyliaspis occidentalis sp. nov.

Adult Female.

Length body 2·55 mm. ; length forewing 2·68 mm.

Colour : chiefly yellow and brown. Head dark brown ; vertex yellowish brown except near margins, median suture and foveal depressions ; compound eyes reddish brown ; genal cones pink ; antennae pink at the base, grading to dark brown towards apex. Thorax mostly brown above, grading to yellow* in places ; sides yellow* and brown ; ventral surface and legs pale yellow, except brown mesosternum ; forewings hyaline with veins and margins brown. Abdomen bright greenish yellow* dorsally, with five transverse segmental brown bands which are narrower near the median line.

Head (Pl. 1, fig. B) flattened above, wider than prothorax but narrower than mesothorax ; vertex minutely punctate, much wider than long, anterior margin on each side angulated to form a projection just internal to base of antenna, foveal depressions (fd) and median suture well-marked, posterior margin concave ; genal cones (gc) projecting antero-ventrally, almost as long as vertex, touching near base, tapering distally and obtusely rounded at apex, with a tuft of subapical setae projecting from latero-ventral surface ; length of the 10-segmented antennae nearly one and one-half times as great as width of head.

Thorax not arched, minutely punctate ; pronotum (pn) nearly five times as wide as long ; praescutum (dorsulum) (ps) passing under pronotum in front, visible part somewhat longer than pronotum. Forewings (Pl. I, fig. A) hyaline, minutely setose, three times as long as wide, apex acutely rounded ; subcostal vein distinct from margin ; hyaline pterostigmatic area before R1, which extends close to apex before fusing with costal margin ; Rs meeting margin just anterior to apex ; stem M+Cu longer than stem of R1; marginal cells fairly large, subequal in area ; vein 1A represented by a clear line devoid of setulae ; 2A strong. Hindwing with veins Rs, M, Cu1, Cu2, 1A and 2A faintly indicated. Hind tibia (Pl. I, fig. E) short and stout, outer angle of apex with a process bearing two black spines of unequal size, inner margin with a single black spine, and proximally to this a further black spine situated subapically on dorsal surface, also two large rounded processes on dorsal side of apex ; proximal segment of hind tarsus expanded, padlike, concave below ventral margins with a row of stout setae, outer margin of apex with an obtuse black spine ventrally.

Genitalia (Pl. I, fig. C) : dorsal valves (dv) united to form a thickened hood overhanging the shorter and rounded ventral valves (vv) ; ovipositor sheath with a pair of lateral protrusible lobes (l) projecting posteriorly about as far as the dorsal valves.

* This yellow colouration is often tinged with, or wholly replaced by, a vivid green.

Male.

Length body 2·23 mm. ; length forewing 2·03 mm., Genal cones, being somewhat narrower than in female, not meeting at base.

Genitalia (Pl. I, fig. D) : forceps (f) curved backwards, tapering bluntly at base and at apex, subequal in length to genital segment and to anal valve (dv), which is sublinear posteriorly and convex anteriorly.

Other details as described for female.

The lerp scale (Pl. I, fig. F) is a circular dome of white sugary material, rugose, and composed of strands laid together unevenly. Usually there are a few long contorted filaments projecting from the surface of the scale.

Host : *Eucalyptus gomphocephala.*

Locality : Perth, Western Australia. (Four colonies in the grounds of the Department of Biology, University, Crawley.)

III. IMMATURE STAGES—EXTERNAL MORPHOLOGY AND DEVELOPMENT.

The *egg* is subovate, with a smooth chorion, and is yellow in colour. At one end is a short peduncle by which the egg is attached to the leaf. Its length is about one-third mm., while the peduncle is about one-fifth as long.

The general features common to *nymphs* of all instars are as follows. (See Pl. II). The body is flattened dorsoventrally. The head (except in the fifth instar) is not demarcated from the rest of the body by a suture ; it bears a pair of antennae and a pair of rudimentary or well-developed compound eyes ; ventrally there is an oral cone from which may be protruded the usual long filamentous maxillary and mandibular setae. The thorax bears dorsolaterally two pairs of wing pads. The three pairs of legs are 3-segmented in all except the fifth instar, where they are 4-segmented ; the extremity of each leg is provided dorsally with two long curved and clavate setae, and ventrally with a process bearing two down-curved claws, each claw being provided ventrally near the base with a stout upcurved seta. The tapering abdomen is more or less distinctly demarcated into seven segments, each with a pair of dorsal sclerites near the posterior border and a corresponding pair ventrally ; it bears one or more pairs of wax glands postero-laterally. Within the abdomen may be seen the mycetomes, appearing as a pair of yellow bodies incompletely divided into three or four segments (the outlines of the mycetomes are stippled in the diagrams).

The body-lengths of typical individual nymphs of successive instars are indicated in the illustrations on Plate II. But the body-length in each instar is very variable, owing chiefly to the fact that the nymphs undergo a gradual increase in size during the instar. This applies also to the other dimensions such as head-width and length of wing-pads. This presents a marked contrast to the condition found in the related family Aleyrodidae, in which the larvae do not increase in length or breadth except at the time of moulting.

There is an obvious reason for this difference : in the larvae of Aleyrodidae the dorsal cuticle is comparatively tough and inextensible, while in the Psyllidae (as in the Aphididae), the cuticle is thin and much less resistant. This allows of a gradual increase in size, instead of several spasmodic increases as observed in Aleyrodidae.

As may be seen from Plate II (fig. F, etc.) the proportions of various parts of the body change gradually throughout the nymphal development. Apart from this, there are a number of more particular characters by which the five instars may be distinguished one from another :—

First Instar (Pl. II, fig. A):

Antennae 3-segmented, with a sensory pit on the posterior border of the penultimate segment. Eyes each consisting of a group of a few ommatidia (typically 4). Wing pads incipient*, projecting laterally from the thorax. Abdomen scarcely if at all wider than thorax (contrast later instars). A single pair of wax glands placed dorso-laterally on the penultimate (apparent 6th) abdominal segment.

Second Instar (Pl. II, fig. B):

Antennae 4-segmented with sensory pit on the posterior border of the penultimate segment. Eyes, as in first instar, each with (typically) 4 ommatidia. Wing pads clearly apparent. Two pairs wax glands (abdominal segments 5 and 6).

Third Instar (Pl. II, fig. C):

Antennae 5-segmented. The ommatidia of previous instars projecting beyond the remaining facets of the developing compound eyes. Three pairs wax glands (abdominal segments 4, 5 and 6).

Fourth Instar (Pl. II, fig. D):

Antennae 7-segmented. Compound eyes well developed. Paired groups of wax glands (abdominal segments 4, 5 and 6). Dorsal abdominal sclerites broader antero-posteriorly than in previous instars.

Fifth Instar (Pl. II, fig. E):

Antennae 10-segmented. Compound eyes well developed. Lateral ocelli visible. Epicranial suture developed : sutures bounding pronotum and praescutum visible but not prominent. Wing pads more or less darkly pigmented. Legs 4-segmented owing to the subdivision of the distal segment (tibio-tarsus) of previous instars.

IV. NOTES ON HABITS AND ECOLOGY.

The whole of the life-history is passed through on the twigs and foliage of the host, usually on low branches or shoots within a few feet of the ground. The life-cycle is completed in a few weeks in the summer. Some nymphs that were kept on floating leaves in the laboratory reached the second instar 6 days after hatching from the egg, while some passed from the second to the fifth instar in 7 days.

The Eggs : These occur in groups on both faces of the Eucalyptus leaves, usually near the petiole. There are typically 60 to 80 eggs in one group, but sometimes over 300 have been counted. These large groups probably result from oviposition by more than one female. The females select fairly young and tender leaves on which to lay their eggs, so that the Psyllid colony moves slowly out along the branches, following the development of new shoots and leaves.

* Crawford ([5]) states that the wing pads become visible after the first moult. But in this species, at least, the projections representing incipient wing pads are visible in the first instar. They appear as lateral outgrowths of the thorax, and retain that appearance during most of the second instar ; it is in the late second or early third instar that they come to point posteriorly, owing to the increasingly rapid growth of the anterior parts of the wing pads as compared with the growth-rate of the posterior parts (Compare figs. A, B and C, Plate II.).

Nymph and Lerp Scale : The newly-hatched nymph usually moves from the blade of the leaf to the petiole, where it comes to rest and begins to secrete the test or lerp scale.

The material of the scale is not wax (the wax glands produce only a very sparse secretion), but the sugary "Honey-dew" exuded from the anus. This substance is at first transparent and fluid, but slowly whitens and solidifies. The first strands of secretion are arranged to form a framework shaped like a flattened pyramid. The outer ends of the strands are attached to the plant and arranged roughly in a circle. The inner ends meet near the centre of this circle, but at some distance from the plant surface, so as to form a radiate framework above the insect. The nymph then fills in the gaps with more secretion to form a complete covering under which it rests protected. This final process was observed under a binocular microscope in one instance, when the nymph was seen to be adding the secretion in a continuous spiral string, by moving the anus round the centre of the scale in gradually increasing circles, in an anti-clockwise direction. The time required for the whole process is something less than 24 hours. The above-mentioned radiate framework of the scale is similar to that figured and described by Dobson (2) for *Spondyliaspis eucalypti* (Dobson).

If the scale is removed, the nymph usually moves about the petiole or stem for some time and then settles in a new position. Here it usually secretes a new scale, either immediately or after a period which may be of several days duration.

As the nymph increases in size, additions are made to the edges of the scale and its centre becomes raised further from the plant surface. Exuviae become attached to its walls and incorporated in its structure. The lerp scales occur usually in dense aggregations, as shown in Plate 1, fig. F.

The lerp scale is a structure peculiar to certain Australian Psyllidae which live on Eucalypts. It has excited interest in Australia and England for more than a century—as early as 1849, Anderson published a chemical analysis of the lerps of some Victorian Psyllidae (His results were as follows : water 15·0% ; sugar, with a little resinous matter, 49·0% ; gum 5·77% ; starch 4·29% ; inulin 13·80% ; cellulose 12·04% = total 100% + ash residue 1·13%). Froggatt (1900) gave an account of its use as food by the natives and settlers in eastern Australia.

Comparison with Protected Stages in Related Families : It may be remarked that the phenomenon of an immature form coming to rest within a protective covering, with concomitant modifications of structure, is a characteristic of the Sternorrhynchous Homoptera, and is to be observed in all four of the families included in that group.

In the Aleyrodidae, the larva becomes stationary soon after emergence from the egg, and the dorsal cuticle becomes toughened, while added protection is provided in many species by the secretion of a dorsal plate of wax ; as development proceeds, the legs and antennae degenerate. In the Coccidae the young larva comes to rest and secretes a scale or a covering of wax, or in some cases lies protected within a gall. In any case, the legs and antennae usually become more or less degenerate. In both these families (excepting female Coccidae) the passage from larva to adult is usually effected by means of a metamorphosis very similar to that found in Holometabolous insects ; this is necessary because of the low grade of structure at which the larval development stops short, and this in turn is partly due to the assumption of a more or less stationary and protected manner of life.

The development of most Aphididae is on the typical Hemimetabolous plan, with a gradual transition from newly-hatched nymph to adult. But some Aphids pass through a phase in which the body is flattened and scale-like and the appendages degenerate (genera *Hormaphis*, *Hamamelistes* and *Cerataphis*: see Pergande (4), and Imms (7)). In these phases the resemblance to Aleyrodid and Coccid scales is both striking and significant.

The mode of development in the Psyllidae is, like that in most Aphididae, typically Hemimetabolous. But here again, as in the other three families, there are forms which come to rest beneath a protective covering—in this case the lerp scale excreted from the anus. In these lerp Psyllids, however, (as exemplified by *S. occidentalis*), the protected life has not yet resulted in any marked modification in the nymphs: the appendages are not degenerate and the body, although flattened, is not unusually so.

It may be suggested, therefore, that the secretion of a lerp scale is a comparatively recent development. Probably its chief advantage is the protection from evaporation which it affords.

Adults: The adults, like the nymphs, suck the sap from leaves or young twigs. They copulate frequently and for long periods, the male and female standing end to end with the genitalia firmly interlocked. In spite of their powers of leaping and flight, the insects seldom move far from the tuft of foliage which bears the colony.

Associated Animals: *S. occidentalis* resembles many other Homoptera, including a number of Psyllidae, in being associated with ants. At Crawley, the colonies of the Psyllid are invariably found to be attended by numbers of ants of a species very common about Perth. The Writer is indebted to Mr. J. Clark, of the National Museum, Melbourne, who has indentified the ants as *Iridomyrmex discors* Forel, var. *exilior* Forel., with the remark that most of the members of this genus are associated with Homoptera, particularly Psyllids and Coccids. In this case the ants are attracted to both adults and nymphs; also they are often seen nibbling at a lerp scale, though they probably do this in attempting to reach the nymph below, as the writer has never seen them carrying any of the dry lerp material.

It may be noted also that *S. occidentalis* is subject to parasitism by Chalcidoid wasps, whose larvae develop in the Psyllid nymphs and cause them to become greatly distended, with the integument stiff and brown.

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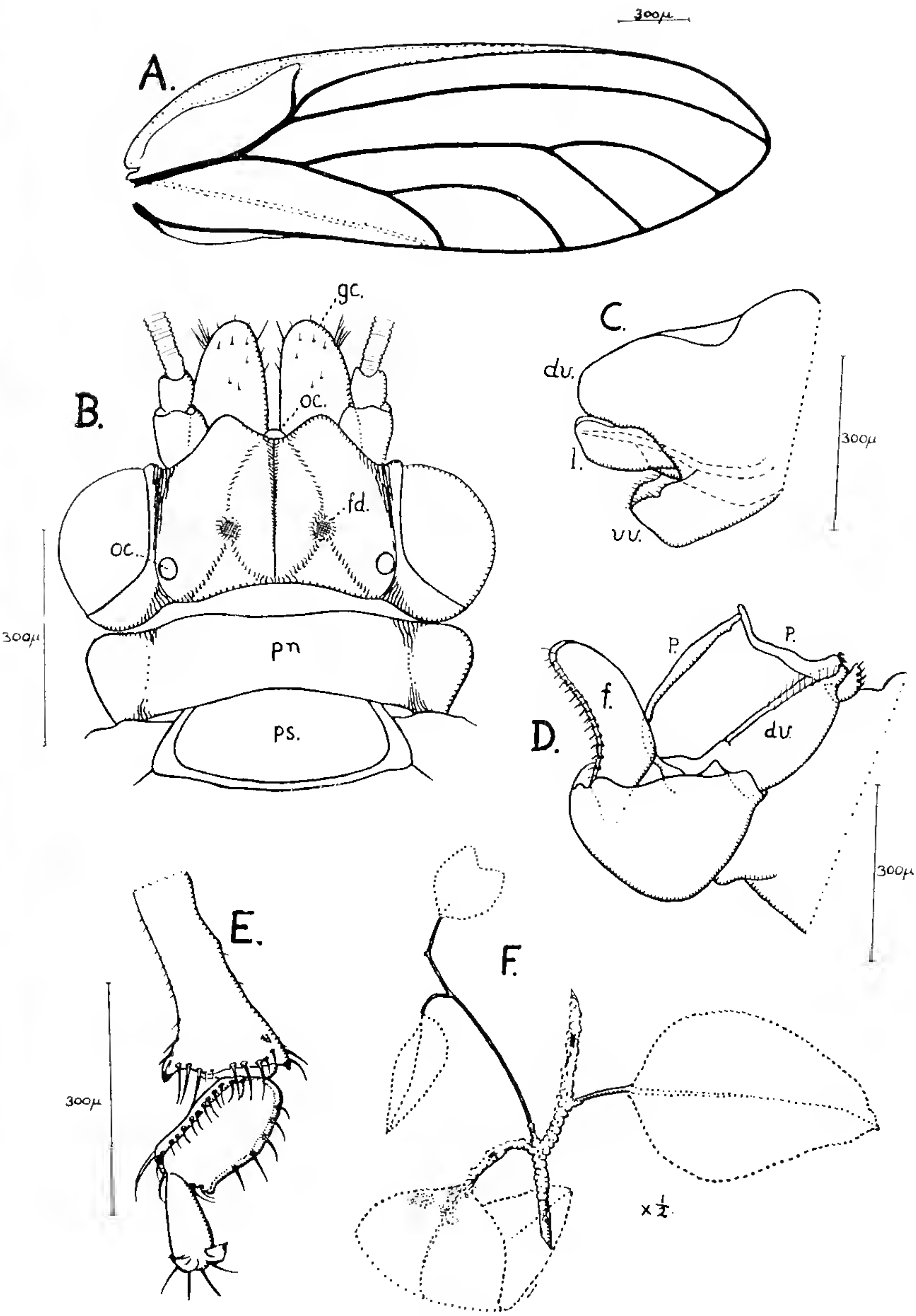


PLATE I.

Spondyliaspis occidentalis n. sp.

A., forewing ♀. B., dorsal view of head and part of thorax ♂ (gc, genal cone; oc, ocellus; fd, foveal depression; pn, pronotum; ps, praescutum). C., lateral view genitalia ♀ (dv, dorsal valves; l, lobes of ovipositor sheath; vv, ventral valves). D., lateral view genitalia ♂ (f, forceps; p, penis; dv, dorsal valves). E., ventral view of right hind leg ♀, showing tarsus and apex of tibia. F., lerp scales on twig of *Eucalyptus gomphocephala*.

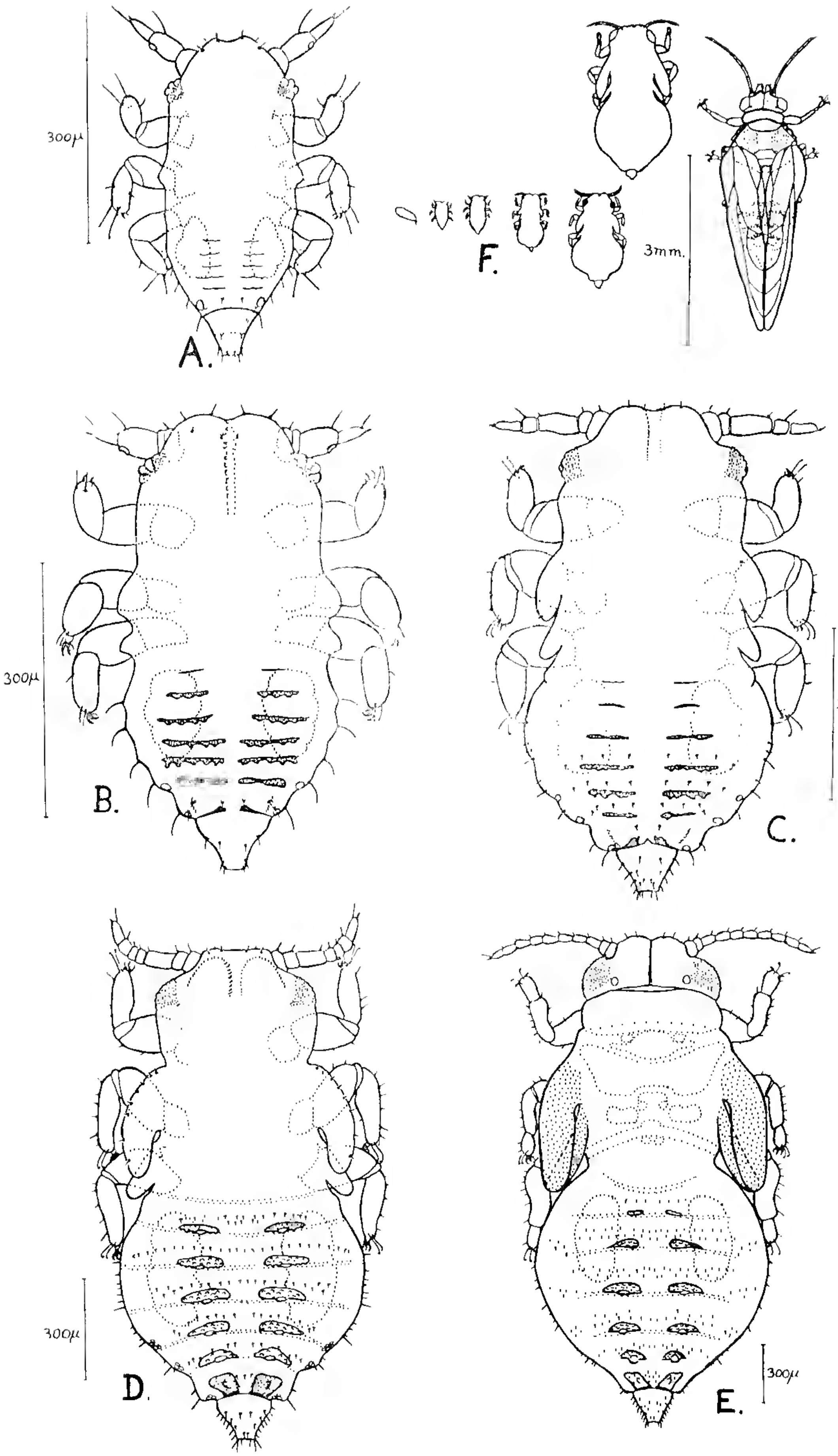


PLATE II.

Spondyliaspis occidentalis n. sp.

Dorsal view of nymphs (outlines of mycetomes stippled). A., first instar. B., second instar. C., third instar. D., fourth instar. E., fifth (final) instar. F., outlines of egg, nymphs of instars one to five, and adult ♀, drawn all to the same scale.

5.—NEW SPECIES OF APIOCERIDAE (DIPTERA) FROM WESTERN AUSTRALIA.*

By KENNETH R. NORRIS.

Read: 28th April, 1936; Published: 17th July, 1936.

INTRODUCTION.

The family Apioceridae is a small group of Asiloid flies of which the known species occur in North and South America, South Africa, Australia and Borneo. It would appear that Australia has a far greater number of species than any of the other countries. A number of species occurs in Eastern Australia, whilst in Western Australia the writer can recognise at least eleven species, some of which are described in this paper. As the flies appear to favour a somewhat arid region with sandy country, and hence as much of Australia is an eminently suitable environment for them, such a diversity of species is not surprising, and it is reasonable to anticipate that future investigation will yield many more forms. No doubt the number of species described from other countries will also be greatly increased.

Hitherto only the genus *Apiocera* has been recognised in Australia; but two species described in this paper belong to a new genus related to *Rhaphiomidas* O.S. In view of this addition to the knowledge of our fauna, previously published statements of family characters for Australian forms are now found to be somewhat restricted, taking account as they do only of the genus *Apiocera*. Consequently a revised synopsis of family characters to cover known Australian species has been included.

FAMILY APIOCERIDAE.

Generally dull-coloured flies, medium to large in size, varying in degree of vestiture from almost bare to hairy.

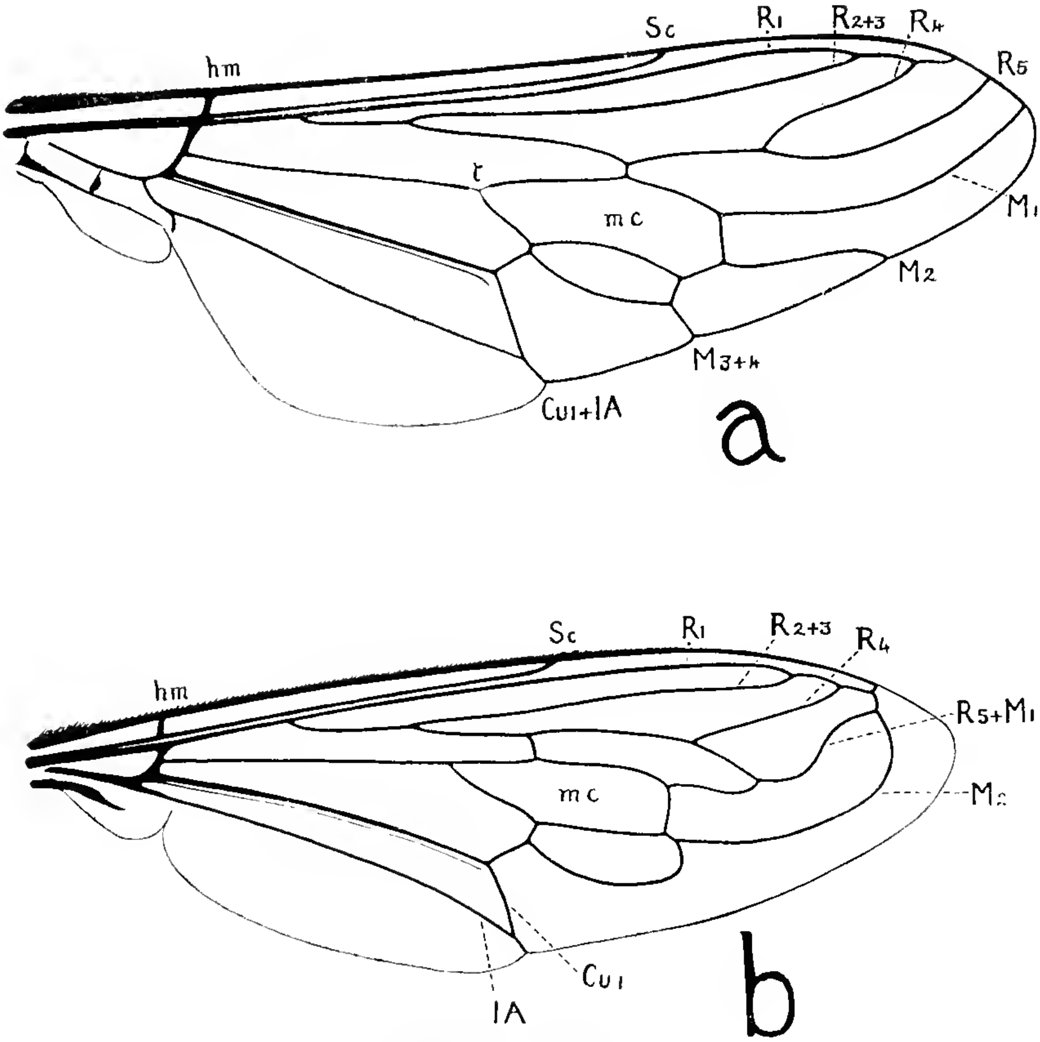
Eyes large, bare, widely separate to closely approximate at vertex; often more widely separated in female. Ocelli very well developed. Antennae inserted close together very near to epistome. These appendages are three-segmented, the second segment being short and globular. A terminal style is usually present, mostly short and pointed. Proboscis projecting forwards horizontally, varying in length from one to four times the length of the head. The flies are flower-feeders and consequently the labella are fleshy and the proboscis non-piercing. Palpi large and two-segmented or small and composed of a single segment. Maxillae correspondingly long or short.

Thorax generally stoutly built. Prothorax often with a circlet of spines above. Thoracic macrochaetae may be well developed, weak, or absent. When present, bristles are confined to the lateral edges of the thorax (humeral, notopleural, supra-alar, post-alar, and scutellar). Pleura devoid of bristles.

* Part of this paper was written whilst the author was studying under a Hackett Studentship at the University of Western Australia.

Legs long and bristly, resembling those of Bombyliidae. Empodium absent, pulvilli well developed.

Wings: The characteristic feature of the wing-venation for the family is that R4, R5, and M1 curve forwards and end before the apex of the wing. Subcosta distinct, extending beyond halfway along the wing. R1 extending to near apex. R2+3 terminates on R1 and sometimes also R4 and R5. M1 ends before apex, M2 before or after apex. M3 fuses with M4 to form a closed cell behind the median cell; from this a compound vein M3+4 may arise and run direct to wing margin. Cu1 strongly developed, meeting 1A at wing margin or a short distance before it. (A genus of this family, *Apomidas,* was described by Coquillett from North America, and his specimen differed from *Rhaphiomidas* merely in having the anal cell open, a character only doubtfully of generic value). Cu2 present, very weakly developed.



TEXT-FIGURE I.

a. Wing of *Apiocera* sp. (t—median thyridium).

b. Wing of *Neorhaphiomidas hardyi,* gen. nov., sp. nov.

Abdomen varying in shape, generally broad basally, tapering distally; eight basal segments easily visible. Macrochaetae of abdomen weak or absent. Male terminalia with upper and lower forceps developed. Female terminalia with a double row of spines.

Habits:

Apioceridae are found for the most part in sandy areas of light rainfall. The adults are usually observed perching on bare sand, but sometimes on vegetation. To judge from the nature of the proboscis the flies are essentially flower-feeders. The writer has not seen any record of the species of *Apiocera* being taken at flowers, and of the species which he has collected in the field only one was directly observed visiting flowers. Indirect evidence of the feeding habits is readily obtained by an inspection of the proboscis and palpi, which in dried specimens can frequently be seen, even after years of preservation, to be sticky with honey, or coated with pollen.

Species of *Apiocera* are extremely powerful on the wing and very wary. Mostly they make a shrill note in flight and several specimens of two different species when kept alive in match-boxes or glass vessels have been noticed to produce a shrill buzzing note without beating the wings, as do many Tabanidae.

Painter ([2]) records that the North American species may run swiftly over the ground. Of five or six of the local species observed in the field by the writer none have been noticed to run. The only ambulatory movement seen was a slow crawling on the part of one female.

The two species of *Neorhaphiomidas* gen. nov. described in this paper are much less agile than *Apiocera*, and easier to capture. *N. hardyi* sp nov. has been observed visiting flowers of pink myrtle (*Hypocalymma robusta*) and is possibly a wasp mimic.

Specific Characters:

Colour affords an unreliable basis for specific diagnosis, as species often exhibit a certain amount of variation and are apt to become rubbed, or after preservation, greasy.

As pointed out by Hardy ([1]), the structure of the head provides reliable specific characters in the shape and proportions of palpi, antennae and proboscis. Width of vertex in conjunction with these characters is also valuable in taxonomy.

Proboscis-length is extremely difficult to determine accurately, owing to the shrinkage which may occur on drying, and the absence of a suitable standard point at the base from which to measure. In this paper the method has been adopted of measuring the distance from the tip of the labella to the proximal end of the strongly chitinised ventral surface of the proboscis (theca). Basally this passes rather suddenly into soft flexible membrane, to the wrinkling of which most of the contraction is due. In specimens obviously of the same species the proboscis may appear to differ tremendously in relative length, but when the theca is measured a good agreement is generally found. All measurements of the proboscis of *Apiocera* in this paper are made from tip to the point in the mid-line where the soft membrane begins.

Male terminalia, again as pointed out by Hardy, do not offer very many characters of use to systematists, many species being very similar in this respect. A few, however, are very distinctive. The structure of the clasper yields useful characters.

Life History:

The nature of the larval and pupal forms of this family is as yet unknown, and as with all seasonal flies with terrestrial larvae, is rather a difficult problem to investigate.

The following observation on oviposition made at Two-People Bay, near Albany, indicates that the larvae are terrestrial, as might have been surmised.

A female of *Apiocera* sp. was observed ovipositing in the rut of a well-worn car track. The insect alighted near the middle of the track and crawled towards the edge, coming to rest where some plants cast a shade on the sand. The tip of the abdomen was bent downwards and forced into the sand to a depth amounting to about one-quarter of its length. Thus it remained for perhaps half a minute, the abdomen undergoing movements of contraction. The abdomen was then withdrawn, and the depression left filled in by a rapid kicking movement of the hind legs. The female then took to the wing and was secured and kept alive.

Digging revealed the fact that the soil was rather compact at the place of oviposition, and also slightly moist. The egg was found to be of an oval shape typical of Diptera, with shining chorion, bright orange in colour and apparently rather soft. After several days in captivity the female was found to have laid a similar egg in the corner of the box. Unfortunately neither of the eggs gave rise to larvae.

Affinities:

Those features in which *Rhaphiomidas* approaches Mydaidae are very probably convergent characters rather than signs of affinity. In important details of anatomy *Neorhaphiomidas* is definitely an Apiocerid.

Hardy ([5]) from his studies in the phylogeny of the terminal abdominal structures is of the opinion that Apioceridae are so close to Asilidae that further research may render it necessary to reduce this family to a subfamily of equal status with Asilinae and Dasypogoninae.

Types:

The type specimens will be deposited in the Perth Museum, Western Australia.

Measurements.

Included in this paper is a table containing the exact proportions of the head-capsule and its appendages for the species described. Proportions mentioned in the text are convenient approximations.

KEY TO GENERA OF APIOCERIDAE FOUND IN AUSTRALIA.

Palpi large and two-segmented, M2 if present,
ends separately after wing apex............*Apiocera*, Westwood.

Palpi, small, composed of a single segment, M2
fuses with R5 + M1, and this complex vein
ends on R1 well before wing apex......*Neorhaphiomidas*, gen. nov.

TABLE EXPRESSING PROPORTIONS OF HEAD-MEASUREMENTS, TAKING HEAD-WIDTH AS A STANDARD.

Species.	Sex.	Head-width.	Proportional Measurements.						
			Head-Width.	Head-Height.	Head-Length.	Separation of Eyes.	Proboscis-Length.	Palpus-Length.	Antenna-Length.
Apiocera deforma sp. nov.	Male	mms. 4·18	100	75	45	23	95	54	36
	Female	?	100	?	?	?	?	?	?
Apiocera pica sp. nov.	Male	4·70	100	69	39	19	87	47	40
	Female	5·07	100	63	43	33	81	47	39
Apiocera tonnoiri sp. nov.	Male	4·42	100	82	43	5	62	40	38
	Female	4·51	100	76	40	23	66	40	36
Apiocera pallida sp. nov.	Male	3·58	100	69	41	29	77	46	43
	Female	3·71	100	65	42	41	74	48	41
Apiocera minor sp. nov.	Male	2·51	100	67	50	41	96	55	59
	Female	2·94	100	66	49	44	93	54	57
Apiocera newmani sp. nov.	Male	2·55	100	68	55	38	156	77	76
	Female	2·88	100	67	58	39	164	73	66
Neorhaphiomidas hardyi sp. nov.	Male	2·47	100	72	49	23	189	?	59
	Female	2·35	100	70	47	24	200	11	59
Neorhaphiomidas pinguis sp. nov.	Male	1·95	100	68	47	24	155	?	49
	Female	1·93	100	70	49	28	176	?	53

The following incorporates Hardy's preliminary revision of *Apiocera* [1] with various alterations. In particular the notation of the venation is brought into conformity with Tillyard's modification of the Comstock-Needham System.

Genus **Apiocera**, Westwood, 1835. (Text-figure 1a, Plate 1, and Plate 2, figs. a-e.)

Mostly large-headed flies with stout thorax and tapering abdomen. Antennae three-segmented with a one- or indistinctly two-segmented style. Palpi two-segmented, prominent; second segment with a pit, probably sensory in function on the outer surface. In one species herein described there is a row of three or more pits on the second segment of palpus.

Venation (Text figure 1a): Costa and R1 meet before apex of wing. Sc between them reaches to or beyond half the length of the wing. R2 + 3 terminates on R1. R4 and R5 run to edge of wing before apex, the former also sometimes ending on R1. M1 runs to margin near wing apex. M2 runs parallel to M1 reaching margin considerably behind the apex. M3 meeting M4 forms a closed cell behind the median cell before the compound vein thus formed reaches wing margin. Cu1 meets IA at or near the wing margin. Anal vein slightly sinuous, downcurving abruptly after leaving Cu at base. Cu2 weak. Certain of the veins may be weak or absent, *e.g.*, R4, R5 or M1 in specimens of *Apiocera maritima*, Hardy.

Thorax: Scutellum well developed, its bristles strong, as are the lateral thoracics. Prothorax mostly concealed by the large head, which is fairly closely applied to thorax. Legs slender, femora not thickened.

Abdomen: Bristles poorly developed. Terminalia of male large and prominent, permanently projecting. Anal papilla elongate.

Notes:

The genus *Apiocera* shows an archaic character in the possession of a vestige of a *thyridium* at the primary dichotomy of the median vein, a feature which occurs also in other genera of Diptera, and also in Mecoptera.

Tillyard has demonstrated the presence of this structure in many fossil Mecoptera and some Trichoptera [7], and I am indebted to this author for pointing out to me its true nature in Apioceridae. The thyridium can be seen as a weakening or bleaching of the chitin of the median vein at the point of its dichotomy into M1 + 2 and M3 + 4.

Curran [6] states that short proboscis-length is a distinguishing character of genus *Apiocera*, but a species occurs in Western Australia in which the proboscis is as long in proportion as that of *Rhaphiomidas*, yet this species can in no way be considered as worthy of generic distinction. The separation made by Curran is therefore not absolutely diagnostic. The characters which should be relied on to distinguish *Apiocera* from other genera are the segmentation of the palpi and the nature of the wing venation.

Apiocera deforma sp. nov. (Plate 1, a, b.)

Male: Head: Height three-quarters of width: ground-colour black. Eyes larger than the average, separated from paired ocelli by a distance equal to the breadth of the median ocellus. Separation of eyes at vertex three-fourteenths of head-width. Paired ocelli on the sides of a prominent tubercle separated from the eyes by deep grooves which unite on the occiput to form a V-shaped mark above the neck. Median ocellus situated in front of paired ocelli at a distance equal to twice the distance between the latter. Front depressed. Ocellar region with black tomentum and a coating of short, black, forwardly-curved hairs. These extend only a short distance in front of the ocelli where the tomentum of the front become white, and the black hairs are replaced by longer and thinner white ones, extending to near the bases of the antennae.

Antennae short, light brown in colour; basal segment with a considerable bulge on the lower surface. This segment has a slight white tomentose covering and has a coating of long soft white hairs. Diameter of second segment greater than its length; with a few white hairs similar to those of basal segment. Third segment dilated, asymmetrical in profile. Style distinct, large. Third segment longer than basal, second segment about one-third its length.

Palpi about one-half as long again as antennae, dark brown in colour. Proximal segment cylindrical with sparse covering of long white hairs below. Second segment the longer, flattened distally, narrow and pointed apically, with a few short white hairs and a row of three or four pits on the outer face.

Proboscis black, twice head length, two and a half times the length of the antennae. Folded labella pointed apically.

Posterior aspect of head with white tomentum. "Post-optic" bristles present, fairly numerous, not extending down posterior margin of eye. White hairs extend in an irregular row parallel to posterior margin of eye, not, however, extending far enough upwards to intermingle with the black bristles above. Two tufts of white hairs behind the insertions of the palpi.

Thorax: Pronotum with white hairs and spines but no black bristles above. Mesonotum black, evenly coated with short black hairs; indications of two faint wedges at anterior end. A white band round the margin as in other species, extending onto sides of scutellum. Pleura dark brown with white tomentum and black and white hairs irregularly scattered.

Legs brown, coxae with white hairs, but devoid of black bristles.

Wings evenly tinted pale brown.

Abdomen stout, ground colour brownish-black. Basal segment with white tomentum and white hairs. A white band on posterior margin of second, third and fourth tergites, extending at sides on to succeeding tergites. Fifth segment almost all white. Following this the sclerites are mainly brownish-black. Venter mostly with white tomentum, but in large patches the brown ground colour is visible.

Terminalia very prominent and swollen. Superior edge of upper forceps with an apex near posterior end. Lower forceps considerably shorter than upper, blunt. Ninth sternite almost as long as lower forceps. Proctiger projecting behind teeth of upper forceps; lateral lamellae narrow, down-curved at tips, lower lamella broad, with a corresponding curve. Tip of upper forceps has soft white hairs but remainder of terminalia more or less densely covered with a coating of black bristles. Claspers unique, being in the form of broad, poorly chitinised plates, light brown in colour tapering rather abruptly distally, and with a slight pubescence.

Female: No female is available for description, but it should, however, be readily recognised by head characters and tinting of wings.

Measurements: Male, body 20 mm. (not including head), Wing 12 mm.

Hab.: Gnangara, W.A., 2 males, O'Connor, December.
Swan River, W.A., 1 male, L. J. Newman.

Notes: The large bulbous genitalia and multiple palpal pits are unique features among local species.

Apiocera pica sp. nov. (Plate 1, c, d, Plate 2, a.)

A large stout fly. Body comparatively short in proportion to width.

Male: Head large, about as wide as thorax and covered with a white tomentum. Eyes large, separated at vertex by one-fifth of the head-width. Height of ocellar triangle about two and a half times the base. Ocellar tubercle thickly clothed with long wavy dark brown hairs which extend in two parallel rows to near the bases of the antennae where they are replaced by white hairs.

Antennae fairly short, basal segment stout, brown, with white tomentum; a strong bulge on the lower surface near the distal end; vestiture consisting of a number of black bristles and a few white hairs. Second segment brown, tomentum white; a whorl of about a dozen black bristles round its middle. Terminal segment black dusted with white, particularly proximally; symmetrical in profile. Style distinct, black.

Palpi longer than antennae, basal segment cylindrical, dark brown in colour; with a few long white hairs below and one or two black bristles. Second segment broad and flattened distally, lighter in colour; truncate apex slightly incised, also with sparse white hairs and one or two black bristles. Palpal pit prominent.

Face very narrow, as antennae are situated close to epistome. The latter has a small fringe of short white hairs.

Proboscis black, folded labella rounded apically and considerably broader than proboscis in profile.

"Post-optic" bristles well developed, not extending far down posterior margin of eye. These spines are intermingled with white, radially directed hairs which are continued down the sides behind the eyes as a fringe resembling an Elizabethan ruff in appearance. Head capsule, the ground colour of which is black, is thickly beset at base of proboscis and below neck with long white hair.

Proboscis twice the length of antennae, about two and a quarter times the length of head.

Thorax: Pronotum with black bristles and white hairs above. Ground colour of mesonotum black. A band of white pulverulence round periphery, not extending onto scutellum. Anteriorly a median white stripe extends back to about the level of the suture. On either side of this is a more prominent white stripe, broadening anteriorly, where each curves outwards. These also extend to about the level of the suture. Along the line of the suture a white wedge points inward from the marginal band. From the latter two other white wedges arise on each side, one behind and one in front of the suture, curving respectively forwards and backwards to touch the sutural mark between its apex. These three wedge-shaped marks on either side run into the paired longitudinal stripes near the hinder end of the latter.

A pair of broad white bars is situated in front of the scutellum and behind the terminations of the vittae; from each of these marks a thin white line extends outwards and forwards to meet the apex of the sutural wedge. A small median white spot is situated in front of the scutellum. The latter is black and has a fringe of white hairs. Areas between the white marks are brownish to blackish in colour. The whole of the mesonotum, excepting the space occupied by the white fringe on scutellum, is beset with a thick coating of brown hairs. Post-alar callus with a dense tuft of white hairs.

Pleura dark brown, with a white tomentum and a dense coating of white hairs which are also particularly abundant on prosternum. Pteropleuron with a patch of black hairs.

Legs long, brown; but so densely black-haired as to appear black. Coxae with white hairs, white tomentum and some black bristles.

Wings hyaline, normal.

Abdomen: Marked with black and white pattern. Ground colour dark brown. Basal tergite mostly sooty black but laterally white and with two white spots posteriorly. The second tergite bears the largest dorsal white markings in the form of two broad, transverse white strips. These marks are separated by a median black band and this broadens over the anterior half of the tergite and laterally sweeps back to the posterior corner of the tergite. Anterior corners white. Third tergite mostly black; two white marks posteriorly, and antero-lateral corners white. Fifth tergite mostly white; black central stripe and posterior edge. Remaining tergites black or brownish. Venter white. Abdomen covered with short black bristles. Basal tergite with dense white hairs and two lateral patches of black hairs. One or two following tergites and the anterior sternites have a few white hairs.

Terminalia dark brown with a thin coating of white tomentum and with a covering of short black bristles. The terminalia of this fly are of a nondescript type which is found in the majority of species and shows no very definite external differences for specific diagnosis. The whole terminalia in the resting condition fit closely together like a box, leaving only a small opening on the dorsum, where the proctiger protrudes. The clasper is distinctive (Plate 2, a).

Female: Similar to male, except that the eyes are more widely separated, being one-third of the head-width apart.

Measurements: Male, body 18.5 mm., wing 14 mm.
Female, body 18.5 mm., wing 14 mm.

Hab.: Gnangara, W.A., 1 male November, 1930; 2 females December. 1930, Perry.
Gnangara, W.A., November, 1930, 2 males, 1 female, O'Connor. 2 females, 1 male unlabelled.

Notes: Among the specimens studied there is a smaller fly which apart from a number of minor characters differs from the above species in abdominal pattern. Probably its true relationship could be best expressed by describing it as a subspecies; but this will not be attempted until a larger number of better preserved specimens are available for study.

Apiocera tonnoiri sp. nov. (Plate 1.e, f. Plate 2, b.)

A large elongated species very distinctive in character of proboscis.

Male: Head very concave posteriorly. Front depressed. Face not projecting. Head-height about nine-elevenths of width. Eyes large, separated at vertex by only the twenty-second part of head width. A very deep narrow groove runs between eyes at vertex behind ocelli, and continues out on to occiput to run in a much shallower form into cervicum. Ocelli crowded forward from normal position. Paired ocelli practically touching eyes, and elongated in a vertical direction. Median ocellus larger, transversely oval, well separated from others. Ocellar tubercle and front with long black hairs. Face and oral margins with white tomentum.

Antennae situated almost on epistome. Basal segment light brown, very convex ventro-laterally; with white tomentum and long, black and white hairs. Second segment brown, shorter than broad, dusted with white and with long black bristles round middle. Third segment light brown, darker distally; with faint white dusting. This segment is slightly longer than the first. Style black.

Palpi honey-coloured, both segments darker at base. Proximal segment the longer, cylindrical, dusted with white, and with white hairs. Distal segment shaped like a quart of an orange, dusted with white and with a coating of long white hairs, and one or two black ones. Pit prominent, situated slightly nearer to base than to apex.

Proboscis brown with very characteristic labella slightly less than one and a half times the length of the head capsule. Occiput with dense white tomentum, a ruff of short white hairs, and a small tuft of black bristles behind each eye apex. Hairs round edge of oral cavity white, extremely short. All white hairs round edge of occiput and near bases of palpi are exceptionally short.

Thorax dark brown, entirely pollenose. Pronotum white pollenose, with white hairs and a circlet of black bristles. Mesonotum with a slender median stripe, dirty-white in colour. A pair of stripes flanking this, broadening anteriorly. Humeral callus and a lateral longitudinal strip behind this white. Lateral and scutellar bristles black. Rest of dorsum with a sooty-brown pollen. Dorsum of thorax with a dense coating of short dark brown hairs. A patch of white hairs on post-alar callus and above wing-base. Scutellum with a sparse coat of white hairs which extend beyond its limits on to posterior part of scutum. Post-scutellum white pollenose. Pleurae brown, entirely covered with white tomentum; in patches with very short black hairs.

Wings hyaline, veins black.

Legs light brown, tomentum white, but sparser distally. Bristles black. Soft white hairs on coxae and bases of femora.

Abdomen long and tapering. Ground colour brown. Basal tergites with a sooty coloured pollen, except at lateral margins, which are white; with a dense coat of fine white hairs, and, on basal tergite, a few black ones. The four last tergites lack this hairy covering. Sternites with sparse white tomentum and white hairs.

Terminalia dusted with white. Proctiger with lamellae separated at tips. A dense beard of long white bristles closes genital cavity from below. Eighth sternite very prominent, whilst ninth sternite which bears the abovementioned beard is in the form of a truncate plate. Clasper, Plate 2, b.

Female: very similar to male but eyes more widely separated at vertex, i.e. by two-ninths of head width. Distance between each lateral ocellus and eye is equal to that between the members of the pair. On account of genitalia, abdomen appears shorter.

Measurements: Male, body 20 mm., wing 13mm. Female, body 18½mm., wing 14mm.

Hab.: Applecross (about five miles east of Fremantle) 12 males, 10 females. February 1935, December 1935, February 1936. K. R. Norris.

The Writer has taken this species at only one locality. The flies occurred round bushes of the Proteaceous plant *Adenanthos cygnorum*. For the most part they rested on the loose sand, but occasionally specimens were seen flying and climbing in the branches of the abovementioned shrub, the extra-floral nectaries of which are, no doubt, the attractive agent. In flight the sound produced resembles that of a large blowfly.

Although within a few paces there were abundant flowering shrubs of pink myrtle (*Hypocalymma robusta*) the flies were never on any occasion observed to visit it although dozens of species of Diptera and other insects were taken on this plant, including a species of **Neorhaphiomidas** gen. nov.

Notes: The proboscis has quite an exceptional structure in the nature of the labella (see Plate 1, f). In preparations of the proboscis and occasionally in dried specimens the pseudotracheal membrane protrudes below the labella, hanging down in the form of a soft, tongue-like, pointed lobe.

Apiocera pallida sp. nov. (Plate 1, j; Plate 2, c.)

A hairy species which is a parallel to *Apiocera maritima*, Hardy, being predominantly white in colour and occurring on white sand dunes and adjacent sandy regions.

Male: Head: Ground colour, black, but completely obscured by dense white pulverulence. Eyes separated at vertex by about two-sevenths of head-width. Inner margins of eyes fairly straight, diverging out at base of head. Ocellar region with light brown hairs projecting up from the white tomentum. Lateral ocelli well separated from eye. Height of ocellar triangle about one and a half times the base. Below ocellar region the hairs are white, extending round oral rim to join the hairs on the back of the head.

Antennae: Basal segment brown, covered with white tomentum, armed distally with long pale bristles, proximally with soft white hairs. Second segment black, globular, with white tomentum and a circlet of pale spines. Third segment yellow at base, black distally, with a patchy white pollen. Style black. Basal and distal segments equal in length.

Palpi equal in length to antennae, basal segment cylindrical, ground colour yellowish-grey; with loose white tomentum and with a sparse coat of long white hairs. Distal segment more or less truncate apically; with white tomentum and a few white hairs.

Proboscis black, about one and two-thirds as long as head capsule and in a similar proportion to length of antennae.

Height of head two-thirds of width, and width two and one-third times length.

A groove marks off face and genae from rim-like edge of oral cavity.

Back of head with white tomentum and a dense ruff of radially-arranged hairs extending down to bases of palpi. Behind each eye apex is a tuft of yellowish bristles. No black bristles at all upon head.

Thorax vittate above. Ground colour blackish. Pronotum white, with white hairs and only white spines above. A median white stripe is present on mesonotum, which fades out before the scutellum. This stripe is flanked by a pair of broader black ones, and these in turn by a white pair which diverge and broaden anteriorly. Humeral calli white. A white patch just above wing-base; another but larger between humeral callus and suture, this latter mark being in the form of an inwardly pointing wedge. Scutellum black. Post-scutellum with white pollen. Ventral and pleural regions with very dark ground colour obscured by dense coating of white pulverulence and white hairs. A tuft of black bristles on humeral callus, lateral thoracics mostly black; a few, however, are pale and yellow. Post-alar callus with a tuft of long bristles, about one-half of which are pale. Scutellar bristles black. Dorsum of thorax with an even coating of short, erect, brown hairs. In front of and on scutellum these become white and longer. There is a few white hairs at anterior of mesonotum as well.

Legs: Coxae and femora yellowish, with white pulverulence and white hair; bristles pale. Tibiae and tarsi yellow, the former with white pollen; bristles yellow proximally, black on terminal leg segments.

Wings hyaline, costa pale, median vein black, remainder brown. Median thyridium particularly obvious. Squamae with dense white fringe. M1 and M2 very weak and pale. Free part of M3 + 4 short or absent. Halters yellowish-brown.

Abdomen short; tergites black, brown laterally. Sternites brown. Tergites edged with white posteriorly. Fourth and fifth tergites with paired white patches above. Those parts of the tergites visible from the sides are mostly white, but tergites two, three and four have brown lateral patches. The four basal tergites have dense white hairs above. Segment five is partly so; but hair of remainder of dorsum is black. Venter entirely with white pollen and white hairs which are longer at the base.

Terminalia brown, with dense white tomentum and white hairs. Similar to those of *A. pica* sp. nov. in shape.

Female: Front wider than in male, occupying two-fifths of the head-width. Abdomen not nearly so hairy dorsally and differing in dorsal pattern. There is a slender, brown, median stripe, and broad paired lateral brown spots on tergites 2-5.

Measurements: Male, body 16 mm., wing 10 mm. Female, body 16 mm., wing 11mm.

Hab.: Garden Island, W.A., 1 female, 11th March, 1933, 1 male 23rd February, 1935, K. R. Norris. Carnac Island, 18 males, 4 females, 2nd February, 1936, K. R. Norris.

Mr. L. Glauert has shown me a specimen collected at Cottesloe on the mainland.

Notes: The first specimen taken was the female from Garden Island. It was perching on a bush on a cliff above the sea. The male from Garden Island was taken on a sand-dune, where other specimens were also seen in a growth of *Calocephalus brownei*. On Carnac Island the species was extremely common, but males were preponderant. Three of the females were evidently recently emerged and were very sluggish, but the males were agile and pugnacious, continually indulging in aerial duels with one another. They occurred on the loose white dunes and beach sand, and also on the more compact earth away from the shore. One female was removed from the possession of a small female Asilid of genus *Cerdistus*. The males may be as small as 13 mm. in length.

Apiocera minor sp. nov. (Plate 1, g, h, Plate 2, d.)

Male: Head-height seven-tenths of width. Eyes widely separated, being three-eighths of the head-width apart at vertex. Inner margins of eyes are parallel. Separation of eyes at vertex is three times the width of ocellar tubercle. Paired ocelli separated from eye margin by a distance which is greater than the distance between them. Ocellar triangle equilateral. Head-capsule black, completely covered with white tomentum. Front and ocelli sparsely covered with long brown hairs, absent from a median region above the antennae, where the tomentum is brown.

Antennae black, long and slender. Basal segment dusted white; when viewed from above with a straight inner margin and a strongly convex outer margin; with a few long black spines, and on the outer face white hairs. Second segment globular, dusted white; a few long black spines in a whorl round its middle. Terminal segment black, cigar-shaped, dusted silvery white; apt to crumple in dried specimens. The third segment is about one-third as long again as is the basal, whilst the black bristles with which the antennae are armed are about equal in length to that of the basal segment. Style prominent.

Face of considerable breadth. Genae with a fringe of white hairs.

Palpi slightly more than three-quarters of the antennal length, basal segment cylindrical, light brown with numerous long white hairs below; equal in length to two-thirds that of the distal segment. Terminal segment cylindrical at base, flattened distally, rounded apically, light brown in colour but darker distally; thin black bristles near upper margin and soft white hairs below.

Proboscis slender, black, twice as long as head; folded labella smoothly angulated apically, distinctly broader than proboscis in profile.

Epistome almost squarely transverse. Face and genae with soft white hairs. Posterior aspect of head with long white hairs and a fairly large tuft of black spines behind the apex of each eye intermingled with white hairs. The hairs near the insertion of the palpi and on the basal segment of these appendages are particularly long.

Thorax: Ground colour black. Pronotum with black spines and white hairs above. Mesonotum with a greyish dust and a pattern of greyish white marks, corresponding roughly in distribution to those of *A. pica* sp. nov. Humeral callus with a tuft of short black bristles. Lateral thoracics and scutellars are extremely long. Pleurae covered with white tomentum and white hairs. A tuft of black bristles above anterior coxae. Mesonotum with an even coating of short brown hairs; those of scutellum white.

Legs brown, long; coxae with white hairs and tomentum and white bristles.

Wings hyaline, normal. Halters brown.

Abdomen: Ground colour, brown. Basal tergite with a pair of white stripes corresponding with lateral edges of scutellum. Second tergite with a pair of similar white stripes posteriorly, half the length of the tergite. The pattern on the third and fourth tergites can perhaps best be described as a black broad arrow on each, pointing forwards; remainder white. Remainder of tergites with white tomentum and a median black stripe. Sternites with white tomentum and anteriorly, white hairs. Basal tergite with a few white hairs, and on either side posteriorly a tuft of black bristles.

Terminalia covered with black bristles, clasper bearing a few black spines below.

Female: Larger than male, front not broader, most readily distinguished from male by the terminalia.

Measurements: Male, body 12.5 mm., wing 7.5 mm.
Female, body 12.5 mm., wing 8 mm.

Width of thorax in both sexes 3 mm.

Hab.: Carlisle, W.A., 2 females, 1 male. D. Swan.
Mullewa, W.A., 1 female, 1 male, L. J. Newman.
Gnangara, W.A., 1 female, November, 1930, O'Connor.
Yelbeni, W.A., 1 female, September, O'Connor.
Kalgoorlie, W.A., 1 female, September, L. J. Newman.

Notes: Closely allied to *A. newmani* sp. nov., but distinguished by the much shorter proboscis, larger labella and less prominent face. There is also a pronounced difference in the flange bordering the gena laterally, as will be seen from the illustrations. The Mullewa, Yelbeni, and Kalgoorlie specimens are smaller and duller than the others.

Apiocera newmani sp. nov. (Plate 1, i, Plate 2, e.)

Male: Head about seven-tenths as high as wide. Eyes widely separated by slightly more than one-third of head-width, inner margins parallel. Head capsule black, completely covered with white tomentum except above antennal bases where there is a brown streak. Ocelli widely separated from eye and arranged almost in the form of an equilateral triangle. Median ocellus larger than others. Long, curling brown hairs extend from behind ocelli to the bases of the antennae, but are absent from the brown streak above-mentioned.

Antennae very long and slender, black. Basal segment dusted white, unusually obliquely truncate distally when viewed from above, and concave on the inner surface; with long black bristles and proximally a few white hairs. Second segment globular, with white dusting and a whorl of about five long black bristles. Terminal segment cylindrical, with a silvery white dusting; style very short and blunt. The third segment crumples up on drying, and is longer than the basal. Antennae inserted a fair distance from epistome which forms a distinct apex below antennae.

Face very prominent. A fringe of white hairs round genae, partly concealing a prominent brown flange which projects and borders the epistome on either side.

Palpi slightly longer than antennae; light brown in colour; basal segment roughly cylindrical, with a few long white hairs. Second segment flattened distally, smoothly rounded at apex, with a few long white hairs proximally; most of the outer surface sparsely covered with black hairs. Pit small.

Proboscis black, very attenuated, labella very small, scarcely broader than body of proboscis in profile.

"Post-optic" bristles present in a tuft behind upper angle of eye; and extending in a row about half-way down the posterior margin of eye. Intermingled with these bristles are white hairs directed like the bristles radially outwards. On the lower aspect of the head capsule behind the eyes these white hairs become continuous with the fringe previously mentioned as running round the genae, and together with two long tufts from near the bases of the palpi hang down to form a long beard. Proboscis twice the length of antennae and three times the length of the head-capsule.

Thorax: Prothorax with black spines and white hairs above. Mesonotum black with three white stripes, the median of which is very slender, and separated from the broader, lateral pair by broad black bands. A white band continuous round edge of mesonotum, including scutellum. Mesonotum with a thin covering of fine brown hairs. Humeral callus with a tuft of short bristles. Lateral thoracic and scutellar bristles very long. Pleura black with white tomentum and a few white hairs, especially below wing and also above anterior coxae, where there is also a tuft of black bristles, though these may be white.

Legs brown, coxae with white tomentum and hairs, and white bristles.

Wings rather small hyaline, free, part of M3 + 4 may be absent. Halters brown.

Abdomen: Ground colour brown, darker at bases of segments. The four basal segments with paired white stripes above, separated by a continuous median black stripe. The white stripes may not extend over the anterior half of the tergites. The basal tergites are white laterally. Sternites of anterior region with white tomentum and a few white hairs. Basal tergite with white hairs and paired lateral tufts of black bristles. Distal segments and terminalia brownish black, with black bristles. Shape of terminalia similar to that in *A. minor* n. sp., but clasper differs in having no stout black spines ventrally.

Female: Larger than the male. Front of same width.

Measurements: Male, body 12 mm., wing 7 mm.
Female, body 13 mm., wing 8 mm.

Width of male thorax 2½ mm., of female thorax 3 m.

Hab.: Gnangara, W.A., 2 females, 1 male, November, 1930, O'Connor.
Gnangara, W.A., 2 females, November, 1930, Perry.
King's Park, Perth, W.A., 4 males, 1 female, November, December, 1935, K. R. Norris.

Notes: The small labella, great length of proboscis, antennae and palpi and in general the slender build distinguishes this species. The fact that the upper margin of the epistome comes to an apex is also rather a peculiarity.

The specimens taken in King's Park were found sitting in open grassy, but not sandy spaces between knee-high clumps of vegetation. They were for the most part around flowering clumps of *Hemiandra pungens* and one specimen was observed to traverse a broad stretch of this plant with abundant flowers, alighting here and there to disappear into the depths of a flower for a moment. This is the only occasion on which the writer has observed an *Apiocera* visiting a flower.

This undoubted species of *Apiocera* proves that proboscis-length is no certain character in diagnosis of genera, for specimens with extreme extension of proboscis may show the overall length of this organ to be between three and four times the head-length. This may well equal or exceed the proboscis-length of the genera other than *Apiocera*.

This species is named in honour of Mr. L. J. Newman, Government Entomologist, W.A.

NEORHAPHIOMIDAS gen. nov.

(Text-figure 1, b. Plate 2, f-j.)

Related to *Rhaphiomidas* Osten Sacken; but distinguished by specialisation of wing venation. Thinly pilose but bristleless flies.

Head fairly small. Eyes large. Anterior ocellus separated from the other two by a considerable distance, and larger than them. Antennae three-segmented, style minute, subapical. Palpi very short, composed of a single segment. Proboscis long and poorly chitinised.

Prothorax, which forms a neck between head and thorax, has a circlet of bristles above. Thorax otherwise devoid of bristles. Scutellum reduced. A prominent nodule in front of halter.

Wing venation. (Text fig. 1, b.): Differs from that of other genera of the family in the fusion distally of the median and radial veins. R2+3 and R4 ending on R1. R5 and M1 fusing a short distance after the origin of the latter. M2 curves up and fuses with this compound vein to make a vein of triple origin, R5+M1+M2 which also ends on R1, just at the point of juncture of the latter with the wing margin, well before wing-apex. Free distal part of M3+4 may be absent. Cu1 meets 1A just before wing margin.

Legs long and fairly strong, empodium absent. Hind legs longer than others and hind femora more or less clubbed.

Abdomen shiny. In females broader than thorax at its widest part; slightly curved ventrally. Females with spines of acanthophorites readily visible. Males with upper and lower forceps developed, but rather small and retracted into the terminal abdominal segments so that only the tips protrude. Anal papilla very broad and short.

Genotype. *Neorhaphiomidas hardyi* sp. nov.

Notes: Osten Sacken remarked that the nodule in front of the halter in *Rhaphiomidas* had no parallel in his knowledge, but it is probably only an overdevelopment of a similarly-placed bulge which can be seen in *Apiocera*, but which does not catch the eye as it does in the other genera. In *Neorhaphiomidas pinguis* sp. nov. described in this paper an intermediate stage can be seen, because in this species the bulge in front of the halter is simple and rounded, and lacks the conical tip found in *Rhaphiomidas* and *N. hardyi* sp. nov.

That the interpretation of vein labelled M2 is correct and that it is not M3+4 can be seen from a female of an undescribed species presented to me by Mr. D. C. Swan. In this specimen vein M3+4 is present, in addition to M2, as a small vein running out to wing margin.

Neorhaphiomidas hardyi sp. nov. (Text figure 1, b. Plate 2, g-j.)

Male: Head small. Head-capsule black, covered with greyish-white tomentum. At vertex, eyes are separated by about two-ninths of head-width. Height of head three-quarters of width. Paired ocelli situated on the sides of a prominent tubercle, separated from the eye by one-half the distance between the ocelli. Median ocellus large and depressed, situated almost half-way between paired ocelli and the bases of the antennae. Ocellar tubercle black, with short black hairs which extend in a row down either side of the front to join a patch of white hairs above the base of each antenna. A slight notch in the inner margin of each eye opposite the bases of the antennae.

Antennae black, faintly white-dusted. Basal segment cylindrical, with a dense coating of black bristles. Second segment globular, shiny, with black hairs similar to proximal segment. Third segment the longest, with a few very small black hairs; broadest at middle, tapering somewhat abruptly distad to this; apex rounded in profile. There is a concavity on the outer surface of the tip which contains a minute style projecting forwards from its posterior face.

Antennae situated practically on epistome, which is rounded at apex. Below the base of each antenna is a small tuft of whitish hairs on the face. A bare, brown flange borders the genae on either side.

Proboscis black, long, about four times the head-length when an overall measurement is made; labella long but not prominent.

Palpi black, very small and composed of a single segment; with a few yellowish hairs.

Back of head with white tomentum. An irregular line of thin black bristles from the upper corner of the eye to about half-way down posterior border: these spines are separated from the actual margin of the eye by a space. Intermingled with these and more widely scattered are a few soft white hairs which continue to near the base of the proboscis, where they are much denser.

Thorax very deep brown in colour. Pronotum plainly visible, as the head is widely separated from the mesothorax. It has a circlet of black bristles above, intermingling with softer hairs. Mesonotum with a coating of very short brown hairs. Two wedge-shaped marks of pale dusting at the anterior end of mesonotum. A small pale patch also appears above the base of each wing. Scutellum small, shiny, with a few soft white hairs; devoid of bristles which are also absent from the remainder of mesothorax. Post-scutellum with greyish-white dust and white hairs. Anterior spiracle encroaching upon lower half of humeral callus. Pleura dusted with white and with a few white hairs. The most exceptional feature of the pleuron, as noted by Osten Sacken is a nodule arising just in front of the halter. This nodule consists of a rounded base with a prominent nipple arising from it and projecting backwards. The whole structure has a few white hairs. Prosternum large with fairly dense long white hairs.

Wings suffused with greyish-brown. Distally and posteriorly the general wing-colour is considerably lighter, the courses of the veins being marked by narrow bands of darker colour.

Venation (Text-figure 1b): Sub-costa ends on costa at about two-thirds wing length. R1 continues well out towards tip of wing, parallel with costa in its distal third. R2 + 3 simple, ending on R1. R4 ending on R1 a short distance after termination of R2 + 3. R5 turns down to fuse with M1, the resultant compound vein turning up to end on R1, after meeting M2. M2 arises with M3 from the median cell by a common stem, separating a short distance from the median cell to curve right up and fuse with R5 + M1 just before these join R1, which ends at this point on the costa by turning abruptly outwards. M3 and M4 form a complete cell with evenly curved boundary, the free portion of M3 + 4 being absent. Cu1 and 1A meet a short distance from the wing margin. The anal vein after leaving Cu at base, not abruptly down curved.

Knob of halter very large and white, stem brown.

Legs dark brown, bristles weak, hind femora thickened. Coxae with white hairs. Hind legs longer than body.

Abdomen stout, not tapering so much distally as in *Apiocera*. Segments 2-5 all of same width. Basal tergite reduced. Dusted greyish; but anterior edge shiny. Remaining tergites shiny, of a deep brown colour. Posterior edge of tergites 3-6 with a thin white band on either side. Sternites evenly tinted lighter brown, with scattered golden hairs.

Terminalia, and terminal segments rather hairy. The terminal organs are rather small and insignificant, quite unlike the average species of *Apiocera*, and partly retracted into the terminal segments of the abdomen. The anal papilla is very broad and flattened; upper lamellae rounded apically. The forceps, particularly the upper are reduced, whilst the aedeagus is roughly cylindrical and upwardly curved. Claspers absent; ninth sternite deeply cleft in median line. Bristles of genitalia small and black.

Female: Abdomen broader than in male, having its widest point at the third and fourth segments. The head is slightly smaller than in the male.

Measurements: Male, body 12mm., wing 9 mm. Female, body 12½ mm., wing 10 mm.

Hab.: Swan River, W.A., 1 male. L. J. Newman. Subiaco, W.A., 1 male, December. L. J. Newman. Swan River, W.A., 1 female, December, 1931. L. J. Newman. Applecross, W.A., 3 males, 9th February, 1936; 1 female, 9th February, 1935, and 3 females, 28th January, 1935. K. R. Norris.

Notes: The vestiture shows some variation in quantity. Ground colour and wing-colour may also be of a lighter brown.

The flies collected by the writer were taken at Applecross, about five miles east of Fremantle. They were feeding on flowers of *Hypocalymma robusta*, and proved to be rather sluggish and more easily caught than any species of *Apiocera*. They were not observed ever to rest upon the sand.

It seems probable that this fly is a general mimic of certain small Psammocharid and Sphecoid wasps which are very abundant in the neighbourhood, visiting the above-named plant. The morphological modifications contributing to the deception are found in the shiny dark integument, the very long legs, the pale lunules on the abdomen, and the darkening of the wings; but these characters would not be very effective if it were not for the habit which the flies have of rapidly flicking the wings whilst investigating the flowers, in exactly the same way as do the small striped Psammocharids of the area. A very close inspection is necessary whilst the insect is still on the flower to ascertain its true nature.

Neorhaphiomidas pinguis sp. nov. (Plate 2, f.)

A small plump species, which is certainly the most diminutive Apiocerid hitherto described.

Male: Head rather similar in appearance to that of *N. hardyi* sp. nov. Ground colour black but covered with a greyish-white tomentum. Eyes separated at vertex by one-quarter of the head-width. Head-height about three-quarters of breadth. Ocellar tubercle, large, mostly black, surrounded by grooves bearing lateral ocelli on its edges, slightly behind highest point. Median ocellus large and transversely elongate, not situated on tubercle but just in front of it, in a black, shining depression. Ocellar tubercle with very long, erect, kinky black hairs. A few short white hairs just above antennae.

Antennae black, basal segment with straight, parallel edges. Second segment broader than the first, and shorter than wide. First and second segments with long black hairs; first with a few white hairs also. Third segment the longest, fusiform, with patches of faint white dusting.

Face and lateral margins of oral cavity with long wavy white hair. Epistome comes to a point a short distance below antennae, and is not transverse.

Palpi very small, black.

Overall length of proboscis about three and a half times the length of the head and about three times the length of the antennae.

Posterior aspect of head with white tomentum and a coat of long thin erect white hairs. These are especially dense and wavy near the base of the head. The black bristles normally present behind the apex of the eye in Apioceridae are few in number and reduced almost to the form of hairs, being very slender.

Thorax: Ground colour deep brown. Prothorax thinly dusted with white, covered with white hairs and lacking black spines above. Humeral calli prominent, greyish-white bearing a shining brown ridge above spiracle. Mesonotum with a broad central dark brown stripe, which is bordered on either side by a narrow greyish-white stripe broadening anteriorly. A dark brown stripe runs from humeral callus to scutellum, whilst laterally the mesonotum has a greyish-white edge, equal in width to the latter. Post-alar callus brown, shining. Scutellum and post-scutellum dark brown, dusted with white. Dorsum of thorax beset with a fairly dense coat of thin, black, wavy hair. Above wing-bases, on humeral callus, post-allar callus and on scutellum is a few pale hairs.

Pleura brown, with white tomentose covering and a coating of long wavy white hairs. The knob which projects in front of base of halter differs from that of *N. hardyi* sp. nov. in shape, being smoothly rounded and lacking the pointed tip. It is covered with white tomentum, and very long, wavy white hairs.

Sterna brown, with white tomentum and, except for mesosternum, white hairs.

Legs dark brown, with white hairs and weak bristles. Coxae, trochanters and femora with white hairs. Posterior femora clubbed, with four stout, black, erect spines on under side at distal end.

Wings hyaline, with a milky sheen. Veins yellowish-brown, venation exactly like that of *N. hardyi* sp. nov. No trace of $M3 + 4$ present. Anal lobe small, alula absent, squame very small.

Abdomen shining, broader than thorax, especially at widest part; this, which is also the thickest part, occurs at segments four and five. Rest of abdomen not so thick, and bent down at tip. Ground colour of abdomen mostly dark brown; but segments 3-8 have each a pair of creamy-white, half-moon shaped marks at the posterior edges of the tergites, whilst sternites 3-8 have a similarly coloured hind border. Basal tergite raised, differing from others in being greyish-white dusted. Hairs of abdomen black and small mid-dorsally but white and soft laterally, ventrally, and on first tergite.

Terminalia (Plate 2, f). Anal papilla very broad, similar to that of *N. hardyi* sp. nov. Ventral forceps broader than in the latter species, and excised apically. Ninth sternite and aedeagus rather similar to those of

N. hardyi but this species differs considerably from the latter in the possession of a pair of claspers, in the form of simple, inward and downwardly curving hooks. All the parts of the terminalia are shiny, translucent and brown, the bristles being small and black.

Female similar to male except that abdomen is broader.

Measurements: Male, body 7 mm., wing 5 mm.
Female, body 7 mm., wing 5 mm.

Hab.: 1 male, Rottnest Island, W.A., 23rd February, 1936.
1 female, Garden Island, W.A., 23rd February, 1935.
Both collected by the Writer.

Notes: The female taken on Garden Island was perching on a dead exposed root on the top of a very high sand dune. In the absence of a net, the insect was captured by hand, this proving an easy matter as it was extremely sluggish and still. It is a rather rubbed specimen with the posterior tibiae broken off.

The male taken on Rottnest Island was flying actively over a clump of *Conostylis candicans*, visiting the dead flowers.

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His thanks are also due to Mr. A. Tonnoir for help with literature not available in Western Australia, and to Mr. L. J. Newman, Government Entomologist, W.A., for the loan of specimens.

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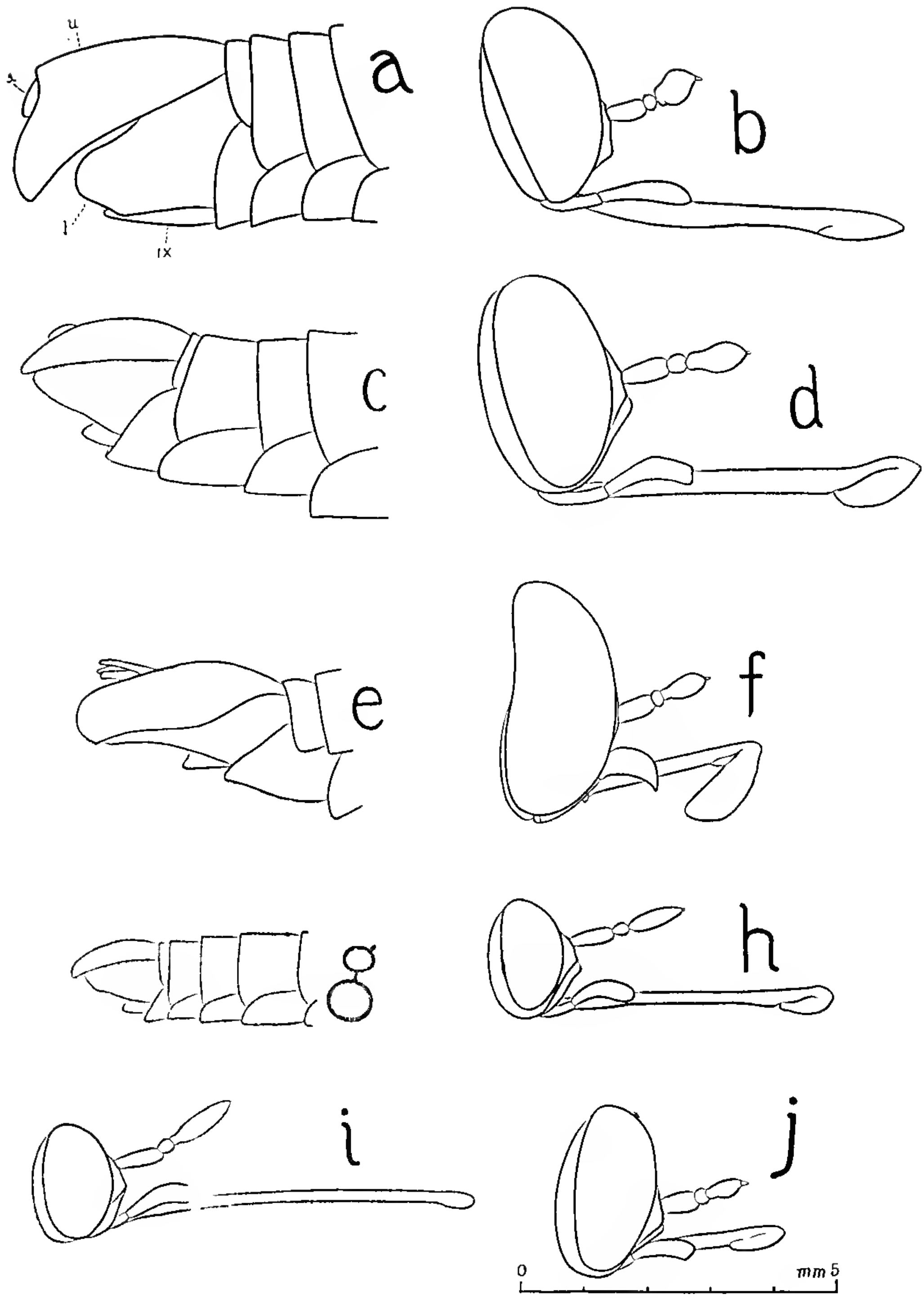

PLATE I.

a. *Apiocera deforma* sp. nov., Terminalia of male.
b. *Apiocera deforma* sp. nov., Head.
c. *Apiocera pica* sp. nov., Terminalia of male.
d. *Apiocera pica* sp. nov., Head.
e. *Apiocera tonnoiri* sp. nov., Terminalia of male.
f. *Apiocera tonnoiri* sp. nov., Head.
g. *Apiocera minor* sp. nov., Terminalia of male.
h. *Apiocera minor* sp. nov., Head.
i. *Apiocera newmani* sp. nov., Head.
j. *Apiocera pallida* sp. nov., Head.

(u—upper forceps, a—anal papilla, l—lower forceps, IX—ninth sternite.)

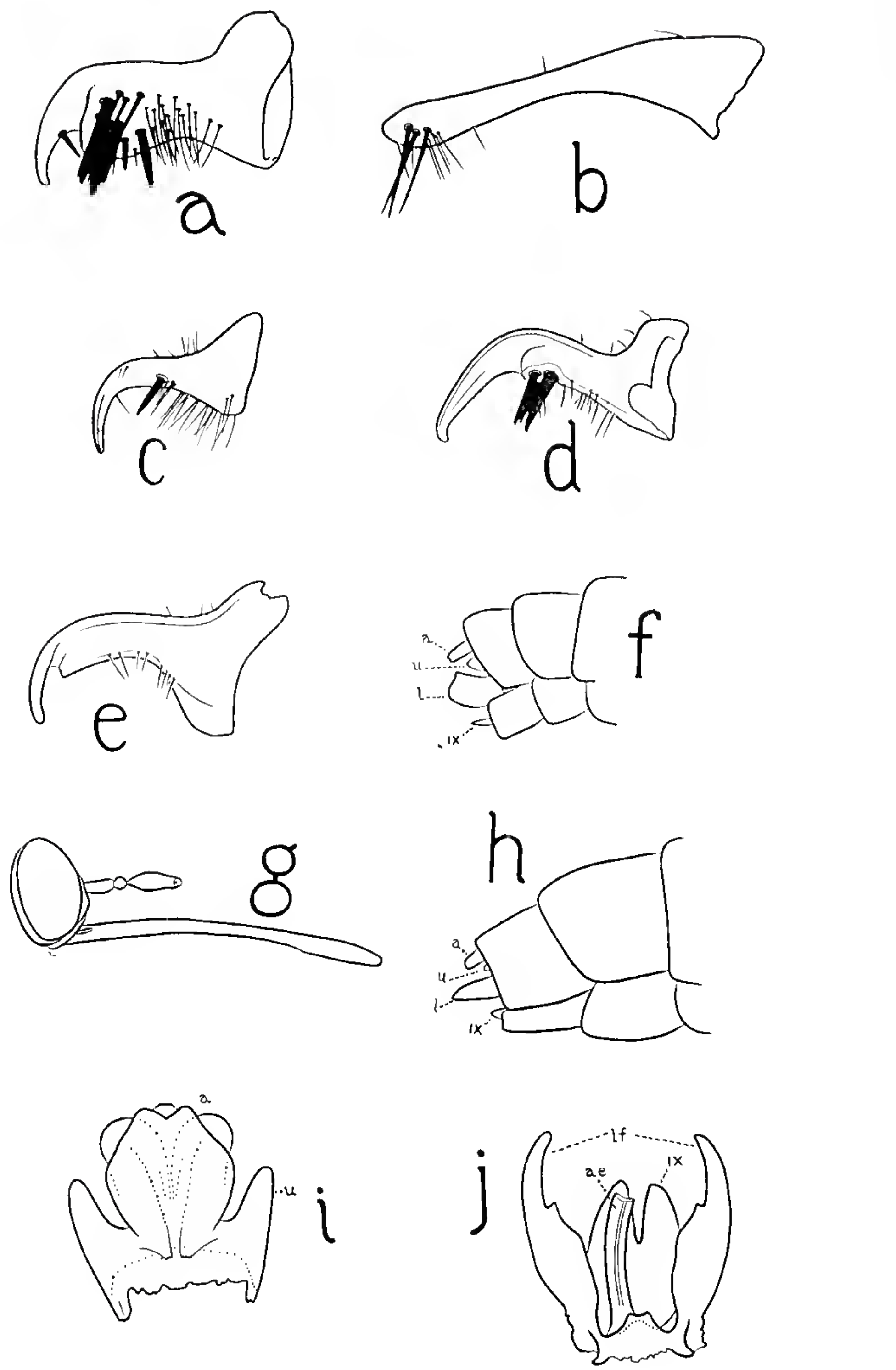

PLATE II.

(Figure g to same scale as preceding plate; Figs. i, j, and a–e, 5 times this magnification; Figs. f and h, $2\frac{1}{2}$ times.)

a. *Apiocera pica* sp. nov., Clasper.
b. *Apiocera tonnoiri* sp. nov., Clasper.
c. *Apiocera pallida* sp. nov., Clasper.
d. *Apiocera minor* sp. nov., Clasper.
e. *Apiocera newmani* sp. nov., Clasper.
f. *Neorhaphiomidas pinguis* gen. nov., sp. nov., Male terminalia.
g. *Neorhaphiomidas hardyi* gen. nov., sp. nov., Head.
h. *N. hardyi* sp. nov., Male terminalia.
i. *N. hardyi* sp. nov., Anal papilla and upper forceps dissected out.
j. *N. hardyi* sp. nov., Lower forceps, aedeagus and ninth sternite dissected out.

(a—anal papilla; ae—aedeagus; l, lf—lower forceps; u—upper forceps; ix—ninth sternite.)

6.—A SOIL SURVEY OF AN AREA AT GINGIN, WESTERN AUSTRALIA,[1]

By

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and

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CONTENTS.

(1) A soil survey of the country in the neighbourhood of Gingin in the district of Swan in Western Australia was undertaken by the Division of Soils of the Council for Scientific and Industrial Research, centred at the Waite Institute of the University of Adelaide, in collaboration with the Department of Agriculture of Western Australia. The field work was carried out by the authors conjointly, assisted by L. C. Lightfoot. The laboratory work, with the exception of portion of the mechanical analyses, which were carried out by H. R. Skewes and G. Parker, was performed by J. S. Hosking.

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I.—SUMMARY.

A soil survey of an area associated with the Cretaceous rocks in the neighbourhood of Gingin in the District of Swan in Western Australia has been made and eleven major soil types recognised and described. The soils fall into five groups:—

1. The Gingin Clay—a rendzina formed on the Gingin chalks. Associated with this are the Ballingah sandy loam, formed on green sand, and the Mt. Pleasant sand.
2. The Whakea sand and related types formed on the ferruginous sandstones above and below the chalk.
3. The Cheriton gravelly sand associated with an occurrence of laterite.
4. The Muchea sand of the coastal plain.
5. Other soils, including the Minjil sand, undifferentiated alluvial soils, etc.

Chemical and mechanical analyses of soil samples representative of the types have been carried out and the results fully discussed.

The agricultural development of the area has been along lines of stock raising. A problem of live-stock associated with the area, enzootic ataxia, has also been discussed.

II.—GENERAL DESCRIPTION OF THE AREA.

(1)—*Location and area surveyed.*

Gingin (31° 21′ south latitude 115° 54′ east longitude) is a small township about 50 miles north of Perth on the Midland Company's railway line to Geraldton. It is situated on the banks of the Gingin Brook where it emerges from the Darling Plateau on to the Coastal Plain. The area surveyed comprises about 15,500 acres. It extends about four miles to the north, one mile and a half to the south and about two and a half miles on either side of the township. In addition, a reconnaissance was made of the coastal plain country to the west, where a series of soil samples was collected for examination and comparison with those of the main area.

(2)—*Settlement and Present State of Development.*

Gingin is an old established pastoral district renowned for the fattening of sheep and cattle, for which purpose it is most largely used. Difficulties, however, have been experienced in the breeding of stock. The progeny of sheep, mares and cows continuously depastured on this country, become affected with what is popularly known as "rickets." The manifestations vary with the animals affected. The condition developed by lambs has no relation to the disease rickets or rachitis, and has been designated "enzootic ataxia" by Bennetts (1932, 1933, 1935). It is characterised clinically by unthriftiness and anaemia, and pathologically by a degeneration of the nervous tissue. There is also a characteristic inco-ordination of gait. In foals and calves the disease develops quite differently, and has some resemblance to true rickets. It has not yet, however, been studied in detail.

Enzootic ataxia was almost unknown when the country was in its virgin state. It commenced to be a serious economic factor about twenty years ago, and the incidence progressively increased following development and pasture improvement, so much so that at the present time breeding is generally carried out from ewes which are brought from outside sound areas each year. If the ewes are retained for more than one year they are given a change on to sound country for about eight weeks during gestation. Under these conditions the lambs are generally quite healthy. In some cases the incidence of the disease in the progeny of ewes, which have been retained for more than one season on the affected country without change, approaches 100 per cent.

Thoroughbred horses were formerly bred at Gingin, but the increasing occurrence of rickets in foals led to the almost complete abandonment of this pursuit some years ago. The situation has recently been altered as a result of a treatment based on the lead hypothesis, and it is now possible to prevent and cure the disease in foals by the administration of ammonium chloride. Thoroughbred horses are now being bred successfully at Gingin. (Bennetts (1935a) and private communication.)

Calves are also affected by the disease, but trouble can be avoided by giving the cows a change of country or by shifting the young stock when they become affected. Diseased foals and calves immediately improve if moved on to sound country, and the progress of ataxia in a flock is definitely arrested almost immediately if the ewes and lambs are changed to sound country. Lambs which are definitely ataxic, however, very rarely recover completely, although the progress of the disease towards the fatal result may be arrested.

The disease also occurs at Dandarragan and Yatheroo, about 50 miles further north of Gingin, and an important feature common to both areas is the occurrence of rocks of the Cretaceous series which are lithologically similar. It seemed, therefore, that there might be some correlation of the disease with the soils formed from these rocks, and it was with this end in view that the soil survey was made.

The principal crops grown at Gingin are rye, oats, and lupins on the drier soils, and summer fodders on the highly productive alluvial flats. Orange growing, for which Gingin was at one time famous, has, for various economic reasons, practically ceased as an important industry.

(3)—*Climatic Features.*

Complete climatic data for either Gingin or Dandarragan are not available, but rainfall observations have been kept for over 40 years, and show an average annual precipitation of about 30 inches. The figures indicate a distinct seasonal fall, approximately 90 per cent. of the annual precipitation falling in the period May to October. The November-April rainfall period is very dry, averaging only half an inch per month. Rainfall figures for a station on the coastal plain country are also available, although for a much shorter period, and show the same character in the seasonal incidence. The rainfall per wet day is remarkably constant throughout the areas under review, being 0.32 inch at all the stations considered. No temperature records are available for this district. However, the figures for Guildford, some 40 miles to the south, illustrate that the hottest periods coincide with those of least precipitation, and that frosts occur occasionally during the winter and early spring. Rainfall data for Gingin and other centres in the district, together with temperature records for Guildford, are given in Table 1.

Table 1.

TABLE 1a—RAINFALL DATA.

Station.	Years of Records.	Rainfall.																Rain per Rain Day.
		Mean Monthly.												Annual.				
		Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.	Max.*	Min.†	Number of Days.	
Gingin ...	1889–1925	0·28	0·46	0·61	1·03	4·40	6·22	6·13	5·01	3·20	2·34	0·53	0·49	30·70	44·04	12·06	96	0·32
Dandarragan	1897–1925	0·30	0·49	0·59	1·04	3·82	5·43	5·40	4·08	3·14	1·96	0·44	0·45	27·14	52·42	10·33	86	0·32
Yatheroo ...	1885–1929	0·17	0·33	0·64	0·93	3·38	5·13	4·91	4·01	2·91	1·75	0·53	0·38	25·07	39·23	12·12	81	0·31
Beermullah	1917–1925	...	...	...	...	...	...	...	...	...	...	...	...	27·53	38·38	...	86	0·32

* 1917 † 1914 (year of drought).

TABLE 1b—TEMPERATURE DATA FOR GUILDFORD, 1900–1931.

Month.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean Maximum	88·7	88·9	85·5	79·7	79·6	65·3	63·7	65·7	68·6	72·0	79·6	85·4	76·1
Mean Minimum	61·8	61·9	59·5	55·3	50·1	47·0	45·1	46·1	48·3	50·7	55·2	59·2	53·3
Highest Recorded	109·9	113·0	110·0	103·2	92·6	84·0	78·1	81·6	93·0	99·0	108·8	109·6	113·0
Lowest Recorded	43·0	42·0	42·1	36·5	29·2	30·0	29·8	30·2	35·0	35·0	39·3	42·0	29·2

(4)—*Physiography and Geology.*

(a)—*Physiography.*

The Gingin area consists physiographically of four major features:—

1. The plateau country and its outliers ranging from about 500 to 700 feet above sea level.
2. The plateau slopes and escarpments.
3. The Gingin Brook valley and the valley of Moonda and Wowra Brooks. These formations range in elevation from 300 to 400 feet.
4. The coastal plain country which ranges from about 250 to 300 feet above sea level in the area surveyed.

The present topography is the result of erosion by the Gingin Brook which flows right through the area and which has been assisted in its work of land sculpture by numerous small tributaries. The present state of the land is that of a much dissected plateau the topography of which still presents a very juvenile aspect. The Gingin Brook rises in the north-eastern part of the area and flows in a south-westerly direction through a steep-sided broad valley which has been cut through the ferruginous sandstones and chalky limestone of the Cretaceous series. North-east of Gingin townsite the course of the brook is temporarily diverted to the east by a large mass of harder lateritic rock, round which it flows forming a bow, and afterwards turning again to the west. As it approaches the lower coastal plain country the valley assumes a more mature aspect and the stream meanders through a broad swampy course to the south-east of Gingin townsite.

The tributaries of the Brook and other small streams of the area are frequently fed by springs rising at the contacts of strata on the hillsides. Generally they form shallow immature valleys, but in some places very deep miniature canyons have been cut through layers of soft friable rock material. This frequently occurs in soft glauconitic sandstone and also in the chalky limestone. In the former, deep cuts about six feet wide at the top and about 20 feet deep have been formed in several places. On the higher slopes between Poison Hill and Ginginup Hill a number of streams rise and flow to the west across the lower country to the coastal plain. The Moonda and Wowra Brooks, which join the Gingin Brook at the extremity of its bow, rise in the higher country to the east, and as they approach the main stream, widen out into a broad fertile alluvial flat which is covered with a thick sward of couch grass (*Cynodon dactylon*) and rushes.

The highlands of the area are all residuals of erosion of the former plateau. The most extensive is that north of Ginginup Hill, including Poison Hill which is over 800 feet above sea level. The western escarpment of this area of highland is well marked and is generally very steep, but below it lies a very gently sloping area which extends for some distance before it reaches the coastal plain country. To the east the plateau slopes steadily down into the valley of the Gingin Brook. One Tree Hill must be considered as an outlier of this same area of highland. The other highlands are those east of the Brook and the Molecap-Moorgup ridge to the south. These are separated by the Moonda-Wowra valley. The area within the bow of the Gingin Brook is of a different nature. It is a mass of harder material which persists as a hill on account of its greater resistance to erosion than the surrounding rock series.

In the south-western part of the area, the coastal plain country meets the Gingin formation and presents little of physiographic interest.

(b)—*Geology.*

Except for the south-western corner of the area under review, where the deep Muchea sand (see page 92) occurs overlying rocks of more recent origin, the outcropping rocks at Gingin consist of Cretaceous sediments. These sediments which were first recorded by F. T. Gregory (1861) occur or extend in a continuous band some 15 miles wide in a north-westerly direction, from a few miles south of Gingin through Yatheroo and Dandarragan to Jurien Bay, for a distance of over 100 miles. The same series is believed to extend beneath the more recent sediments of the Swan Coastal Plain many miles to the south, and have been encountered in deep borings in the neighbourhood of Perth (Gibb-Maitland, 1919, page 44). The Gingin sediments have been assigned to the lower part of the upper Cretaceous. The highly fossiliferous chalk contains certain characteristic crinoids and ammonites by which the series has been correlated with the lower Santonian (middle Senonian) of the English and European Cretaceous (Gibb-Maitland, 1919, page 46). Further discussion of the geology of the area has recently been published by Forman (1930).

The sediments at Gingin, consisting of upper and lower ferruginous sandstones with an intervening chalk horizon and basal sandstones and shales, are exposed over an area from the west of Poison Hill in the north to a little south of Moorgup Hill. They occupy the valley of the Gingin Brook, and to the east they disappear about three miles from the township. The granite and gneiss of the Darling Plateau lie about eight miles east of Gingin, and the intermediate country consists of a sandy plateau.

The junction of the Gingin sediments with those of the coastal plain is marked by the boundary of the Muchea sand and other soils of the coastal type which bear in a north-westerly direction above Gingin. The coastal plain generally is superficially composed of recent sands and swampy soils with Tertiary limestone patches, and extends to within eight or 10 miles of the coast, where it gives place to the coastal hills of limestone and calcareous wind blown sands.

The uppermost member of the Cretaceous series is a dense ferruginous sandstone or ironstone with a lateritic covering, which, having withstood the agencies of weathering and disintegration, is exposed above a level of 600 to 650 feet. It forms the surface of the table land in the central northern portion of the area, and presents a bold face to the west along the Poison Hill scarp. Further extensions occur to the east above Whakea homestead, and on the south-east in the form of a ridge running in a direction slightly north of east from Moorgup Hill. The soil associated with this series is a deep red sand which has been described as the Whakea sand (see page 82).

These sandstones pass downward into the upper greensands consisting of glauconitic clays, shales and sandstones which vary in colour from cream to very deep green. The colour is due to an abundance of the minerals Glauconite, a hydrated silicate of iron and potassium, and to a lesser degree to Dufrenite, a green phosphate of iron. Exposures of these beds are seen on the steep slopes to the south of Poison Hill and Moorgup where landslides have uncovered them, and in two very deep gullies in the upper part of the Gingin Brook Valley.

The surface exposure of the greensands is marked by a covering of deep red to brown very sandy soils which at the surface appear to be continuous with the Whakea sand. They are, however, characterised by a clay subsoil.

The next and most important member of the series is the Gingin Chalk which forms a very useful stratigraphic horizon. Its occurrence is always indicated by the rich black rendzina soil studded with limestone fragments and formed by weathering and disintegration, in situ, of the chalk and accumulation of organic matter. This soil has been designated the Gingin Clay (see page 80), and the areas of it on the soil map show the extent of the chalk exposures.

It was expected that the chalk would be found in a continuous band, outcropping along the length of the escarpment and slopes of the tableland from Poison Hill to Moorgup. This, however, is not the case. When the beds outcrop on a hillside, debris from the overlying greensands and ferruginous sandstones tend to obliterate the upper boundary of the chalk. Landslides have been quite frequent on the steeper slopes of the plateau, and where they have occurred the surface indications of the chalk are frequently obliterated.

Some distance south of Poison Hill, a recent and somewhat extensive landslide has exposed a wall of greensand and in a creek below, under 20 feet or more of a mixture of red soil, glauconitic clay and sandstone, a black clay profile two feet deep overlying chalk can be seen. Below Moorgup Hill, on the southern side, there is evidence of a chalk outcrop, but another landslide has obliterated the outcrop completely. Even bearing this effect in mind, a study of the contour and soils of the slopes makes it apparent that the chalk is by no means continuous at the surface.

The largest exposure of the Gingin Chalk occurs in a fairly wide band along the intermediate levels of the western escarpment. Its greatest width is over half a mile, but it tails out at Poison Hill in the north and to the south, ends in a tongue-shaped exposure about a quarter of a mile wide south-west of Ginginup Hill. It occurs again on the Ginginup escarpment, at Mt. Pleasant, and as small patches on the hillsides in the eastern portion of the area. Outliers occur at One Tree Hill, Molecap Hill, and on Cheriton to the east of the Gingin Brook.

From the contour data obtained during the course of the survey the thickness of the chalk horizon appears to vary over the area. It is about 25 feet at Poison Hill and 50 feet or more to the south of this. On the top of One Tree Hill there is about 15 feet of chalky limestone overlying greenish glauconite clay. At Molecap the limestone cap is about 12 feet thick, and passes down into a layer of phosphatic nodules about 6-12 feet thick.

Below the chalky limestone with its associated glauconitic sandstones or phosphatic beds, where these occur, is a second horizon of ferruginous sandstones and grits very similar in all respects to that above the chalk. The actual rock material of the lower ferruginous sandstones is rarely exposed, being covered with a deep red sandy soil. It was impossible to delineate the boundary between the upper and lower ferruginous sandstones where the chalk is absent, as the soils formed from each appear to be practically identical.

The central southern portion of the area, covered by the Cheriton gravelly sand (see page 88), is underlain by a dense and massive lateritic formation, which in many places outcrops at the surface.

The main soil types show a good correlation with the stratigraphic horizons, and each geological formation is always associated with its characteristic soil at the surface. The minor soil types have been formed principally by the action of water which has been responsible, in many cases, for leaching of the major soil types, and for the occurrence of swampy and alluvial patches.

Gingin and Dandarragan are two of the few districts in Australia which are abundantly supplied by nature with potash and phosphates, both in the rocks themselves and in certain of the soils. The following minerals are responsible for the unusually high content of potash and phosphate in the soils at Gingin, and their influence is shown by the analyses given later in this paper.

Glauconite (hydrated silicate of iron and potash).
Apatite $Ca_5F(PO_4)_3$.
Dufrenite, $Fe'''_2(OH)_3PO_4$.
Calcite, $CaCO_3$.

A comprehensive account of the mineralogy of the district is given by Simpson (1933).

III.—DESCRIPTION AND CLASSIFICATION OF THE SOILS.

A study of the soil profiles of the area has led to the recognition of 11 distinct types in the field. In addition to these there is a group of poorly drained soils generally swampy in character, which owing to their restricted occurrence and heterogeneous nature do not justify differentiation at the present juncture. Five types are characteristically associated with definite geological strata from which they have been formed in situ while two other equally important types have been produced from one of these as a result of leaching. In general the characteristic profiles of the more extensively developed types are deep.

The broad characteristics of these soil types are summarised in Table 2.

Table 2.

Summary of Soil Types.

Soil Type.	Area.		Profile.	Topography.	Remarks.
	Acres.	%			
Gingin clay ...	570	3·6	Black sandy clay to heavy clay of very variable depth, over black sandy clay to heavy clay containing calcium carbonate and chalk fragments throughout the profile, on chalky limestone. Profile rich in organic matter.	Upper slopes of the escarpment and summits of chalk outliers	Soil of very variable depth. Deep profiles associated with extensive chalk outcrops along the escarpment, and shallow soils with the outliers. Chalk fragments increase in size and abundance with depth.
Whakea sand	6,318	40·1	Deep profile: grey red to grey-red brown coarse sand with little organic matter 0–15in., over red to red-brown coarse sand 15in.–84in.: fine gravel and occasionally stone throughout the profile.	Plateau, and plateau slopes	Soil associated with ferruginous sandstones and grits. Soil cover varies with the depth of the outcropping rock from more than 20ft. to a mere surface cover. Stone, where present, increases with depth.
Koorian sand	1,641	10·4	Grey to grey-yellow or orange coarse sand with very little organic matter 0–12in., over a yellow to orange coarse sand 12in.–84in.	Plateau slopes	Produced from Whakea Sand by a process of mild leaching.
Wowra sand ..	1,018	6·4	Grey to grey-brown very coarse sand, almost devoid of organic matter, 0–18in., over white very coarse sand 18in.–84in.	Plateau slopes and valleys of tributary creeks.	End product in leaching of sand of the Whakea type.

Table 2—*continued.*

SUMMARY OF SOIL TYPES—*continued.*

Soil Type.	Area.		Profile.	Topography.	Remarks.
	Acres.	%			
Moorgup gravelly sand	90	0·6	Dark grey to black fine gravelly coarse sand with very little organic matter 0–15in., over dark grey fine gravelly coarse sand 15in.–30in., over an increasingly yellow or red more gravelly coarse sand.	Summit of plateau outliers	Soil associated with ferruginous sandstones and grits. Occasionally the deeper layers resemble more a fine gravelly deposit than a true soil.
Cheriton gravelly sand	1,535	9·7	Deep profile. Grey, gritty, coarse sand with a little organic matter 0–6in., over cream to yellow coarse sand containing pebbles 6–40in., over coarse sand, becoming lighter in colour, but richer in pebbles, over, massive "lateritic" deposit.	Moderately flat or slightly rolling	Soil cover varies from a deep sand, to a mere surface cover where the "lateritic" or sandstone beds outcrop at the surface.
Minjil sand ...	753	4·8	Grey-yellow to grey-brown, coarse sand with organic matter 0–12in., over yellow to brown sand 12in.–36in., with heavy gravel layer 27in.–36in., over yellow to brown, red mottled, sandy clay 36in.–84in. Gravel decreasing with depth.	Moderately flat or slightly rolling.	Although the gravel is concentrated in a definite band, it occurs both above and below this level.
Mt. Pleasant sand	201	1·3	Grey-red to brown, coarse sand with little organic 0–9in., over red to brown sand 9in.–18in., over a variable depth of vari-coloured and mottled heavy clay. $CaCO_3$ present in deeper clay layers.	Slopes of plateau or outliers immediately below the chalk	Associated with the lower boundary of the Gingin clay and Whakea sand normal phase.
Ballingah sandy loam	152	1·0	Black to grey-brown, coarse (occasionally gravelly) sand, with a little organic matter 0–12in., over grey to red-brown coarse sandy loam 12in.-48in., over vari-coloured sandy clay loam to sandy clay, over decomposing glauconitic rock. Distinct green shade throughout the profile.	Plateau slopes.	Soil associated with glauconitic clay, shale or sandstone outcrop.
Unnamed sand	25	0·2	Grey-brown sand 0–12in., over a brown mottled sandy clay 12in.–20in., over greyish-brown, green, mottled clay 20in.–42in.	Flat.	Along the upper boundary of the type, stone is encountered throughout the profile.
Muchea sand	1,736	11·0	Dark grey to grey coarse sand practically devoid of organic matter 0–12in., over a pure white coarse sand 12in.–60in., over white sand streaked with iron staining. Water table at about 72in.	Flat coastal plain.	At Gingin, owing to the higher level of the country, the water table never encountered; white sand persists to 84in.
Undifferentiated alluvial and other poorly-drained soils	1,725	10·9	Profile at the fertile Moonda-Wowra Brook flat. Grey organic loam 0–4in., over grey to grey-white sand 4in.–27in., over deep white coarse sand 24in.	Bottomland.	Soils associated with the alluvial flats of the various watercourses and poorly drained areas.

(1)—*Gingin Clay.*

The distinctive heavy black *rendzina* soil associated with the chalk, from which it has been formed *in situ*, has been called the Gingin clay, owing to its characteristic confinement to the chalk horizon of the Gingin Cretaceous series and its heavy texture.

The Gingin clay varies in depth from a few inches to several feet, the shallow profiles from 6 to 18 inches being more generally associated with the chalk outliers and the deep ones with the more extensive outcrops along the escarpment. In the winter the soil is usually somewhat sticky but during the summer, it contracts and extensive fissuring occurs, giving to the soil a distinctly columnar structure. In the deeper soils, cracks about three inches wide and several feet deep are common. The surface has a granular structure when dry and breaks up into fragments of pea size or smaller.

Chalk fragments, varying in size from the finest disintegrated rubble to large unaltered boulders, occur not only throughout the profile but also scattered over the surface of the ground. In the deeper profiles, lime is almost, if not entirely, absent from the surface layers but makes its appearance further down, and the fragments then increase in size and abundance with depth till they merge imperceptibly into the dense unaltered limestone. In the shallow phases where the chalk is never more than 18 inches below the surface, the profile is rich in calcium carbonate throughout. At One Tree Hill the soil varies from 12 to 18 inches in depth, and except for an increasing amount of limestone rubble from the surface downward, there is little differentiation in the profile. The calcium carbonate content is high throughout, amounting to 27 per cent. in the sample taken from this locality. On Molecap Hill the unaltered chalk occurs at a depth of 15 inches and the soil is extremely rich in calcium carbonate, one profile containing 46 per cent. in the first six inches and over 60 per cent. below Shallow profiles also occur along the escarpment where the calcium carbonate is rarely present in the surface layer to the extent of more than about 2 per cent., although it rises to over 30 per cent. below 8 inches. In the field, the Gingin Clay is generally quite black in colour, but occasionally it has a greyish appearance due to admixture with white chalk fragments. In preparing the samples for analysis many of the soft chalk fragments are unavoidably crushed and pass through the 2 mm. sieve causing an unduly high $CaCO_3$ content in the fine earth.

At the surface the Gingin Clay varies in texture from a sandy clay loam at One Tree Hill to a heavy clay in the vicinity of Cleveland. Below the surface horizon the clay content increases only slightly in the shallow phases, but in the deeper profiles heavy clays generally occur in the subsoil. The proportion of silt is low, rarely rising above 5 per cent., whereas the sand is generally somewhat high considering the nature of the soil. Coarse sand predominates in the profiles associated with the escarpment and fine sand in those on the outliers. This soil type is characterised also by the high proportion of organic matter, varying from 4 to over 13 per cent. in the surface with smaller amounts in the subsoil.

The Gingin Clay, owing to its topographical situation, is particularly well drained. In the virgin state, excepting for occasional tea-tree (*Melaleuca Huegelii*) and mannagum (*Acacia microbotrya*) it was practically treeless and carried a rich natural pasture consisting principally of Yatheroo Oat (*Avena barbata*).

The mechanical analyses and chemical data are given in Table 3.

Table 3.—MECHANICAL ANALYSES AND CHEMICAL DATA OF GINGIN CLAY AND MT. PLEASANT SAND.

Soil type	Gingin Clay.								Mt. Pleasant Sand.		
Variation	Shallow.						Deep.				
Sample number	2996	2997	3001	3003	3004	3006	2999	3000	3545	3546–8	3549
Depth in inches	0–8	8–15	0–12	0–6	6–15	0–6	0–12	12–24	0–9	9·52	52–60
Horizon	A	BC	AB	AB	BC	A	A	B	A	B	BC
	%	%	%	%	%	%	%	%	%	%	%
Chalk	...	28	31	14	25	1	...	...	...	...	12*
Fine gravel, 3 mm.—2 mm.	...	...	...	...	...	...	1	1	1	1	10
Coarse sand, 2·0 mm.—1·0 mm.	1·9	1·8	0·3	0·3	...	1·7	2·1	1·5	3·5	1·3	0·3
1·0 mm.—0·5 mm.	12·9	9·8	3·2	1·7	1·1	4·2	4·6	3·8	18·1	7·4	1·2
0·5 mm.—0·2 mm.	16·8	11·1	12·5	4·4	2·9	7·6	17·1	13·8	20·3	8·2	2·7
Total	31·6	22·7	16·0	6·4	4·0	13·5	23·8	19·1	41·9	16·9	4·2
Fine sand	16·5	12·1	25·1	13·3	9·7	15·9	25·0	21·3	38·1	15·2	21·1
Silt	5·6	2·8	2·6	4·0	2·6	7·4	5·4	3·3	4·9	4·6	10·7
Clay	24·4	18·6	15·8	17·3	12·9	43·8	32·0	43·8	11·7	55·6	48·1
Loss on acid treatment	5·0	35·0	31·5	51·8	66·0	10·7	4·4	5·1	0·6	1·4	12·0
Moisture	6·3	4·7	4·2	4·8	3·7	7·1	5·8	7·1	1·9	8·7	6·0
Calcium Carbonate $CaCO_3$	0·5	30·8	27·1	46·7	62·2	2·6	0·1	0·3	...	...	11·3
Phosphoric acid P_2O_5	0·38	0·40	0·21	0·57	0·47	2·24	1·49	1·51	0·06	0·08	0·06
Potash K_2O	0·78	0·62	0·34	0·45	0·36	1·84	3·15	3·29	0·57	1·83	0·69
Manganese Oxide Mn_3O_4	0·014	0·013	0·019	0·021	0·005	0·020	0·007	0·009	...	...	...
Nitrogen N	0·59	0·29	0·40	0·40	0·26	0·35	0·17	0·10	0·086	0·045	0·021
Organic Carbon C	7·79	4·46	4·63	5·21	3·54	4·26	2·43	1·28	...	...	...
Organic matter	13·4	7·7	8·0	9·0	6·1	7·3	4·2	2·2	...	...	...
Carbon/nitrogen ratio ... C/N	13·1	15·3	11·5	13·0	13·6	12·2	14·5	13·4	...	...	...
Soil reaction ... pH	6·7	7·7	7·9	7·9	8·1	7·7	6·3	7·3	5·5	7·1	8·5

* Stone.

(2)—*Whakea Sand.*

The Whakea sand which covers approximately 40 per cent. of the area surveyed is associated with both the upper and lower ferruginous sandstones and grits from which it is formed *in situ*. It occurs at all levels from the top of the plateau to the rolling downs country. It varies in depth from a mere surface cover on the plateau, where it is associated with outcropping rocks, to a very deep sandy soil estimated at over 20 feet in some places. Fine siliceous gravel is characteristic of the soil as a whole, but whereas the deeper profiles are quite free from stone to a depth of several feet in the shallower varieties ferruginous pebbles are common and increase in size and abundance with depth, gradually merging into the undecomposed rock below.

The soil varies in colour from a bright red to a red-brown or brown. In he virgin state, the surface, to a depth of from 9 to 15 inches, is tinged grey with the small amount of organic matter that is present, but in those areas where the soil has been under cultivation for many years, particularly under lupins, it has a distinct dark chocolate to almost black colour. It was impossible on the scale employed to separate the soils formed from the upper or lower sandstones, although the browner shade was noticed as more characteristic of the soils formed from the latter strata.

The texture of the soil is that of a definitely coarse sand, generally altering only lightly with depth, and although borings were made to over 7 feet, only in a few instances was a sandy clay loam subsoil reached. The high sand content is very characteristic and the ratio of coarse to fine sand averages about 6:1, though frequently it is much wider.

The total sand content of the profile varies between 84 and 96 per cent., with the fine sand tending to increase with depth. In the one subsoil showing clay accumulation the proportion of sand is still above 60 per cent. The silt fraction is remarkably constant at about 4 per cent., and the clay content rarely exceeds about 10 per cent. even in the deeper sand layers. Mechanical analyses and chemical data relating to this soil are given in Tables 4 and 5.

A heavier textured phase of this type is associated with certain outcrops of ferrnginous grits on slopes immediately below the plateau level. These patches are recognised as of high productivity particularly of oats and Gingin clovers (*Trifolium cernuum* and *T. glomerata*), and are known locally as Warine soils owing to the natural occurrence of a native Yam (*Dioscorea hastifolia*) of that name which was used by the natives as a food.

Owing to the elevation and very sandy nature of the Whakea sand, the drainage is particularly good, especially on the steeper slopes. This soil has been cleared almost entirely, the only timber remaining being scattered marri (*Eucalyptus calophylla*). Isolated patches of regrowth, however, show parrot bush (*Dryandra floribunda*), various banksias including *Banksia Menziesii*, and *B. attenuata* and a blackboy (*Xanthorrhoea gracillis*).

Table 4.—Mechanical Analyses and Chemical Data of Whakea Sand.

Soil Type.	Whakea Sand.											
Sample Number	3025	3026	3027	3010	3011	3012	3007	3008	3009	3022	3023	3024
Depth in inches	0–15	15–60	60–80	0–15	15–60	60–80	0–15	15–60	60–80	0–15	15–60	60–80
Horizon	A_1	A_2		A_1	A_2		A_1	A_2		A_1	A_2	
	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	...	...	...	...	...	...	...	...	...	...
Fine gravel, 3 mm.—2 mm.	2	3	6	...	1	2	1	1	1	1	1	3
Coarse sand 2·0 mm.—1·0 mm.	23·1	24·3	19·5	25·2	20·0	17·6	9·7	9·2	10·3	8·5	9·0	9·7
1·0 mm.—0·5 mm.	47·1	38·3	32·6	54·9	48·9	45·4	27·1	27·1	19·5	12·2	17·9	14·2
0·5 mm.—0·2 mm.	17·9	23·2	25·6	4·8	9·9	12·2	29·1	28·1	32·0	40·6	29·7	27·2
Total	88·1	85·8	77·7	84·9	78·8	75·2	65·9	64·4	61·8	61·3	56·6	51·1
Fine sand	7·5	10·7	17·5	6·5	10·1	12·4	18·3	19·7	22·8	24·6	29·3	34·8
Silt	1·6	1·5	2·7	3·1	4·3	3·8	4·7	5·2	4·8	5·2	5·8	5·0
Clay	1·7	1·8	2·0	4·3	6·2	8·4	8·7	9·7	9·9	8·0	8·2	9·0
Loss on acid treatment	0·3	0·1	0·2	0·3	0·2	0·3	0·2	0·1	0·1	0·2	0·2	0·2
Moisture	0·2	0·2	0·2	0·4	0·4	0·5	0·9	0·9	0·8	0·6	0·6	0·6
Phosphoric acid ... P_2O_5	0·049	0·051	0·051	0·042	0·041	0·041	0·061	0·050	0·041	0·025	0·023	0·022
Potash ... K_2O	0·031	0·037	0·045	0·025	0·036	0·039	0·054	0·044	0·039	0·027	0·028	0·033
Manganese Oxide ... Mn_3O_4	...	...	...	0·001	0·002	0·001	0·001	0·001	0·002	...	...	...
Nitrogen ... N	0·035	0·009	0·006	0·027	0·011	0·009	0·078	0·023	0·013	0·019	0·010	0·009
Organic carbon ... C	0·63	...	...	0·55	...	...	1·28	0·49	0·210	...	...	...
Carbon/nitrogen ratio ... C/N	18·0	...	...	20·2	...	...	16·4	21·3	16·1	...	...	...
Soil reaction ... pH	6·0	6·1	6·3	6·4	6·4	6·5	6·4	6·5	6·5	6·3	6·3	6·3

TABLE 5.—MECHANICAL ANALYSES AND CHEMICAL DATA OF THE WHAKEA SAND AND KOORIAN SAND.

Soil type	Whakea Sand.							Koorian Sand.					
Variation	Normal.							Yellow coloured.				Orange coloured.	
Sample Number	3013	3014	3015	3017	3018	3019	3020	3032	3033–4	3037	3038	3035	3036
Depth in inches	0–15	15–54	54–66	0–12	12–42	42–60	60–80	0–12	12–80	0–6	6–42	0–12	12–80
Horizon	A_1	A_2		A_1	A_2	B		A_1	A_2	A_1	A_2	A_1	A_2
	%	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	2	...	...	2	7	...	...	...	...	...	...
Fine gravel 3 mm.—2 mm. ...	3	6	16	3	3	8	6	...	...	...	...	...	...
Coarse sand, 2·0 mm.—1·0 mm.	13·8	12·7	14·7	10·1	10·0	7·9	10·3	16·4	20·6	2·6	3·2	2·7	2·6
1·0 mm.—0·5 mm.	24·7	15·6	14·6	22·3	22·5	15·9	15·5	59·1	55·6	39·3	29·0	10·6	8·9
0·5 mm.—0·2 mm.	22·7	24·2	19·3	26·1	26·3	22·6	18·3	7·5	10·3	39·8	41·9	51·5	46·9
Total	61·2	52·5	48·6	58·6	58·8	46·4	44·1	83·0	86·5	81·7	74·1	64·8	58·4
Fine sand	23·0	30·4	33·2	22·4	20·5	21·7	19·6	8·2	5·8	12·5	18·8	26·2	32·8
Silt	3·5	3·8	5·0	4·4	3·0	3·3	6·2	3·4	1·5	1·2	1·3	1·8	1·6
Clay	9·1	11·8	12·4	12·1	16·0	26·2	27·0	4·1	6·0	3·6	5·2	5·0	6·4
Loss on acid treatment ...	0·5	0·2	0·1	0·2	0·1	0·0	0·2	0·4	0·1	0·2	0·1	0·3	0·2
Moisture	0·9	0·8	0·8	1·2	1·1	2·5	3·6	0·4	0·2	0·2	0·3	0·5	0·4
Phosphoric acid P_2O_5	0·085	0·068	0·059	0·069	0·067	0·067	0·107	0·010	0·009	0·004	0·002	0·019	0·016
Potash ... ... K_2O	0·059	0·069	0·065	0·154	0·160	0·237	0·313	0·020	0·027	0·022	0·025	0·034	0·031
Manganese oxide Mn_3O_4	0·002	0·001	0·003	0·003	...	...	...	...	...	...	...	...	...
Nitrogen ... N	0·070	0·026	0·019	0·055	0·029	0·029	0·024	0·044	0·009	0·019	0·010	0·038	0·011
Organic carbon C	1·31	0·49	0·44	0·98	...	...	...	1·04	0·20	0·47	...	0·81	...
Carbon/nitrogen ratio C/N	18·8	18·8	23·1	17·9	...	...	...	23·6	22·1	24·7	...	21·2	...
Soil reaction ... pH	6·2	6·3	6·4	5·9	6·0	5·9	6·0	5·9	6·2	5·9	6·2	6·1	6·5

(3)—*Koorian Sand.*

The Koorian sand is distributed throughout the district in moderately extensive patches and occupies about 10 per cent. of the total area. It appears to have been formed from the Whakea sand by a process of moderate leaching, but on the other hand, where it is found on the lower levels of the downs country, it may have originated from the less ferruginous lower members of the Cretaceous system. The boundary between the normal Whakea sand and this type is often quite indefinite, the change from the one to the other being gradual and indicated by an orange-coloured transitional soil. To the west of One Tree Hill and again in the north-west corner of the area, this orange-coloured variation of the Koorian sand occupies a large area, but has been included with this type, with which it shows more affinity. At the other extreme the Koorian sand merges into a phase of the highly leached Wowra sand.

The profile varies in colour from brownish yellow to yellow or orange, the surface layers having a somewhat greyer shade in the virgin state, due to organic matter. Where lupins have been cultivated on this soil the surface, like the Whakea sand, may be almost black in colour. In texture the profile is remarkably uniform throughout, and resembles the Whakea sand both in the coarseness of the sand and in the occasional occurrence of stone on the surface and throughout the profile. Fine gravel, however, is absent.

The total sand content amounts to over 90 per cent. in every case examined, but whereas in the yellow variety the coarse sand is always very high, in the orange variety examined it is some 20 per cent. lower. The clay content is generally somewhat lower than in the Whakea sand. Although the soil was sampled to over 84 inches, a heavy subsoil was never encountered. Mechanical analyses and chemical data relating to the type are given in Table 5.

In these well drained soils, marri (*E. calophylla*) are again dominant, excepting in the vicinity of the Wowra and Muchea sands, when the banksias (*B. prionotes* and *B. attenuata*) become more prominent. In the virgin state parrot bush (*Dryandra floribunda*), furze stinkwood (*Jacksonia furcellata*), other banksias (*B. Menziesii* and *B. grandis*), blackboys (*X. gracillis*, *X. spp.*), zamia palm (*Macrozamia Reidlei*), and blue billy (*Stirlingia latifolia*) are common.

(4)—*Wowra Sand.*

In the south-eastern corner of the area at a level of 400 to 600 feet, there is developed a very deep white coarse sand which has no doubt been formed by the extensive leaching of the sands of the Whakea type. Further occurrences much more restricted in extent are found throughout the district along the courses of short tributary creeks. Many of these areas are of only recent origin, being associated with springs which have developed since clearing, and are slowly extending into the surrounding Whakea or Koorian sands. In the neighbourhood of these springs on the alluvial flats, where poorer drainage conditions exist, the Wowra sand passes gradually into swampy soils.

The normal profile, which is extremely uniform in texture throughout, consists of a light grey or grey-brown to almost white, very coarse loose sand, from 12-18 in. deep, and practically devoid of organic matter, over pure white to pinkish very coarse sand to a depth of more than 7 feet. The coarse sand alone amounts to more than 90 per cent., of which over 80 per cent. has a grain size greater than 0.5 mm. As would be expected from the intense leaching these soils have undergone, not only the silt and clay fractions but also all plant nutrients are virtually absent.

This sand is of little value either agriculturally or pastorally. Analyses of two profiles are given in Table 6.

The vegetation consists of several banksias (*B. prionotes*) characteristic of deep sands, (*B. attenuata, B. grandis*), blackboys (*Xanthorrhoea gracilis, X. Preissii, X. reflexa*), Christmas bush (*Nuytsia floribunda*), zamia palm (*Macrozamia Reidlii*), parrot bush (*Dryandra floribunda*), furze stinkwood (*Jacksonia furcellata*), hakea (*Hakea prostrata*), with an occasional coastal blackbutt (*Eucalyptus Todtiana*) and marri (*E. calophylla*), with a ground cover of blue billy (*Stirlingia latifolia*), scrub tea-tree (*Melaleuca trichophylla*), *Calythrix angulata*. *Scholtzia umbellifera*, and various heaths. Grasses are almost, if not entirely, absent.

Where moister conditions prevail, tea-trees (*Melaleuca spp.*), black wattle (*Acacia cyanophylla*), together with bracken fern (*Pteridium aquilinum*), are more common.

Table 6.—Mechanical Analyses and Chemical Data of the Wowra Sand, Moorgup Gravelly Sand and Cheriton Gravelly Sand.

Soil type	Wowra Sand.				Moorgup Gravelly Sand.		Cheriton Gravelly Sand.					
Variation	—				—		Deep profile.					
Sample Number	3052	3053	3054	3055	3029	3030	3065	3066	3067	3069	3070–1	3072
Depth in inches	0–18	18–45	0–18	18–45	0–15	15–45	0–4	4–18	18–24	0–6	6–42	42–48
Horizon	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_2	A_1	A_2	A_2
	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	...	...	...	...	...	...	25	...	3	23
Fine gravel 3 mm.—2 mm.	...	...	...	...	5	7	...	3	3	2	2	4
Coarse sand 2·0 mm.—1·0 mm.	15·7	15·3	41·1	23·4	19·7	22·2	4·7	5·1	4·0	5·2	7·4	10·6
1·0 mm.—0·5 mm.	63·4	53·8	55·1	65·7	35·6	31·7	20·9	19·0	15·9	20·1	15·6	16·3
0·5 mm.—0·2 mm.	15·9	21·3	1·6	7·0	26·5	28·5	46·3	46·9	44·2	43·1	39·6	37·9
Total	95·0	90·4	97·8	96·1	81·8	82·4	71·9	71·0	64·1	69·4	62·6	64·8
Fine sand	3·7	8·5	1·3	3·2	10·1	11·9	22·8	24·7	31·0	25·0	33·4	32·0
Silt	0·3	0·7	0·3	0·6	2·1	1·7	1·3	1·5	1·6	1·4	1·4	1·4
Clay					2·9	2·9	1·7	2·1	2·8	2·2	2·0	1·4
Loss on acid treatment	0·0	0·0	0·0	0·0	0·5	0·3	0·3	0·1	0·1	0·3	0·1	0·1
Moisture	0·2	0·0	0·1	0·0	0·7	0·3	0·4	0·2	0·2	0·3	0·2	0·1
Phosphoric acid ... P_2O_5	Tr.	Tr.	0·002	Tr.	0·036	0·035	0·010	0·003	0·002	0·010	0·004	0·002
Potash ... K_2O	0·011	0·005	0·006	0·007	0·018	0·018	0·018	0·012	0·015	0·015	0·012	0·006
Nitrogen ... N	0·041	0·005	0·015	0·001	0·078	0·023	0·059	0·012	0·009	0·044	0·010	0·006
Organic carbon ... C	0·71	0·076	0·35	...	1·66	0·57	0·991	0·217	0·160	0·753	0·127	...
Carbon/nitrogen ratio ... C/N	17·2	15·2	18·3	...	21·3	24·9	16·8	18·1	15·6	17·1	12·7	...
Soil reaction ... pH	5·3	6·2	6·1	6·0	6·4	6·8	6·2	6·1	6·3	6·2	6·2	6·3

(5)—*Moorgup Gravelly Sand.*

Associated with the Whakea sand, there occurs, on the summits of the plateau outliers above the Whakea homestead and along the Moorgup ridge, a deep dry and loose coarse sand, rich in fine gravel, which has been named the Moorgup gravelly sand. The surface, although containing little organic matter, varies in colour from a dark grey to almost black. At about 12 to 15 inches the colour becomes lighter, and at 30 inches changes to a grey yellow or grey red, which colours become more marked with depth. Over 5 per cent. of fine gravel was found throughout the profile sampled and the sand content, principally coarse sand, constituted over 90 per cent. Below about 30 inches the soil often changes to a fine gravelly horizon. The mechanical analysis and chemical data of a profile of this type are given in Table 6.

The areas have been cleared but a few marri (*B. calophylla*) remain and banksias (*B. prionotes* and *B. grandis*) are common.

These soils, like the Wowra sand, are regarded as of low fertility for either farming or grazing purposes.

(6)—*Cheriton Gravelly Sand.*

The Cheriton gravelly sand occupies a moderately extensive and almost continuous belt, broken only by the alluvium of the Gingin Brook, in the central southern portion of the area, including the townsite. It consists of a very gritty sand of variable depth overlying a massive "lateritic" or ironstone gravel bed, which frequently outcrops at the surface and forms a layer, not penetrable with the ordinary borer or crowbar. The soil varies from a mere surface cover to several feet in depth, and contains throughout the profile pebbles which increase in abundance and merge into the gravel bed below. In the shallow soils the pebbles occur at the surface. Evidence from more complete profiles exposed in several cuttings suggests that the gravel bed rests on a yellow to brown sandy clay. Drainage appears particularly free, the soil generally being very loose and dry.

The deeper profiles show below the normal coarse sandy surface, coloured grey by organic matter, a white, cream to yellow coarse sand containing up to 25 per cent. of "lateritic" pebbles in its lower layers. The yellow colour of the subsurface reaches its maximum intensity at about 36 to 42 inches, thereafter becoming almost white again.

Two of the deeper profiles have been examined in detail. As with the other soils of the district, the proportion of sand is extremely high, amounting to over 90 per cent. throughout the profile examined, the ratio of coarse to fine sand being of the order of 3 : 1 in the surface and 2 : 1 in the subsurface horizon. Fine gravel, present in small amounts, has with the sand a characteristic gritty feel. Silt and clay are negligible.

Mechanical analyses and chemical data of these soils are given in Table 6.

Three vegetation associations were observed on this soil type:—

1. Where the soil is deep the vegetation consists of an almost pure forest of marri (*E. calophylla*).
3. As the soils become shallower, or as they approach the sands of the coastal plain, the marri are gradually replaced by banksias.
3. On the shallowest soils this association in turn becomes less prominent, and the trunkless blackboy (*Xanthorrhoea gracilis*) becomes dominant.

The natural vegetation of the second and third associations consists of various banksias (*B. Menziesii*) typical of gravelly soils (*B. attenuata*, *B. grandis*, and *B. prionotes*), furze stinkwood (*Jacksonia furcellata*), Christmas bush (*Nuytsia floribunda*), prickly poison (*Gastrolobium spinosum*), blackboys (*X. gracillis*, *X. Preissii*, *X. reflexa*), and hakea (*Hakea prostrata*), with blue billy (*Stirlingia latifolia*) in the vicinity of the coastal sands.

(7)—*Minjil Sand.*

Apart from the soils of the bottomlands, this type is found at the lowest levels of the Cretaceous country, and in the yellower variation occasionally shows signs of incipient swampiness, as evidenced by the presence of blue gums, rushes and reeds. The browner variation is slightly more elevated, and appears to be associated with outcrops rich in glauconitic material, as shown by the content of phosphate and potash.

The type is characterised by (a) its yellow to brown colour and weakly podsolised nature, (b) the fine gravel throughout the profile, and (c) a band of lateritic and ferruginous pebbles, varying in thickness from three to 20 inches, usually encountered at about 30 inches. To a depth of 36 inches the soil consists of a yellow to brown coarse sand, the first 12 inches being somewhat greyer in shade due to organic matter. The gravel layer occurs in the lower levels of the sand and overlies a yellow to yellow brown, red mottled, sandy clay which becomes lighter in texture below 60 inches. The gravel does occur over a limited range, both in the sand above the gravelly layer and in the clay below it, but rapidly dies out in either direction. The sand content of the A. horizon amounts to from 84 to 88 per cent., of which three-quarters is coarse sand. The silt amounts to barely three per cent., while the clay varies from five to 10 per cent. In the subsoil the ratio of coarse to fine sand persists, although the total sand fraction is only about 60 per cent., the silt rises slightly and the clay attains an average of about 30 per cent.

Occurring as it does on the lower slopes and having a shallow clayey subsoil, the drainage is somewhat restricted, portions being even swampy in nature. On the more elevated situations, marri (*Eucalyptus calophylla*) and wattles (*Acacia spp.*) are common, whereas the associated vegetation under restricted drainage conditions consists of flooded gums (*E. rudis*), fresh water paper bark (*Melaleuca rhaphiophylla*) and various reeds and rushes.

Mechanical analyses and chemical data for the type are given in Tables 7 and 8.

Table 7.

MECHANICAL ANALYSES AND CHEMICAL DATA OF THE MINJIL SAND.

Soil type	Minjil sand.												
Variation	Yellow surface soil.						Intermediate.				Brown surface soil.		
Sample Number	3039	3040	3041	3043	3044	3045	3560	3561	3562–3	3564–6	3047	3048	3049
Depth in inches	0–15	15–30	30–60	0–6	6–27	27–33	0–12	12–24	24–43	43–72	0–12	12–27	27–33
Horizon	A_1	A_2	B	A_1	A_2		A_1	A_2		B	A_1	A_2	
	%	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	...	...	1	9	1	2	20	2	...	...	7
Fine gravel, 3 mm.—2 mm.	1	2	4	1	1	4	1	1	5	2	1	3	3
Coarse sand,													
2·0 mm.—1·0 mm.	6·8	6·7	8·8	4·3	4·7	9·9	3·8	3·0	8·0	4·8	7·6	9·7	9·8
1·0 mm.—0·5 mm.	18·9	15·6	11·6	23·6	19·6	20·2	24·2	17·6	16·8	15·6	22·0	16·5	18·7
0·5 mm.—0·2 mm.	33·3	34·0	22·6	40·2	36·5	31·1	38·3	37·1	32·2	23·7	33·1	28·2	22·9
Total	59·0	56·3	43·0	68·1	60·8	61·2	66·3	57·7	57·0	44·1	62·7	54·4	51·4
Fine sand	25·3	31·2	24·2	20·6	24·4	23·0	21·0	27·9	26·7	18·3	25·9	31·6	28·8
Silt	3·0	4·1	6·0	2·3	2·1	2·3	3·0	3·1	3·0	4·8	2·7	3·2	3·4
Clay	8·2	7·3	25·9	6·9	11·8	12·6	8·1	10·1	12·6	29·9	5·6	8·5	13·1
Loss on acid treatment ...	0·4	0·1	0·1	0·1	0·0	0·0	0·2	0·2	0·2	0·4	0·0	0·4	0·2
Moisture	1·1	0·6	1·8	0·7	0·7	0·8	0·5	0·6	1·0	4·1	1·3	1·7	2·7
Phosphoric acid ... P_2O_5	0·046	0·028	0·047	0·018	0·022	0·022	0·022	0·026	0·033	0·041	0·187	0·247	0·412
Potash ... ... K_2O	0·050	0·041	0·035	0·041	0·054	0·054	0·035	0·041	0·046	0·651	0·682	0·826	0·967
Nitrogen ... ... N	0·106	0·021	0·020	0·052	0·038	0·018	0·039	0·025	0·020	0·011	0·070	0·039	0·047
Organic carbon ... C	1·80	0·33	...	0·86	...	...	...	...	...	...	1·00	0·46	0·52
Carbon/nitrogen ratio C/N	17·0	15·7	...	16·5	...	...	...	...	...	...	14·3	11·7	11·2
Soil reaction ... ... pH	5·9	6·4	6·5	6·0	6·4	6·7	5·8	6·2	6·4	5·2	5·7	5·6	5·4

Table 8.

MECHANICAL ANALYSES AND CHEMICAL DATA OF THE MINJIL SAND, BALLINGAH SANDY LOAM, AND THE UNNAMED SAND.

Soil type	Minjil Sand.				Ballingah Sandy Loam.			Unnamed Sand.	
Variation	Brown Surface Soil.				——			——	
Sample Number	3551	3552	3553	3554–8	3538	3539–42	3543	3050	3051
Depth in Inches	0–12	12–24	24–28	29–80	0–12	12–60	60–72	0–6	6–45
Horizon	A_1	A_2		B	A	B	BC	A	B
	%	%	%	%	%	%	%	%	%
Stone	1	4	30	2	...	...	...	1	1
Fine gravel 3 mm.—2 mm	2	3	7	4	3	1	...	2	...
Coarse sand :									
2·0 mm.—1·0 mm.	8·7	8·8	12·3	6·9	11·6	2·3	0·4	7·6	3·8
1·0 mm.—0·5 mm. ..	23·4	20·8	19·7	13·9	19·5	5·0	1·3	23·8	13·4
0·5 mm.—0·2 mm. ...	31·6	32·3	30·9	21·5	21·9	34·0	33·5	23·5	14·8
Total ...	63·7	61·9	62·9	42·3	53·0	41·3	35·2	54·9	32·0
Fine sand	22·5	25·7	25·7	19·7	26·9	25·6	23·9	27·6	17·2
Silt	3·1	1·8	2·1	2·8	4·7	6·6	6·7	3·3	4·6
Clay	7·4	8·3	7·9	30·7	10·8	18·6	25·8	10·1	40·4
Loss on acid treatment ...	0·2	0·4	0·3	0·6	0·6	0·8	0·9	0·4	0·9
Moisture	1·3	1·1	1·1	4·7	2·9	7·2	8·8	1·5	5·5
Phosphoric acid P_2O_5	0·092	0·090	0·142	0·084	0·77	1·91	1·59	0·059	0·066
Potash ... K_2O	0·180	0·184	0·199	0·338	1·80	4·12	4·38	0·535	1·706
Nitrogen ... N	0·068	0·033	0·025	0·017	0·067	0·032	0·024	0·093	0·031
Organic carbon C	...	...	...	...	...	...	...	1·151	0·266
Carbon nitrogen ratio C/N	...	...	...	...	...	...	...	12·4	8·6
Soil reaction ... pH	5·7	6·0	6·4	5·2	5·3	5·4	5·5	5·7	7·1

(8)—*Mount Pleasant Sand.*

This type is very restricted in extent, and is associated with the junction of the chalk and lower greensand. The surface layer, a red to dark chocolate sand almost identical with that of the Whakea sand overlies a variable thickness of red, reddish yellow, brown or grey mottled clay, occurring at a depth of from nine to 24 inches. This clay, often containing calcium carbonate in the deeper layers, overlies the decomposing rock, fragments of which may occur throughout the profile. In the surface the proportion of fine sand is generally higher than in the Whakea sand, and although the clay content rises abruptly to over 50 per cent. in the subsoil, the silt content even in the deepest layers, remains practically constant, at about four per cent. throughout the profile. Data relating to this type are given in Table 3.

Drainage conditions appear somewhat restricted in certain areas, but the type is considered favourably from an agricultural point of view. The Mount Pleasant sand has been completely cleared except for a few marri (*E. calophylla*). The original vegetation most probably resembled that of the Whakea sand.

(9)—*Ballingah Sandy Loam.*

Like the former type the Ballingah sandy loam is very limited in extent, and occurs in isolated patches throughout the Whakea sand areas. The actual boundary between these types in the field is often extremely difficult to trace owing to the great similarity in colour and texture at the surface. The Ballingah type, however has a distinct brownish-green shade and slightly heavier texture which becomes apparent on closer inspection.

This soil occurs *in situ* associated with the outcrops of glauconitic clays and standstone, decomposing fragments of which occur abundantly throughout the profile. The fine sand fraction separated by mechanical analysis is always a dark green in colour, reflecting the high percentage of glauconitic material which is present.

The surface consists of a black to grey-brown coarse, occasionally gravelly, sand to sandy loam with little organic matter, to a depth of about 12 inches, where the soil changes to a distinct sandy loam and finally to a sandy clay loam or light clay, which overlies at varying depth the basal rock. The colour of the clay varies from a red, through greenish brown to a distinct green, with variegated mottling. The total sand content in the surface is about 80 per cent., but falls to less than 60 per cent. in the subsoil, as the clay content increases. Silt amounting to about five per cent. increases only slightly with depth. Data referring to this type will be found in Table 8.

This soil does not suffer from drought as do most of the sandy soils and is recognised as one of the most fertile arable and pasture soils of the district. Like that of the Mount Pleasant sand the original vegetation of the Ballingah sandy loam was most probably similar to that of the Whakea type.

(10)—*Unnamed Sand.*

To the west of Whakea homestead on the eastern bank of the Gingin Brook, there is an area of soil about 25 acres in extent totally unlike any other profile so far described. A grey brown surface sand containing a little organic matter and averaging 6-12 inches in thickness, overlies a brownish green mottled sandy clay which becomes slightly heavier at about 20 inches, changing in colour to a greyish brown or green with reddish yellow mottling. Fine gravel is present in the surface and in the part most remote from the brook, stone is often encountered at shallow depths. The mechanical analysis and chemical data of a profile of this type will be found in Table 8.

The area has been practically cleared, but isolated tea-trees (*Melaleuca* spp.) and flooded gums (*E. rudis*), rushes and reeds are still present.

(11)—*Muchea Sand.*

The south-western portion of the area is covered by a sandy soil overlying the more recent tertiary deposits of the coastal plain. Although practically useless from an agricultural point of view its interest lines in the fact that it represents a climax in the process of podsolisation. This soil type has an extremely wide distribution on the western coastal plain and owing to its typical development at Muchea, a small township 18 miles south of Gingin, has been named the Muchea sand.

The normal profile consists of a deep white coarse sand. Except for decomposing root material the soil is practically devoid of organic matter, and the small amount, which gives a greyish shade to the surface layer, disappears completely at about 18 inches. In typical profiles near Muchea the white sand has a brown streaked appearance due to iron staining, at about five feet and the water table occurs at about six feet. In the vicinity of Gingin, however, the soil occurs at a somewhat higher level, the water table is deeper, and the brown streaked layer was not encountered in the sites sampled. Near the boundary with the other soil types of the area the sand has a yellow shade.

The soil consists almost entirely of siliceous sand, silt and clay being less than one per cent. and plant nutrients virtually absent. The ratio of coarse to fine sand is always wide but decreases from 7 : 1 in the surface to 3 : 1 in the deep sub-surface. Fine gravel characteristic of most of the Cretaceous soils is entirely absent, although the predominating portion of the coarse sand fraction, which amounts to from 50 to 60 per cent. of the soil, is that between 1.0 mm. and 0.25 mm. Mechanical analyses and chemical data of the Muchea sand are given in Table 9.

Swampy and poorly drained patches are frequent throughout the type. The surface of these is somewhat loamy in texture and overlies in extreme cases a sandy clay layer which, however, changes to a white or iron-stained sand of the normal type at about 24 inches. The surface varies in colour from grey to black owing to the increased organic matter accumulation. These soils are included with the poorly drained soils on the map.

Outside the area of the Gingin Soil Survey, sheoak (*Casuarina glauca*) flats are common in this type. The soils of these flats are grey sandy loams over a cemented sandy clay subsoil at a depth of about 8 to 12 inches. No profiles of this type have been examined during this survey.

The species which constitute the vegetation of the Muchea sand are practically identical with those occurring on the Wowra sand, but they occur in several associations which are definitely related to the varying conditions of drainage. The banksia-blackboy association of the Wowra sand is characteristic of the deeper better drained phases, but where the water table is closer to the surface, *Regelia ciliata*, paperbark trees (*M. rhaphiophylla*), tea-trees (*Melaleuca* spp.), swamp spearwood (*Kunzea ericafolia*), and black wattle (*Acacia cyanophylla*) become more common.

TABLE 9.

MECHANICAL ANALYSES AND CHEMICAL DATA OF THE MUCHEA SAND AND ALLUVIAL AND POORLY DRAINED SOILS.

Soil type	Muchea Sand.						Alluvial and other Poorly Drained Soils.							
Variation	Normal.						Moonda-Wowra Brook Alluvial Flat.			Alluvial.			Undrained Sandy Soil.	
Sample number	3076	3077–8	3074	3075	3079	3080	3061	3062–3	3064	3568	3569	3570	3058	3059–60
Depth in inches	0–12	12–80	0–6	6–80	0–15	15–45	0–4	4–33	33–45	0–12	12–24	24–45	0–9	9–45
Horizon	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_2	A_1	A_2	A_2	A_1	A_2
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	...	...	...	...	...	...	...	...	...	1	...	...
Fine gravel, 3 mm.–2 mm.	...	...	...	...	...	...	...	...	...	2	3	4	...	1
Coarse sand :														
2·0 mm.–1·0 mm. ...	6·2	6·9	3·1	6·8	3·9	7·6	2·9	5·0	6·8	5·4	1·6	12·7	6·6	6·4
1·0 mm.–0·5 mm. ...	45·0	28·2	39·4	28·0	33·2	24·0	9·4	20·7	24·8	19·7	8·3	20·2	27·4	23·8
0·5 mm.–0·2 mm. ...	34·3	41·9	41·2	39·0	47·0	41·3	20·0	47·1	46·5	15·7	10·2	19·3	33·4	33·6
Total	85·5	77·0	83·7	73·8	84·1	72·9	32·3	72·8	78·1	40·8	20·1	52·2	67·4	63·8
Fine sand	11·8	21·7	14·1	24·8	12·4	25·3	16·3	16·0	17·1	16·5	20·8	20·5	27·8	33·0
Silt	0·3	1·0	1·0	1·3	1·0	1·5	19·5	6·7	3·7	25·0	30·7	6·5	1·9	2·8
Clay							16·0	3·5	1·0	12·9	24·5	17·9		
Loss on acid treatment ...	0·0	0·0	0·0	0·0	0·2	0·0	1·2	0·2	0·1	0·7	0·7	0·4	0·1	0·0
Moisture	0·3	0·1	0·2	0·0	0·3	0·0	4·4	0·5	0·2	2·6	3·6	2·5	0·5	0·1
Phosphoric Acid ... P_2O_5	Tr	Tr	0·001	Tr	0·001	0·001	0·068	0·013	0·001	0·016	0·016	0·010	0·013	0·005
Potash ... ... K_2O	0·005	0·004	0·005	0·005	0·007	0·004	0·034	0·008	0·004	0·040	0·026	0·048	0·014	0·010
Nitrogen ... ... N	0·039	0·005	0·026	0·004	0·056	0·005	0·421	0·025	0·006	0·098	0·029	0·023	0·073	0·009
Organic carbon ... C	1·212	0·135	0·544	...	1·041	0·096	5·91	0·356	...	...	...	...	1·10	0·15
Carbon/nitrogen ratio C/N	31·1	27·0	20·9	...	18·6	19·2	14·0	14·2	...	...	...	...	15·1	13·6
Soil reaction ... ... pH	5·3	5·3	5·5	6·2	5·1	5·1	4·9	6·1	6·2	5·8	6·4	6·9	5·6	6·2

(12)—*Undifferentiated Alluvial and other poorly drained Soils.*

Associated with the brook and spring system of the district there is a group of soils, many of which are swampy in the undrained state. This group is by no means homogenous, and the profiles are, to a large extent, governed by the adjacent soil types. Along the courses of the streams, the profile consists generally of about 12 inches of a brown to black organic loam overlying a black organic clay which gradually becomes lighter in colour and texture with depth and eventually passes into a sand. The water table is practically at the surface, and hydrogen sulphide is common throughout the profile. In the vicinity of Gingin, where the brook passes over the lateritic beds, ironstone gravel occurs in these soils and the clay continues to a greater depth.

To the west of Gingin where the brook flows out on to the coastal plain these soils show more affinity with the sands of the Muchea type. The profile consists of a sandy loam surface overlying a grey sand with more or less ironstained sand below.

To the east of the town the Moonda and Wowra Brooks pass through a large fertile alluvial flat before their confluence with the Gingin Brook. The profile of this flat, which is fairly uniform, is as follows:—

Grey organic loam 0-4″.
Grey to white sand 4-30″.
White coarse sand (similar to the Wowra sand subsoil) 30″+.

The silt and clay, which are present in the surface soils in much larger amounts than in the previously described sandy soils, fall away to small figures in the subsurface, whereas the sand content almost doubles itself, and increase in coarseness. A second alluvial profile which appears to occur in isolated areas along the banks of the brooks has a grey colour throughout and is again characterised by an even higher percentage of silt and clay in the surface and subsurface soils. The subsurface is as usual high in sand, especially coarse sand. Chemical data and mechanical analyses of these two profiles are given in Table 9.

On the higher levels, above these bottomlands in proximity to the Wowra sand, deep white sands occur which, owing to swampy conditions, carry a dense growth of rushes and reeds or grasses. While showing many affinities with the Wowra sand, the poorly drained nature of these soils combined with the organic accumulation at the surface make their inclusion in this group a more natural one. An analysis of this type of profile is shown in Table 9. The area to the north-east of Granville, occurring in a distinct depression, is in places submerged below the water-table, and is included with these soils.

Along the actual course of the Gingin Brook and to a lesser extent along the Wowra and Moonda Brooks giant fresh-water paperbarks (*Melaleuca rhaphiophylla*) grow to a height of from 25-40 feet under the most swampy conditions while somewhat smaller tea-trees (*Melaleuca spp.*) also occur together with a ground cover of bracken fern (*Pteridium aquilinum*). Various rushes (*Juncus spp.*), nut grasses (*Cyperus spp*), together with a small amount of couch grass (*Cynodon dactylon*), Guildford grass (*Romulea rosea*), and grasses characterised the cleared flats.

IV.—LABORATORY INVESTIGATIONS.

(1)—*Mechanical Analyses.*

Mechanical analyses were carried out on 104 samples taken from the 34 sites, and representative of all soil types; a selection of typical examples is tabulated in the text.

Apart from the Gingin clay and the surface alluvial samples, the surface and subsurface soils are exceptionally light and coarse in texture, being characterised not only by the high sand content but also by the high proportion of coarse sand present. The total sand content ranges from 83 per cent. in some of the Whakea sand samples to practically 100 per cent. of the mineral fraction in certain of the Wowra sand and Muchea sand profiles; the proportion of sand rarely falls much below 90 per cent. The ratio of coarse to fine sand varies from about 3:1 in many types to exceptionally high figures in samples of the Wowra sand, the weighted mean, however, being about 6:1. In the Gingin clay, the sand content amounts to 50 per cent., although here the proportion of the sand fraction is quite variable. A low or very low silt content is characteristic of all soils except the alluvials where, as might be expected, it rises to as high as 25 per cent.; in the Gingin clay the mean silt content is 7 per cent. and for the remaining types 2 per cent. or less in the surface, with slightly lower values in the subsurface. In the surface samples of the Gingin clay, the clay content amounts to nearly 40 per cent., whereas in the sandy types it averages little more than 5 per cent. In the Whakea sand and Minjil sands, the mean is about 7.5, but it is considerably lower in the remaining sandy types, being virtually absent in the Wowra sand and Muchea sand. The subsoils, where encountered, of each type are distinctly heavier and generally consist of sandy loams to sandy clay loams, except in the case of the Gingin clay and Mount Pleasant sand, where distinctly heavy clays still low in silt may occur.

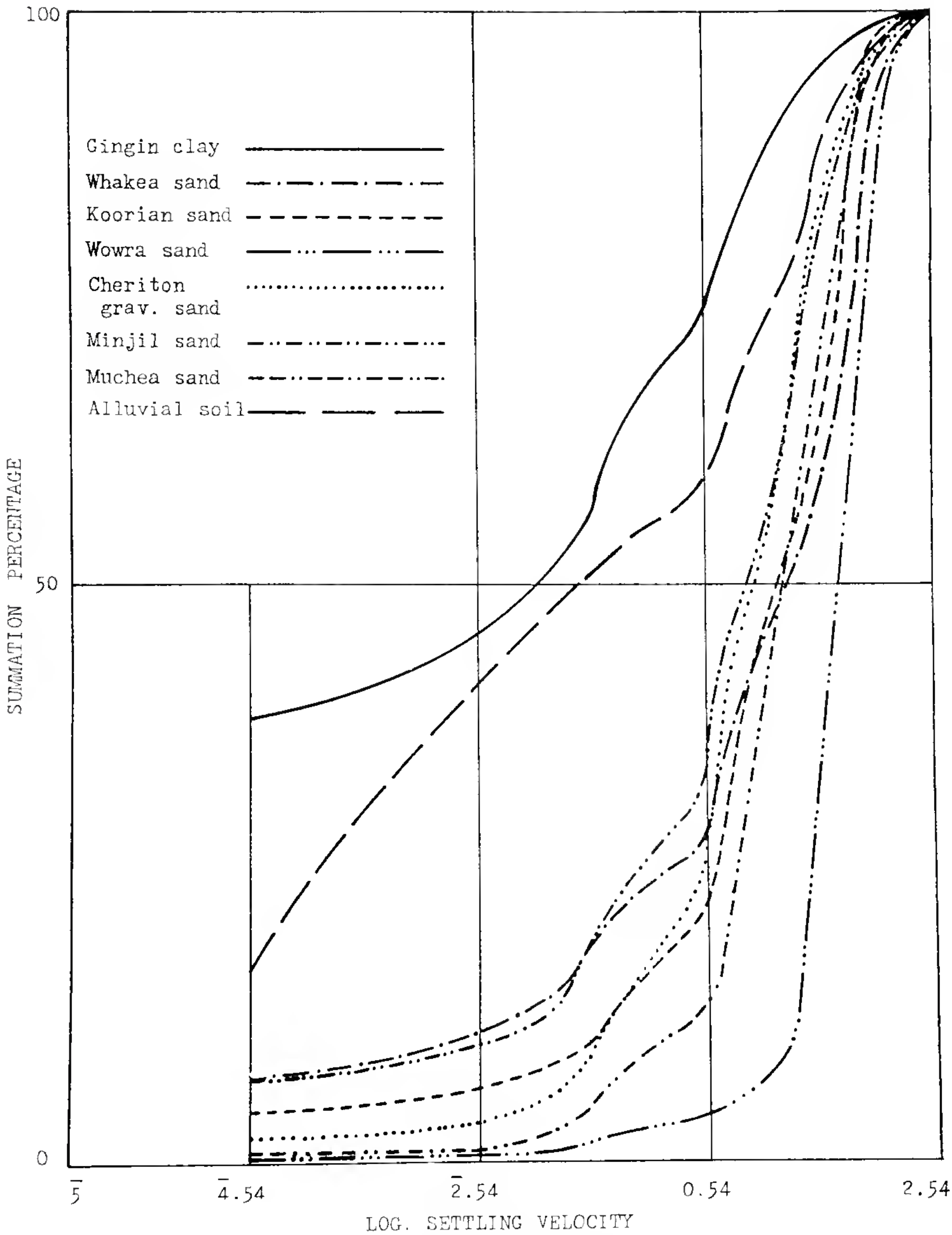

Figure 1. Summation curves illustrating the mechanical analysis of the surface samples of various types.

The general form of the mechanical analysis summation curves of the surface samples is illustrated in Fig. 1, which brings out the characteristics of the mineral portion for each type. The distribution triangle (Fig. 2) emphasises the lightness of the surface and subsurface soils, together with the heavier nature of the Gingin clay, the alluvial surface samples and the subsoils of the sandy types.

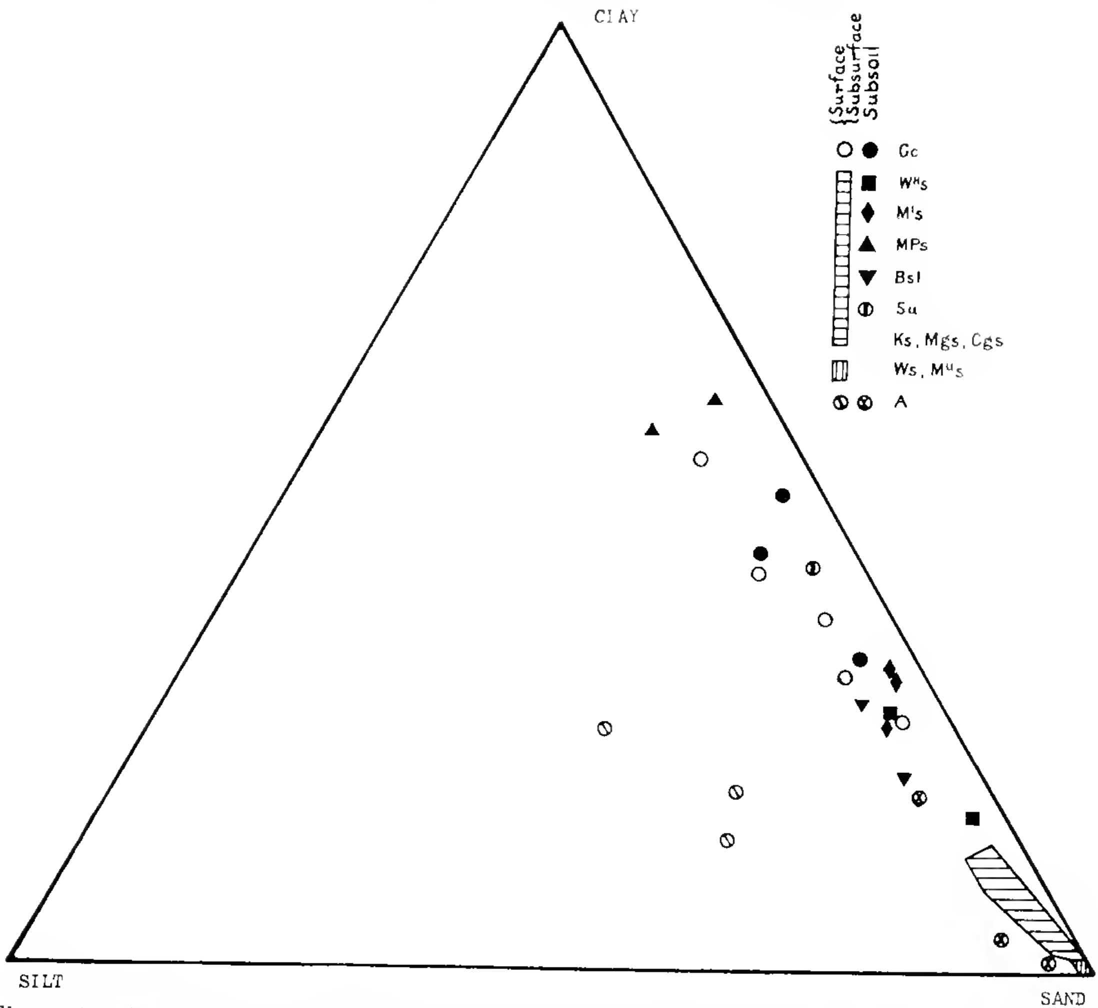

Figure 2. Mechanical analysis distribution triangle of the Gingin soils. Hatched areas and open figures represent surface and subsurface samples of the types as listed; block figures—subsoil samples. (The type designations are those employed on the soil map.)

The coarse sand fraction.[1]

Owing to the exceptionally high coarse sand content of the soils, this fraction was subdivided by means of sieves into five further fractions of which the three 2.0 mm. to 1.0 mm., 1.0 mm. to 0.5 mm., and 0.5 mm. to 0.2 mm., the limiting value of the coarse sand, are given in the tables in the text.

Apart from the Whakea sand and the Koorian sand, which show a marked variation, the sandy soils in general show a certain uniformity in the size distribution of the coarse sand grains not only in the surface samples but throughout the profiles. The variation in the proportions of the various coarse sand fractions within any type may be accounted for in a corresponding variation in the grain size in the underlying rocks. In the case of the Whakea sand where these rocks consist of the coarse-grained ferruginous sandstones a very coarse-grained sand (Sample No. 3025) results, but where they consist of greensands, a finer-grained sand (Sample No. 3022) would be expected. The Koorian sand shows also a similar variation, being coarser when formed secondarily from coarse-grained soils of the Whakea type and less coarse on the mudstones of the lower levels (compare samples Nos. 3032 and 3037). There is for all the types, with the exception of the Minjil sand and the Cheriton gravelly sand, a general tendency for the coarse sand to become finer in grain with depth.

(1) Percentage figures in this section refer only to those of the coarse sand and not to the soil as a whole.

The coarseness of grain reaches its maximum in the surface of the strongely leached Wowra sand, one sample showing 42 per cent. of the coarse sand separate over 1.0 mm. in diameter. This fraction is generally of the order of 20 per cent. in the Wowra sand, the Moorgup gravelly sand, the Whakea sand, and the yellow variation of the Koorian sand. It falls to between 6 and 10 per cent. in the Minjil sand, and the Cheriton gravelly sand, and at most amounts to only 3 or 4 per cent. in the Muchea sand and in certain areas of Koorian sand.

There is a distinct increase in the content of the fraction between 1.0 mm. and 0.5 mm. The greatest variation for any soil type, from 16 to 71 per cent. of the coarse sand, occurs in the Koorian sand and the least in the Minjil sand, where the content approximates very closely to 35 per cent. not only in the surface but throughout the profile. The Wowra sand shows a mean value for this fraction of about 60 per cent. In the remaining soils the variation is from about 30 to 50 per cent. throughout the profiles.

The fraction between 0.5 mm. and 0.2 mm., accounting for the remainder of the coarse sand, must necessarily show a corresponding wide variation; it reaches the minimum of 2 per cent. in the Wowra sand, where it is invariably low, and the maximum of 80 per cent. in the Koorian sand. It is uniformly high in the Cheriton gravelly sand, where the mean value is about 65 per cent., and Minjil sand, where again the fraction is remarkably constant throughout the type, the mean value being about 55 per cent. In the remaining sands, the general variation is again from 30-50 per cent. of the total coarse sand.

The fine sand fractions of some of the soils have also been further subdivided, the results being tabulated in the Appendix.

(2)—*Soil Reaction.**

Table 10.

DISTRIBUTION TABLE FOR pH VALUES OF SOIL TYPES.

Soil type.	Horizon.	pH Range. 4·5 to 5·0	5·0 to 5·5	5·5 to 6·0	6·0 to 6·5	6·5 to 7·0	7·0 to 7·5	7·5 to 8·0	8·0 to 8·5
Gingin Clay ...	A ...	...	...	...	1	1	...	3	...
	B–BC	...	...	...	...	...	1	1	1
Mount Pleasant Sand	A ...	...	...	1	...	...	...	...	...
	B_1 ...	...	...	...	...	1	...	...	...
	B_2 ...	...	...	...	...	...	...	1	...
Alluvial Soils and Unnamed Sands	A_1 ...	1	...	2	...	...	...	...	...
	A_3 ...	...	...	1	1	...	...	...	...
	deep A_2 or B	...	...	...	1	1	1	...	...
Remainder (sandy soils)	A_1 ...	...	4	11	10	...	...	...	...
	A_2 ...	...	4	1	19	1	...	...	...
	deep A_2 or B	...	5	...	9	2	...	...	...

* The Antimony Electrode was used throughout the course of the work for the determinations of all reaction values, the soil to water ratio being 1 to 2.5.

The reaction range for the majority of the soils for the whole area is very narrow, no less than 68 per cent. of the values for all soils falling between pH 5·5 and pH 6.5. The complete range in the surface soils is from pH4.9 in the case of the alluvial soil from the Moonda Brook flat, to pH 7.9 for the Gingin clay on Molecap Hill. The reaction of the Gingin clay soils is somewhat lower than would be expected when the high content of calcium carbonate is considered, but these low values can, however, be explained by the high buffering action of the organic matter present.

The range in values for the Gingin clay surface soils is from pH 6.3 to pH 7.9, with a slight increase in the subsurface soil from pH 7.3 to pH 8.1. For all other surface soils, excluding the alluvium, the range is from pH 5.1 to pH 6.4. There is generally a slight increase in the reaction value with depth, the range in the sub-surface being from pH 5.1 to 6.8 and in the subsoils or deeper sub-surface samples from pH 5.4 to pH 6.7. In the deep subsoil of the Mount Pleasant sand, where calcium carbonate occurs the value rises to over pH 8.0. These figures are set out in the form of a distribution table in Table 10.

TABLE 11.
REPLACEABLE BASES IN GINGIN CLAY AND WHAKEA SAND.

Soil type.	Sample number.	Depth in ins.	Soil reaction.	Clay.	Organic matter.	Milli-equivalents per 100 gm. of soil.					Percentage of total bases.			
						Ca	Mg	K	Na	Total	Ca	Mg	K	Na
			pH	%	%									
Gingin clay ...	3001	0–12	7·9	16	8·0	30·71	1·07	0·78	0·15	32·71	94	3	2	1
	3003	0–6	7·9	17	9·0	30·83	1·81	0·63	0·29	33·56	92	5	2	1
	2996	0–8	6·7	24	13·4	48·34	4·80	0·58	0·30	54·02	89	9	1	1
	3006	0–6	7·7	43	7·3	36·71	2·86	2·87	0·31	42·75	85	7	7	1
	2999	0–12	6·3	32	4·2	23·21	5·70	1·63	0·69	31·23	75	18	5	2
	3000	12–24	7·3	44	2·2	26·96	6·58	1·52	0·86	35·92	75	18	5	2
Whakea sand ...	3007	0–15	6·4	9	2·2	3·62	1·26	0·43	0·06	5·37	68	23	8	1
	3008	15–60	6·5	10	0·8	1·92	1·25	0·07	0·03	3·27	59	38	2	1
	3009	60–80	6·5	10	0·4	0·83	0·89	0·10	0·03	1·85	45	48	5	2
	3013	0–15	6·2	9	2·2	3·79	1·45	0·28	0·03	5·55	68	26	5	1
	3014	15–54	6·3	11	0·8	2·25	0·84	0·16	0·03	3·28	68	26	5	1
	3015	54–66	6·4	12	0·7	1·29	1·08	0·12	0·02	2·51	51	43	5	1

(3)—*Replaceable Bases.*

Twelve soils, representing five surface and one sub-surface sample of the Gingin clay and two profiles of the Whakea sand, have been examined for replaceable bases, the results being summarised in Table 11.

The extremely high proportion of replaceable calcium is to be noted in the Gingin clay samples and also the persistence in composition of the successive depths of profile 2999-3000. Sample 2996, although containing only 24 per cent. clay, shows a high degree of saturation, the high organic matter content contributing largely to this figure. Sodium is low in all samples examined, the average being about 1 per cent.

As would be expected from the acid nature and low clay content, the Whakea sands contain little in the way of replaceable bases. The high proportion of calcium in the surface, and its lower figure, consequent on the rise in the proportion of magnesium below, is to be noted.

(4)—*Chemical Analysis.*

(i)—*Nitrogen, Organic Carbon and Organic Matter.*

Table 12.

DISTRIBUTION TABLE FOR NITROGEN CONTENT OF GINGIN SOILS.

Soil type.		Sandy soils.										Gingin clay and surface alluvium.				
Nitrogen	%	0 to 0·01	0·01 to 0·02	0·02 to 0·03	0·03 to 0·04	0·04 to 0·05	0·05 to 0·06	0·06 to 0·07	0·07 to 0·08	0·08 to 0·09	0·09 to 0·1	0·1 to 0·2	0·2 to 0·3	0·3 to 0·4	0·4 to 0·5	0·5 to 0·6
Horizon	A_1	...	3	3	4	3	4	1	5	2	2	2	...	1	3	1
	A_2	7	8	7	6	...	1	...	...	...	...	...	...	...	...	...
	deep A_2 or B	8	4	5	1	2	...	...	...	...	...	1	2	...	...	...

With the exception of the Gingin clay and the surface of the creek alluvium in which the nitrogen rises to over 0.5 per cent., the nitrogen content is generally low and never exceeds 0.1 per cent. In the surface samples of the Gingin clay, the range is from 0.17 per cent. to 0.55 per cent., with a mean value of 0.37 per cent.; below the surface layer the nitrogen falls, the mean being 0·22 per cent. Generally there is no significance in the variation in the nitrogen content of the surface samples of the remaining types, the variation being fairly wide, though of the same order in each individual type. The range is from 0.10 per cent. for a soil of the Minjil sand near Strathalbyn to less than 0.02 per cent. in the Whakea sand to the south of Molecap Hill, and in the Wowra sand near Cleveland, with a mean value of 0.05 per cent. There is a sudden drop in the content below the surface horizon, especially in the case of the two extremely podsolised soils, the Wowra and Muchea sands, where the nitrogen practically disappears; the range here is from 0.05 per cent. in the sample of Mount Pleasant sand to 0.001 in the Wowra sand sample previously mentioned. The mean value is about 0.02 per cent. In the deeper layers of the A_2 horizon or in the subsoils, the nitrogen is even less. The nitrogen figures are summarised in the form of a distribution table in Table 12.

Organic carbon was determined on a number of representative samples from each type. It reaches its maximum in the Gingin clay, rising to nearly 8 per cent. in the surface sample from Mt. Pleasant. The range in the carbon content of the surface samples of the latter type is from 2.4 to 7.79 per cent. with a mean value of 4.86 per cent.; the mean value for the subsurface is somewhat lower, being 3.07 per cent. Exclusive of the alluvial surface sample from the Moonda flat which contains nearly 6 per cent. of carbon, the maximum value reached in the remaining soils is 1.8 per cent. in the sample of the Minjil sand from Strathalbyn, but in general the content is less than one per cent. The variation from type to type is of the same order as that for the nitrogen content. Below the surface horizon the carbon content drops considerably, the range being from 0.08 to 0.57 per cent.

The frequency distribution of the carbon to nitrogen ratios is shown in Table 13. The ratios for the Gingin clay, a typical grassland soil, fall in a restricted range, and for the other soils the usual high values and extensive range (Hosking, 1935), characteristic of woodland soils are found. In the sandy soils the organic material consists mainly of decomposing fibrous woody and root material, especially in the case of the Muchea and Wowra sands, while it is only in the Gingin clay that it can be considered to be highly "humified."

Table 13.

DISTRIBUTION TABLE OF CARBON TO NITROGEN (N = 1) RATIOS OF THE SOILS EXAMINED.

Soil type.	Horizon.	C : N Ratio.											
		8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32
Gingin Clay...	A	...	1	3	1	...	...	...	...	...	...	...	...
	AB–BC	...	...	1	1	...	...	...	...	...	...	...	...
Remaining soils. ...	A_1	...	1	4	4	7	4	4	1	1	...	...	1
	A_2	1	1	4	4	...	3	1	1	1	1	...	...
	deep A_2 and B	...	3	...	1	1	...	...	1	...	...	...	...

(ii)—*Hydrochloric Acid Extract.*

The standard hydrochloric acid extraction was made on all the soil samples and potassium and phosphoric acid determined in all the extracts. Manganese was also determined on the Gingin clay soils and certain of the Whakea sand samples.

(a)—*Potash.*—The potash content varies enormously not only from type to type, but even within the types themselves. A broad grouping of the soils into four classes based on potash content has been made as illustrated in the accompanying distribution table No. 14. The first two groups of soils derive their high potash content from the underlying rocks, which are extremely rich in glauconite.

(*i*) The Gingin clay, Mount Pleasant sand, Ballingah sandy loam, and the unnamed sand, constitute the first class, in which no sample contains less than 0.2 per cent., but may contain as much as 4 per cent. In the Gingin clay the content varies in the surface from 0.3 per cent. in the shallow soil at One Tree Hill to over 3.0 per cent. in the deep soil from below Gingiup, the mean value being about 1.3 per cent. The proportion of potash in the subsoil is of the same order as that in the surface. The highest percentage recorded is 4.38 per cent. in the deep subsoil of the Ballingah sandy loam associated with the glauconitic outcrops.

(*ii*) The Minjil sand has been placed in a class by itself since it forms an overlap between classes (i) and (iii). In the surface the potash varies from 0.03 per cent. in the yellower varieties to over 0.6 per cent. in the browner varieties. The potash content of the surface and subsurface is similar, but it generally rises considerably in the clay subsoil.

(*iii*) The Whakea sand, Koorian sand and the two alluvial profiles examined fall into a third class where the potash content in the surface varies from 0.02 per cent. to 0.2 per cent. The variation in the A_2 horizon is of exactly the same order except in the alluvial soil from the Wowra plains which is practically devoid of potash, and really belongs to the following class.

In this class, the Koorian sand and alluvial soils fall entirely in the lower portion of the range between 0.02 and 0.04 per cent. The weakly podsolised nature of these soils would account for the lower content of potash, considering the material over which they lie.

(*iv*) With the exception of the Moorgup sand, the remaining soils are very highly leached, a fact which would account for the very low potash content, which is never greater than 0.02 per cent. In the Wowra and Muchea sands potash is virtually absent.

(b)—*Phosphoric acid.* The phosphoric acid content varies from type to type and within the types themselves, the content being of the same order as for the potash. A grouping into four classes with the same limits is again possible, as illustrated in Table 14, and although in general the order of the soils is the same, a slight re-arrangement within the groups is necessary.

This high phosphate content of certain classes is definitely associated either with the coprolite or phosphatic beds at the base of the chalk, or to a lesser extent with the glauconitic beds rich in dufrenite.

(*i*) The Gingin clay and Ballingah sandy loam constitute the first class. The phosphoric acid varies in the surface samples from 0.2 per cent. at One Tree Hill to the extraordinarily high figure of 2.2 per cent. in the outcrop near Cleveland, with a mean of close on 1 per cent., and again there is only a slight variation in the content below the surface. In the Ballingah sandy loam profile, in the surface, the content is 0.8, and this rises abruptly at 12 inches to 1.5 per cent., and in the subsoil to over 2.0 per cent. phosphoric acid.

(*ii*) The Mount Pleasant sand falls into the second class with the Minjil sand where the range in the surface is from 0.02 to 0.2 per cent. phosphoric acid, the same as in the following class, but distinguished by an increase in the subsoil to over 0.4 per cent.

(*iii*) The Whakea sand, the unnamed sand, and the Moorgup gravelly sand constitute the third class with amounts varying from .01-.08 per cent. phosphoric acid. There is again little variation with depth.

(*iv*) The remaining soils constitute the final class as very deficient in phosphoric acid. The one alluvial soil in the surface does show a relatively high proportion of 0.06 per cent. phosphoric acid, but has been included with this class, since below the surface layer the phosphate amounts to little more than a mere trace, which is characteristic of most of these leached soils.

Table 14.

DISTRIBUTION TABLE FOR POTASH AND PHOSPHATE PERCENTAGE FOR THE GINGIN SOIL TYPES.

—	Soil Type.	Horizon.	Class 4.		Class 3.									Class 2.											
														Class 1.											
			0·01	·01–·02	·02–·03	·03–·04	·04–·05	·05–·06	·06–·07	·07–·08	·08–·09	·09–0·1	0·1–0·2	0·2–0·3	0·3–0·4	0·4–0·5	0·5–0·6	0·6–0·7	0·7–0·8	0·8–0·9	0·9–1·0	1·0–2·0	2·0–3·0	3·0–4·0	4·0–5·0
Potash K_2O	Gingin clay, Mt. Pleasant sand, Ballingah sandy loam, Unnamed sand	A ...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	2	...	1	...	...	2	...	1	...
		Shallow B	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	2	...	2	...
		Deep B ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1
	Minjil sand	A_1 ...	...	...	...	1	1	1	...	...	...	...	1	...	...	...	...	1	...	...	...	...	...	...	...
		A_2 ...	...	...	...	...	2	1	..	...	...	...	1	...	...	...	...	...	...	1	...	...	...	...	...
		B ...	...	...	...	1	...	1	...	...	...	...	...	...	1	...	...	...	...	1	1	...	...	...	...
	Whakea sand, Koorian sand, Alluvial soils	A_1 ...	...	...	4	3	1	2	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
		A_2 ...	1	...	4	3	1	...	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
		Deep A_2 ...	1	...	1	3	2	...	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...
	Moorgup gravelly sand, Cheriton gravelly sand, Wowra sand, Muchea sand	A_1 ...	4	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		A_2 ...	5	5	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...
		Deep A_2 ...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Phosphate P_2O_5	Gingin clay, Ballingah sandy loam	A ...	...	...	...	...	...	...	...	...	...	...	...	1	1	...	1	...	1	...	...	1	1	...	...
		Shallow B	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	2	...	...	...
		Deep B ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
	Minjil sand, Mt. Pleasant sand	A_1 ...	...	1	1	...	1	...	1	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...
		A_2 or shallow B	...	...	3	...	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...
		B ...	...	...	1	1	1	...	...	...	...	1	1	...	...	1	...	...	...	...	...	...	...	...	...
	Whakea sand, Unnamed sand, Moorgup sand	A_1 ...	...	...	1	1	2	1	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		A_2 ...	...	...	1	1	1	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Deep A_2 or B	...	...	1	...	2	2	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Alluvial soils, Koorian sand, Wowra sand, Cheriton gravelly sand, Muchea sand	A_1 ...	9	4	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		A_2 ...	11	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Deep A_2	5	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

(c) *Manganese.*—Manganese has been determined in the Gingin clay and some of the Whakea sand samples. The manganese content (entered in the tables as the percentage of the oxide Mn_3O_4) of these soils is very low indeed. In the Gingin clay surface samples, the mean value is 0.016 per cent. Mn_3O_4, the range being from 0.007 to 0.21 per cent., and in the surface it is slightly lower, the mean value there being about 0.01 per cent. In the Whakea sands it is only present in the merest traces, the mean for all the samples examined being less than 0.002 per cent.

(iii)—*Lead.*

Owing to a suspicion that lead-poisoning might be the cause of the ataxial condition affecting stock at Gingin, a determination of this element was made on three of the Gingin clay samples (Numbers 2996, 2999 and 3006), and two of the Whakea sands (Numbers 3007 and 3013), together with soils (Numbers 3081 and 3085) from the unaffected country, for comparisons. Blanks on the materials used were run at the same time. The method used was that of Bertrand and Okada (1933) modified to suit the local soils. Although 200 gm. samples of the soils were used, no trace of lead, determinable by macro-chemical methods, was found either in the affected or non-affected soils.

V.—SOILS FROM THE UNAFFECTED AREAS.

A brief reconnaissance of the soils of the coastal plain which appear to possess certain inhibiting and curative properties was made in the vicinity of Glencoe homestead. Rainfall figures given in Table 1 for Beermullah Lake show that the climatic conditions here are practically identical with those in the Gingin areas. The underlying rocks consist mainly of hard compact limestone containing small mollusc shells of presumably Tertiary age. A soft friable limestone, possibly an aeolian formation, was also observed. Some of the limestone associated with the red sands or sandy loams near Glencoe is of a crustal nature and resembles a secondary formation rather than a rock *in situ*. Ridges of a ferruginous nature are often encountered outcropping throughout the area.

The country is gently rolling with only low hills and is drained by the Gingin Brook and its tributary, the Mungala Brook. To the north-east of Glencoe and at the headwaters of the Mungala Brook the country examined is known as the Beermullah Plains. These plains are distinct in soil and vegetation characteristics from the coastal plain, the Glencoe and the Gingin country.

The soils of Glencoe and Beermullah may be divided into five types:—(i) a grey brown to red brown or chocolate sand to sandy loam; (ii) a series of red or brown to yellow sands; (iii) sandy soils carrying a jam

(*Acacia acuminata*) and York Gum (*Eucalyptus foecunda* var. *loxophleba*) association; (iv) black swampy clays, and (v) the Muchea sand already described.

(i) The profile of this type generally consists of—

0-12in.	Grey brown to red brown sandy loam;
12-24in.	Red brown to brown, grey mottled, sandy clay;
24-36in.	Brown, green mottled, heavy clay;
36in.	Limestone.

The type occurs fairly extensively in the area covered. The surface, although generally of a brownish shade, tinged grey with the little organic matter it contains, has often a distinct chocolate shade, especially where it has been under crop. To a depth of 12 inches it varies in texture from a sand to a sandy loam and overlies a red brown, mottled grey sandy clay to heavy clay. At 24 inches, this clay subsoil becomes even heavier, except where mixed with decomposing rock material, when the sandy clay texture persists; it still retains its brownish colour although the mottling changing to a distinct green becomes far more pronounced. The profile directly overlies the limestone, and $CaCO_3$ is often present in the lower layers of the soil which is seldom more than 3 feet deep. Limestone is often encountered on the surface, and ridges of ferruginous sandstone are common throughout this country. In the vicinity of these ferruginous outcrops, stone is frequently found in the profile.

The soil carries a vegetation of marri (*Eucalyptus calophylla*), flooded gum (*E. rudis*), tea-trees (*Melaleuca* spp.), blackboys (*Xanthorrhoea* spp.) and wattles (*Acacia* spp.).

(ii) A series of sands varying in colour from yellow or brown to red occur frequently throughout the Glencoe area, the common profile consisting of—

0-12in.	Grey, yellow, brown or red sand containing little organic matter;
12-30in.	Yellow, brown or red sand;
30-36in.	Yellow, red mottled, sandy loam;
36-42in.	Brown, green mottled, sandy clay loam.

The depth of the sand varies somewhat, but the change to the underlying sandy loam is characterised by the appearance of the red ferruginous mottling which increases to a depth of 36 inches. At this depth the texture becomes somewhat heavier and the soil becomes browner, while the mottling gradually changes to a distinct green, pointing, as in the first soil, to the presence of reducing agencies. At 24 inches small ferruginous sandstone fragments are encountered which increase in size and abundance till 30 inches is reached, thereafter they decrease again with depth. Scattered limestone is frequently found over the surface.

The vegetation is somewhat similar to that of the Muchea sand.

(iii) Near Lakes Bootine and Beermullah, sandy soils are found, characterised not only by the growth of jam (*Acacia acuminata*) and York gum (*E. foecunda* var. *loxophleba*), but also by the occurrence of a hard pan layer at about 14 inches.

The profile in general consists of:—

0-8″ yellow red to brown sand.
8-14″ red brown to greenish grey sandy loam.
14″+ hardpan layer.

The surface, varying in depth from 6 to 11 inches, overlies a shallow layer, never more than about 6 inches, of a red brown to greenish-grey mottled sandy loam, below which at about 12 to 14 inches there occurs a definite hardpan layer, seldom penetrable to more than a few inches with ordinary sampling tools. In one case (sample No. 3087) the hardpan was penetrated to a depth of 30 inches. This layer consisted of a red to yellow clay with sand pockets of much the same colour throughout.

(iv) A fairly heavy black crumbly soil is often found in some of the smaller depressions. In winter these soils are distinctly swampy, but like the Gingin clay they dry out in the summer and thus suffer considerable contraction, resulting in the formation of a network of deep cracks throughout. It consists of a uniform black clay of a varying thickness, overlying limestone with fragments of this material scattered through the profile and over the surface. Tea trees, which form a considerable thicket, especially round the borders, together with reeds and rushes, are practically the only form of vegetation.

(v) The Muchea sand has already been described on page 92.

The mechanical analyses and chemical data for these soils, excluding those for the Muchea sand, are given in Tables 15 and 16.

TABLE 15.

MECHANICAL ANALYSES AND CHEMICAL DATA OF SOILS FROM GLENCOE STATION.

Soil type	Grey brown to red brown sandy loam.									Black clay.
Locality	North-west from Glencoe homestead.						East of homestead.			Near Mungala Brook.
Sample number	3081	3082	3083	3572	3573	3574	3578	3579	3580	3576
Depth in inches	0–15	15–24	24–36	0–9	9–24	24–30	0–10	10–30	30–42	0–12
Horizon	A	B	BC	A	B	BC	A	B	BC	A
	%	%	%	%	%	%	%	%	%	%
Stone	1	1	2	...	1	19	9	8	17	4
Fine gravel, 3 mm.—2 mm.	...	...	...	...	...	5	3	5	8	...
Coarse Sand										
2·0 mm.—1·0 mm.	0·8	0·5	1·2	0·5	0·3	0·5	5·5	1·8	3·5	0·6
1·0 mm.—0·5 mm.	10·4	7·3	5·2	14·9	7·9	5·8	10·0	3·6	4·4	5·5
0·5 mm.—0·2 mm.	33·6	25·3	16·5	46·8	24·4	16·8	28·1	11·1	9·4	18·3
Total	44·8	33·1	22·9	62·2	32·6	23·1	43·6	16·5	17·3	24·4
Fine sand	32·4	24·0	15·5	25·7	16·1	11·4	24·7	12·6	18·5	18·0
Silt	6·0	5·0	6·3	2·9	3·9	4·8	7·8	9·9	15·3	6·7
Clay	13·4	32·5	44·5	6·8	40·0	44·6	18·8	49·6	34·9	42·5
Loss on acid treatment ...	0·8	0·9	1·0	0·5	1·3	9·1	1·3	2·1	2·1	1·9
Moisture	2·3	5·7	9·4	1·0	7·4	8·8	3·7	10·9	13·1	7·2
Calcium carbonate ... $CaCO_3$	...	...	...	...	...	7·82	...	...	...	0·13
Phosphoric acid ... P_2O_5	0·021	0·014	0·009	0·014	0·011	0·013	0·050	0·011	0·005	0·015
Potash ... ... K_2O	0·402	0·887	1·243	0·116	0·779	0·884	0·224	0·454	0·402	0·606
Nitrogen ... ... N	0·067	0·053	0·044	0·047	0·043	0·063	0·114	0·046	0·038	0·055
Organic carbon ... C	1·15	0·65	0·38	...	...	...	...	...	...	...
Carbon/Nitrogen/ratio... C/N	17·1	12·3	8·5	...	...	...	...	...	...	...
Soil reaction ... ... pH	6·7	7·0	7·1	6·9	7·0	8·0	7·0	7·7	7·7	7·9

Table 16.

MECHANICAL ANALYSES AND CHEMICAL DATA OF SOILS FROM THE VICINITY OF GLENCOE STATION.

Soil type	Red brown sand.				Hardpan soils.					
Locality	Glencoe.				East of Lake Bootine.			Near Lake Beermullah.		
Sample number	3582	3583	3584	3585	3085	3086	3087	3587	3588	3589
Depth in inches	0–12	12–28	28–36	36–42	0–8	8–14	14–30	0–11	11–14	14–16
Horizon	A_1	A_2	B		A_1	A_2	B_1	A_1	A_2	B_1
	%	%	%	%	%	%	%	%	%	%
Stone	...	...	6	2	1	2	2	4	2	10
Fine gravel, 3 mm.—2 mm.	...	2	2	2	2	1	1	2	1	2
Coarse sand 2·0 mm.—1·0 mm.	1·6	1·5	1·3	1·2	1·9	2·0	1·7	0·8	0·6	...
1·0 mm.—0·5 mm.	10·5	8·1	9·8	9·5	12·1	12·4	10·6	11·1	8·0	...
0·5 mm.—0·2 mm.	41·1	36·0	35·8	34·5	37·6	34·2	27·8	45·1	35·7	...
Total	53·2	45·6	46·9	45·2	51·6	48·6	40·1	57·0	44·3	...
Fine sand	39·3	44·8	31·9	25·5	29·8	27·1	24·1	22·2	17·9	...
Silt	1·9	1·8	2·7	2·3	7·7	7·2	5·6	6·8	5·8	...
Clay	4·4	6·4	17·1	23·6	8·7	14·2	26·7	12·0	28·0	...
Loss on acid treatment	0·3	0·2	0·4	0·4	0·2	0·2	0·2	0·3	0·9	...
Moisture	0·4	0·5	1·6	3·3	1·3	2·1	4·0	1·2	3·1	...
Phosphoric acid P_2O_5	0·017	0·017	0·016	0·007	0·008	0·004	0·003	0·011	0·007	0·004
Potash K_2O	0·018	0·029	0·062	0·071	0·094	0·090	0·123	0·127	0·313	0·766
Nitrogen N	0·028	0·014	0·016	0·010	0·061	0·048	0·040	0·064	0·056	0·032
Organic carbon C	...	...	...	...	0·62	0·40	0·29	...	...	...
Carbon/nitrogen ratio C/N	...	...	...	...	10·2	8·3	7·2	...	...	...
Soil reaction pH	6·4	6·4	6·6	7·0	5·4	5·3	5·8	6·0	6·8	7·4

Except in the heavy black soil the sand fractions constitute about 80 per cent. of the mineral matter of the surface layers, varying from 72 per cent. in the profile 3578 to over 90 per cent. in the brown sandy soil 3582. Unlike the Gingin soils, the coarse sand does not preponderate to the same extent, the ratio of coarse to fine sand rarely exceeding about 2:1 throughout the profile. In the sandy loams this ratio may become narrower with depth. Silt is uniformly low throughout the profile, varying from 2 to 8 per cent., the single exception being sample No. 3580. Clay, excepting in the swampy soil, is always low in the surface, but increases sharply in the subsoil in all the profiles.

With the exception of the swampy type, the soils vary in their reaction from distinctly acid to neutral in the surface, but with the advent of the limestone, change to alkaline in the subsoils.

The nitrogen content varies in the surface from 0.114 per cent. in sample No. 3081 to 0.02 per cent. in the sand No. 3582, with a mean of about 0.06 per cent. The highest content, varying from 0.047 to 0.114 per cent., occurs in the soils of the first type, and the lowest in the second type described above. The soil characterised by the jam (*Acacia acuminata*) contain about 0.06 per cent. There is a decrease in the subsurface to a mean of 0.04 per cent. with only a further slight diminution in the subsoils.

Phosphoric acid is highest in the first type described where it varies from 0.014 to 0.05 per cent. in the surface. The complete range for all the surface soils examined is from less than 0.01 in the jam soils to 0.05 of the former type with a general mean of 0.03 per cent. The mean falls to 0.02 per cent. in the subsurface and again is only slightly less in the subsoil.

Potash is generally high except in the red brown sand where it is less than 0.02 per cent. throughout the profile. In the remaining soils it varies in the surface from slightly less than 0.1 per cent. in the jam soil to 0.6 per cent. in the swampy soil, the mean being about 0.26 per cent. There is a distinct increase in the subsurface and subsoil, sample No. 3083 showing over 1.2 per cent.

VI.—RELATION OF SOIL TYPE TO AGRICULTURAL PRODUCTION AND DEVELOPMENT.

1.—*Enzootic Ataxia in Lambs.*

The presence of the abnormal condition for which Bennetts (1932) has adopted the term enzootic ataxia, affecting young lambs in the Gingin district, has been recognised in Western Australia during the past 20 years. According to Bennetts (1932) this disease is similar to conditions in lambs described as occurring in other countries, notably in *Peru, Sweden* and the *British Isles.*

It appears from information supplied by Bennetts that the disease occurs over the whole of the area at Gingin underlain by Cretaceous rocks, quite irrespective of soil type. The disease is also apparent in those parts of the coastal plain watered by the Gingin Brook. Country adjacent to the Moore River, whose head waters are in the granite and gneiss of the Darling Plateau, is apparently unaffected. At the junction of these two streams there are two adjacent farms, the one watered by the Moore River being unaffected and the other watered by the Gingin Brook being affected by the disease. The Beermullah Plains and other country associated with the Mungala Brook are reported to be sound.

Recent investigations show that the disease occurs in several other districts in Western Australia, and while most commonly met with on Cretaceous country, is not confined to it. Several properties at Mt. Barker, on granitic formations, are affected and the disease has been encountered at Rosa Brook, where no Cretaceous or other limestone formations occur. Present data indicate that portions of the South-West coastal country are also affected, as the disease occurs in the vicinity of Busselton and Yallingup.

(2)—*Incidence of Depraved Appetite in Stock.*

This area is one of the few in Western Australia in which bone-chewing and carrion-eating in cattle rarely occur. Removal of stock to other districts arrests the development of enzootic ataxia but generally induces depraved appetite.

(3)—*Agricultural Production.*

In the virgin state the Gingin clay was practically treeless, though well grassed. It now carries a good pasture of clovers, medics and grasses and is never set down to crop.

The Whakea sand is cultivated for rye, oats and lupins, and carries grasses in pasture years. The lupins of the district are noted for their excellent condition and quality, and exercise a marked influence in building up the soil in nitrogen and humus, thus causing a darkening in the surface layer. The response of the Whakea sand to superphosphate is reported to be slight.

The Koorian sand carries very poor pasture, but in the more productive areas is cultivated in rotation with pastures. The Minjil sand, on the other hand, carries good pasture and is used for cultivated crops.

The Cheriton Gravelly sand, Wowra and Muchea sands are of very low fertility and are generally left in the virgin state. The former has been used for orchard purposes but the trees are returning a very low yield at present. The soils of the alluvium provide rich summer pastures and are being further developed by drainage.

VII.—ACKNOWLEDGMENTS.

The authors wish to express their thanks to Professor J. A. Prescott, Chief of the Division of Soils; to Dr. L. J. H. Teakle, of the Department of Agriculture of Western Australia, for advice and criticism during the course of the work; to Dr. H. W. Bennetts for his information and assistance on the many aspects of the enzootic ataxia; to Mr. F. G. Forman for his advice and criticism concerning the treatment of the section on the Geology and Physiography of the area: to the Department of Lands and Surveys, Western Australia, for the final preparation of the map in shape for printing. They are indebted to the residents of the district, Messrs. A. W. and Ian Edgar, Harper and Wedge, for their generous co-operation during the course of the survey.

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APPENDIX.

TABLE 17.

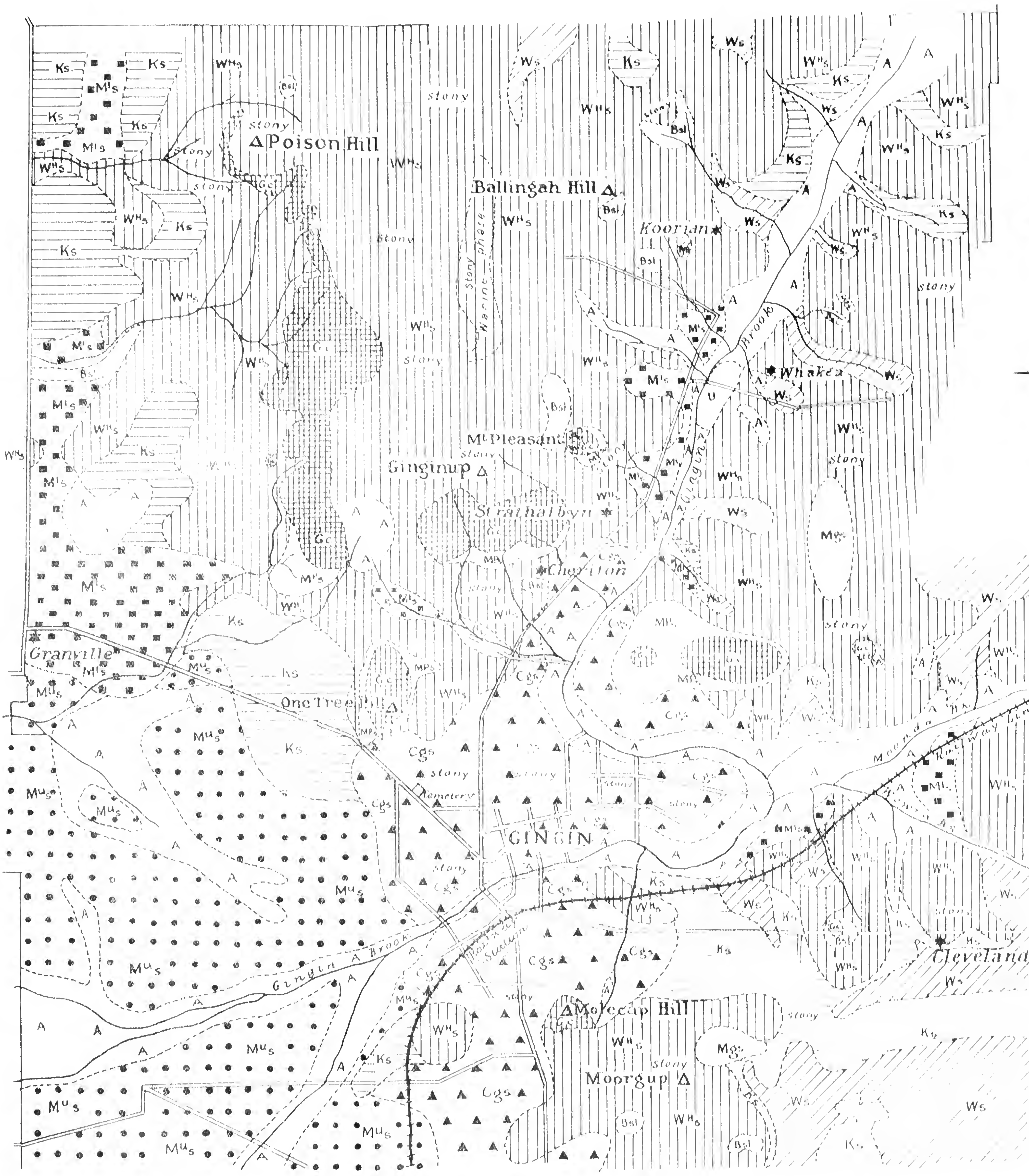
FRACTIONATION OF THE COARSE AND FINE SAND OF SELECTED SURFACE SAMPLES.

Soil Type	Gingin Clay.			Whakea Sand.				Koorian Sand.		Wowra Sand.	Moorgup Gravelly Sand.	Cheriton Gravelly Sand.		Minjil Sand.			Un-named Sand.	Muchea Sand.		Alluvial Soils.	
Sample Number ...	2999	3001	3006	3007	3013	3022	3025	3032	3035	3053	3029	3065	3069	3039	3047	3560	3050	3074	3076	3061	3068
COARSE SAND—	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
On 1·5 mm. mesh	0·5	...	0·4	1·2	2·8	1·5	3·7	0·8	0·3	1·4	4·6	1·2	1·9	1·6	1·9	0·7	2·2	0·2	0·3	0·5	0·8
On 1·0 mm. mesh	1·6	0·3	1·3	8·5	11·0	7·0	19·4	15·6	2·4	13·9	15·1	3·5	4·3	5·2	5·7	3·1	5·4	2·9	5·9	2·4	4·6
On 0·5 mm. mesh	4·6	3·2	4·2	27·1	24·7	12·2	47·1	59·1	10·6	53·8	35·6	20·9	20·1	18·9	22·0	24·2	23·8	39·4	45·0	9·4	19·7
On 50 mesh (1) ...	8·9	6·8	5·1	23·4	15·3	19·6	14·6	6·3	31·4	17·9	22·2	32·8	28·4	22·0	21·9	27·0	16·8	33·3	28·0	13·2	11·8
Through 50 mesh ...	8·2	5·7	2·5	5·7	7·4	21·0	3·3	1·2	20 1	3·4	4·3	13·5	14·7	11·3	11·2	11·3	6·7	7·9	6·3	6·8	3·9
FINE SAND—																					
On 90 mesh ...	4·1	3·3	1·4	2·8	4·0	3·5	1·3	0·5	5·5	1·9	1·6	5·9	6·7	4·9	5·3	3·6	5·0	2·8	2·0	3·0	1·7
On 120 mesh ...	5·2	3·0	1·5	2·3	4·3	4·0	1·1	0·7	7·8	1·5	1·7	5·8	5·0	4·5	4·8	4·3	3·8	2·9	2·0	2·7	1·3
On 200 mesh ...	8·8	9·6	5·7	4·4	7·5	7·8	2·0	1·8	6·8	2·4	2·7	5·8	7·4	7·1	7·6	6·1	6·9	4·5	4·0	4·4	2·5
Through 200 mesh...	6·9	9·2	7·3	8·8	7·2	9·3	3·1	5·2	6·1	2·7	4·1	5·3	5·9	8·8	8·2	7·0	11·9	3·9	3·8	6·2	11·0
Total	48·8	41·1	29·4	84·2	85·2	85·9	95·6	91·2	91·0	98·9	91·8	94·7	94·4	84·3	88·6	87·3	82·5	97·8	97·5	48·6	57·3

(1) 50 mesh equivalent to about 0·25 mm. sieve.

SOIL SURVEY OF
GINGIN AREA

~ SWAN DISTRICT ~
WESTERN AUSTRALIA



KEY TO SOIL TYPES

GINGIN CLAY	Gc	MOORGUP GRAVELLY SAND	Mgs	MINJU SAND	M
WHAKEA SAND	Whs	CHERITON " "	Cgs	MUCHLA SAND	Mus
KOORIAN SAND	Ks	BALLINGAH SANDY LOAM	Bsl	SAND (Unnamed)	U
WOWRA SAND	Ws	Mt PLEASANT SAND	MPs	Undifferentiated alluvium and poorly drained soils	A

Soil type boundaries thus, *Roads thus* *Streams thus* Gingin Bk.

Railway thus *Homesteads thus* *Hills thus* △

SCALE

Chains 40 30 20 10 0 ½ 1 1½ Miles

J. S. HOSKING
G. A. GREAVES } Soil Surveyors.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

11

Soi Sa Co Fr

7.—THE ESSENTIAL OILS OF THE WESTERN AUSTRALIAN EUCALYPTS.

PART III.

THE OILS OF *E. SALMONOPHLOIA*, F. v. M., and *E. TETRAGONA*, F. v. M.

By E. M. WATSON.

Read 12th May, 1936; Published 12th August, 1936.

EUCALYPTUS SALMONOPHLOIA.

E. salmonophloia, the salmon gum, occurs over a large area of country roughly defined by the Midland and Southern railways from Mullewa to Gnowangerup, and extending as far eastwards as Kalgoorlie and Salmon Gums. It is described in the "Key to the Eucalypts of Western Australia" (Forests Department, Bulletin 34).

The material used in the present investigation was collected by Mr. G. H. Burvill, from Reserve 8102, about half a mile north of Circle Valley, near Salmon Gums. It was obtained about the middle of August, 1934, from vigorous sucker growth about 15 feet high, growing from old stumps, and was identified by the Government Botanist, Mr. C. A. Gardner. The leaves are copiously dotted with oil glands, and their venation is characteristic of the cineol-pinene oils which contain no phellandrene.

Baker and Smith (1920) have investigated the oil of the salmon gum obtained from material collected at the same time of the year (July or August), but from an unknown locality in Western Australia. A comparison of their results with those of the present investigation is therefore of interest.

	Baker and Smith.	Present Author.
Yield	1·44 per cent.	1·40 per cent.
Specific Gravity*	0·9039	0·9137
Refractive Index	1·4681	1·4731
Specific Rotation	+ 6·3°	− 4·12°
Solubility in 70 per cent. alcohol ...	In $3\frac{1}{2}$ volumes	In $1\frac{3}{4}$ volumes
Saponification value	4·9	14·0
Cineol	48 per cent. (a)	46·4 per cent. (b)
Amount volatile below 183°	91 per cent.	76·5 per cent.

(a) By phosphoric acid. (b) By *o*-cresol.

The differences between the oils centre around the comparative absence of high boiling material in the oil distilled by Baker and Smith, and may be due either to a difference in origin of the two specimens, or to the possibility that the distillation by Baker and Smith was not carried to completion. The first supposition is not in agreement with the views of Baker and Smith on the constancy of composition of oils from a given species of *Eucalyptus*, whilst the second is not in accord with the observed yields. It must be borne in mind, however, that the material used by Baker and Smith would be in a much drier condition than that used in the present investigation, a higher percentage yield of oil therefore being obtainable without distillation to completion.

*Physical properties are given at 20°C unless otherwise stated.

Apart from this, the oils were very similar to one another. Both contained phenols and high boiling aldehydes, and their cineol contents were very similar. Phellandrene was not detected in either, whilst the amount of pinene present was appreciably lower than in otherwise somewhat similar oils; aromadendrene was identified in both.

The esters in the present oil are made up almost entirely of geranyl acetate, whilst about 85 per cent. of the alcohol content is geraniol. There are at least three distinct phenols present, one of which is, in all probability, the solid phenol australol, whilst the other two have not yet been obtained in crystalline form. One of these gives a purple colouration with ferric chloride, whereas the other gives a permanent deep green colour. They have not yet been obtained in sufficient quantity to be fully characterised or identified. On distillation, no separation of white insoluble material was noted as recorded in the oils previously described in this series (Watson, 1934-35), although a small amount of precipitate had settled out during the storage of the oil. Nearly 80 per cent. of the oil was volatile below 195° C. and this rectified oil contained about 54 per cent. of cineol, an amount considerably below the Pharmacopœial requirement for a medicinal eucalyptus oil.

Botanically and in the field, *E. salmonophloia* shows closest similarity to *E. Flocktoniae*, in the texture, character and colour of the bark, the colour of the heartwood, the habitat and in general appearance. The chemical nature of their oils, however, indicates that they are of rather different types. Thus the oil from the salmon gum does not form a precipitate on distillation, and contains phenols and high boiling aldehydes. The presence of the latter is considered by Baker and Smith to be indicative of a higher type of eucalypt.

EUCALYPTUS TETRAGONA.

E. tetragona, the mealy gum or blue mallee, occurs in the southern portion of Western Australia, from the Stirling Range eastwards to Cape Arid. Its leaves are thick and rigid and are covered with a white meal; they are only sparsely dotted with oil glands and the veins are divergent and spaced, the intramarginal vein being removed from the edge.

The material used was collected by Mr. Burvill in May, 1935, in the country adjacent to the south boundary of Esperance Location 444, about 1½ miles north-west of Scaddan, and was identified by Mr. Gardner.

The oil, which distilled very slowly, was pale green in colour, had a pleasant odour and was viscous and sticky. It consisted chiefly of high boiling substances, less than 25 per cent. being volatile below 230° C. This more volatile portion consisted of cineol, *d*-pinene and *l*-phellandrene, whilst the higher boiling material consisted mainly of aromadendrene and the serquiterpene alcohol, eudesmol, together with smaller amounts of geraniol, phenols, aldehydes and esters.

The presence of eudesmol in quantity in this oil is of interest, its occurrence in Western Australian oils having been recorded only once previously, in the oil of *E. accedens*. In the latter case, eudesmol was only present in small amount,* and was not accompanied by phellandrene.

*Baker and Smith, p. 123: "Eudesmol was detected."

EXPERIMENTAL.

EUCALYPTUS SALMONOPHLOIA.

The leaves were steam distilled in the form of the terminal branchlets and they were in a partly air-dried condition. The oil distilled very rapidly at first, about 80 per cent. coming over in the first hour, the distillation being complete in 3½ to 4 hours; the yield of undried oil was 1.40 per cent. by weight. The oil was pale yellow in colour and had a fairly pleasant odour. The dried oil, when examined some seven months later, was golden yellow in colour, and a small amount of insoluble material had separated out. In addition to those already given, the oil had the following properties:—Acid value, 2.2; saponification value (a) hot, 11.8, (b) cold, 11.1; acetyl value (a) hot, 61.7, (b) cold, 54.1.

The high solubility in alcohol indicates a low proportion of hydrocarbons.

The cold saponification value is a measure of the amount of geranyl acetate present (Baker and Smith, p. 367) and corresponds to 3.9 per cent. of this ester. The hot saponification value corresponds to 4.1 per cent. of esters calculated as $C_{12}H_{20}O_2$, leaving the small amount of 0.2 per cent. of esters other than geranyl acetate. The saponification value of the acetylated oil, determined in the cold, corresponds to 11.6 per cent. of geraniol, whilst that determined hot corresponds to 13.7 per cent. of alcohols calculated as $C_{10}H_{18}O$, a difference of 2.1 per cent. of alcohols other than geraniol. The oil slowly restored the colour to Schiff's reagent, showing the presence of aldehydes; estimation by means of hydroxylamine hydrochloride gave 4.5 per cent. by weight of aldehydes calculated as $C_{10}H_{16}O$. With alcoholic ferric chloride, a deepening in colour indicated the presence of phenols, estimated volumetrically to be 4.8 per cent. The oil gave the usual reactions for aromadendrene.

FRACTIONATION.

300 Grams of the oil were distilled under atmospheric pressure and the following fractions separated:—

Fraction.	Boiling Range.	Amount.	Specific Gravity.	Refractive Index.	Specific Rotation.
1	Up to 152°C.	1·7 per cent.	0·8666	1·4493	
2	152–162°	1·5 ,,	0·8829	1·4577	+ 11·05°
3	162–174°	50·45 ,,	0·8970	1·4653	+ 4·98°
4	174–182°	22·8 ,,	0·9097	1·4674	— 3·98°
5	182–195°	2·5 ,,	0·9230	1·4733	— 12·46°
6	195–230°	10·15 ,,	0·9549	1·4871	— 26·05°

The residue (10·75 per cent.) was further fractionated at a pressure of 24 mms.

7	114–135°	2·8 per cent.	0·9550	1·4973	— 32·77°
8	135–160°	1·35 ,,	0·9670	1·5072	— 12·20°
9	160–190°	0·95 ,,	0·9861	1·5096	+ 4·10°

The distillation was then stopped owing to decomposition.

Fraction 1 was colourless and strongly acidic, containing an appreciable amount of acetic acid.

Fraction 2 was pale yellow in colour and had a pinene-like odour. From the combined fractions 1 and 2, an oil rich in pinene was separated and from which the nitrosochloride was isolated in quantity.

Fraction 3 was pale yellow in colour and had a pleasant cineol-like odour. Its cineol content was 52.2 per cent.; acid value, 1.85; saponification value, 5.4 (corresponding to 1.9 per cent. of geranyl acetate); acetyl value, by cold hydrolysis, 16.1 (corresponding to 2.9 per cent. of geraniol), and by hot hydrolysis, 18.9 (corresponding to 3.7 per cent. of alcohols calculated as $C_{10}H_{18}O$). It contained no phenols or aldehydes.

Fraction 4 was practically colourless and had a pleasant camphoraceous odour. Its cineol content was 62.8 per cent. and it contained no aldehydes or phenols. Its acid value was 1.4; saponification value, 12.7 (corresponding to 4.4 per cent. of geranyl acetate); acetyl value, by cold hydrolysis, 35.8 (corresponding to 12.5 per cent. of geraniol), and by hot hydrolysis, 42.5 (corresponding to 14.85 per cent. of alcohols calculated as $C_{10}H_{18}O$). Phellandrene was absent.

Fraction 5 was small and had a very pale yellow colour. Fractions 5 and 6 both contained appreciable amounts of cineol.

Fraction 6 was clear yellow in colour and had strong negative rotation, due partly to aldeyhdes, since the fraction restored the colour to Schiff's reagent. The acid value was 2.3; saponification value, 16.7 (corresponding to 5.8 per cent. of esters calculated as geranyl acetate); cold acetyl value, 150 (corresponding to a total amount of 52.3 per cent. of geranyl acetate or 36.5 per cent. of geraniol in the original fraction); hot acetyl value, 172 (corresponding to a total of 60.0 per cent. of geranyl acetate, or to 42.6 per cent. of alcohols, calculated as geraniol, in the original fraction).

Small quantities of two distinct phenols were present in this fraction. Extraction of the acidic substances gave an oil which partly crystallised; the crystals, when dissolved in alcohol, gave a transient green colour with ferric chloride, the solution then becoming yellow, whilst the liquid gave a fine purple colour when similarly treated. The crystalline body was probably australol (Baker and Smith, p. 396), whilst the phenol giving the purple colouration does not appear to have been described.

Fraction 7 was clear yellow in colour. With ferric chloride it gave a strong orange colouration (possibly due to the presence of another phenol), tinged with purple; high boiling aldehydes and aromadendrene were present.

Fraction 8, which was somewhat deeper in colour, gave a clear purple colouration with ferric chloride; it restored the colour to Schiff's reagent and gave the usual reactions for aromadendrene.

Extraction of the phenolic substance gave an oil of characteristic phenol-like odour. It could not be induced to crystallise; fusion with phthalic anhydride gave no characteristic colouration, whilst coupling with diazotised benzidine gave a deep orange red dye. Neither its benzoyl nor bromine derivatives could be obtained in crystalline form.

Fraction 9 was deep golden yellow in colour and was very viscous. It gave good reactions for aromadendrene, and with ferric chloride gave a permanent deep green colouration. It was not found possible to separate the phenol producing this colour in crystalline form, nor to prepare crystalline derivatives from it.

EUCALYPTUS TETRAGONA.

The oil was distilled from thoroughly air-dried leaves; it distilled extremely slowly, a yield of 0.48 per cent. being obtained on 14 hours' distillation. The dry oil had the following properties:—Specific gravity, 0.9390;

refractive index, 1.4954; specific rotation, + 3.65°; acid value, 1.0; saponification value (hot), 6.8, (cold), 6.6; acetyl value (hot), 107.5, (cold), 19.8; completely soluble in 1 volume of 80 per cent. alcohol, almost so in 10 volumes of 70 per cent. alcohol.

The hot saponification value corresponds to 2.4 per cent. of esters calculated as $C_{12}H_{20}O_2$, and the cold value to 2.3 per cent. of geranyl acetate. The cold acetyl value is equivalent to a geraniol content of 3.6 per cent., whilst the difference between the cold and hot values is equivalent to 32.0 per cent. of alcohols calculated as eudesmol, $C_{15}H_{26}O$. The cineol content (by o-cresol) was 15.4 per cent.; phenols (by caustic absorption), 3.7 per cent.; aldehydes (by hydroxylamine), 0.80 per cent. The aromadendrene content was so high that the colouration with bromine vapour completely obscured the qualitative test for cineol.

FRACTIONATION.

Sixty Grams of the oil were distilled and the following fractions separated:—

Fraction.	Boiling Range.	Amount.	Specific Gravity.	Refractive Index.	Specific Rotation.
1	Up to 160°C.	7·4 per cent.	0·8599	1·4697	+ 20·2°
2	160–195°	12·3 ,,	0·8603	1·4724	+ 12·3°
3	195–230°	5·2 ,,	0·8758	1·4836	+ 9·3°

The residue (75.1 per cent.) was then further fractionated at a pressure of 23 mms.

Fraction.	Boiling Range.	Amount.	Specific Gravity.	Refractive Index.	Specific Rotation.
4	110–140°	4·0 per cent.	0·9245	1·4958	—
5	140–160°	26·1 ,,	0·9526	1·5043	+ 4·3°
6	160–170°	35·6 ,,	—	1·5065	—
7	170–180°	4·2 ,,	—	1·5080	—
	Residue	5·1 ,,			

Fraction 1 was colourless, had a pleasant terpene-like odour and consisted mainly of *d*-pinene.

Fraction 2 was colourless and consisted of cineol, *d*-pinene and *l*-phellandrene (nitrosite, m.p. and mixed m.p. with an authentic specimen from the oil of *E. dives*, 110° C.).

Fraction 3 had a faint yellow colour, contained small amounts of cineol and *l*-phellandrene, and gave a reddish colour with ferric chloride.

Fraction 4 was clear yellow in colour; it had saponification value 30.8 and gave a purplish-red colour with ferric chloride; it contained no aldehydes but gave very strong reactions for aromadendrene.

The remaining fractions appeared to be free from phenols, but all contained considerable amounts of aromadendrene, particularly fraction 5. High boiling aldehydes were present, to greatest extent in fraction 6; esters were present to a lesser extent than in fraction 4, the saponification values of fractions 5 and 6 being 7.4 and 4.3 respectively.

Fraction 7 consisted very largely of eudesmol. It solidified almost immediately and after drying on a porous tile and recrystallising from dilute alcohol, gave the characteristic needle crystals of eudesmol (m.p. 79°). Fraction 6 had a cold acetyl value 22.3, and a hot acetyl value 135.5, the difference corresponding to nearly 45 per cent. of alcohols calculated as eudesmol. On seeding, the eudesmol crystallised out rapidly.

The author wishes to express his thanks to Mr. G. H. Burvill and Mr. C. A. Gardner for their assistance.

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Perth Technical College.

8.—CONTRIBUTIONES FLORAE AUSTRALIAE OCCIDENTALIS No. IX.

By CHARLES A. GARDNER.

Read: 9th June, 1936; Published: 25th August, 1936.

CASUARINACEAE.

Casuarina Dielsiana Gardner sp. nov.

Arbor dioica, ramis erectis; ramulis tenuibus, erectis, flexuosis; internodiis striatis numero non definitis; dentibus 6, deltoideis, appressis, erectis; amentis ♂ nondum cognitis; strobilo ramulum gracilem abbreviatum terminante, ellipsoideo-subgloboso saepe recurvato 6-sticho; bractea lata, crassa, truncata, apice dilatata; bracteolis longe exsertis, integerrimis, ovatis, pallidis, dorso striatis; achaenio atro-fusco, ala obliqua.

Dioecious. An erect tree of 5-7 metres in height, the branches erect, the branchlets slender, flexuose, bright green, with indefinite internodes. Scale-leaves in whorls of 6, erect, appressed, acutely deltoid, hyaline and white in the upper half, the internodes finely striate.

Cones on short slender lateral branches, which are usually spreading or recurved, ellipsoidal to subglobose in outline, 6-stichous, glabrous; bracts broad and thick, almost quadrangular at the truncate apex, and embracing the bracteoles; bracteoles prominently exserted, entire, ovate, obtuse, pale grey in colour, irrgularly striate on the dorsal surface. Achenes oblong-cuneate, dark brown with a transparent oblique wing.

Summit of Mount Singleton on the southern boundary of the Austin District, in red stony soil, W. E. Blackall and C. A. Gardner (2218) 9th July, 1931.

Branchlets 7-16 cm. long; internodes mostly 7-8 mm. long; cones 2-3 cm. long; bracteoles 3.5 mm. broad.

The species has a close affinity to *Casuarina Huegeliana* Miq., from which it differs in the number of teeth to the whorl, the prominent subtending bracts which are as wide as the two bracteoles which they support, and proportionately thick, as well as in the shorter slender flexuose branchlets and striate bracteoles.

I have collected specimens of this species from near Mullewa, in which the number of teeth or scale-leaves is constantly seven, and the cones broader.

The Type is Gardner 2218 in the State Herbarium.

Casuarina tessellata Gardner sp. nov.

Frutex dioicus, ramis rigidis erectis; dentibus 9, appressis, ovatis, rigidis; internodiis valde sulcatis; amentis ♂ nondum cognitis; strobilo erecto, cylindrico, sublaeve, ramulum terminante; bractea lata, truncata, apice triangulari, in cuspidem deciduam producta; bracteolis inclusis, truncato-triangularibus, angustis fissuris tessellatis; achaenio atro-fusco, ala pallida obliqua.

Dioecious. An erect shrub of 3-5 metres in height, the branches rigid and erect; scale-leaves in whorls of 9, erect, appressed, ovate, rigid; internodes deeply sulcate. Cones erect, terminating short erect branches, cylindrical, almost smooth, dark grey in colour; bracts broad, truncate, triangular at the apex with a deciduous setaceous point, finely fissured; bracteoles not exserted beyond the bracts, triangular-truncate, and along with the bracts presenting a uniform tessellated or finely fissured surface; achenes black, the oblique wing hyaline.

Branchlets 9-12 cm. long; internodes 9-11 mm. long; cones 3.5-4.5 cm. long, 1.5-1.9 cm. diameter; bracteoles 2.5 mm. broad.

Near the southern boundary of the Austin district, on the northern slopes of Mount Singleton, forming dense thickets in red loamy soil. W. E. Blackall and C. A. Gardner, 9th July, 1931.

This species is closely related to *Casuarina Helmsii* Ewart and Gordon, but differs from that species in the distinctly sulcate branchlets, the cones not sessile, but always on distinct peduncle-like branches, and the thick and prominent bracts, while the bracts of *C. Helmsii* are so thin that the apertures formed by the opening bracteoles appear continuous.

The Type is Gardner 2217, in the State Herbarium, Western Australia.

PROTEACEAE.

Grevillea scabrida Gardner sp. nov.

Frutex intricato-ramosus; foliis linearibus, 5-nervosis, marginibus incrassatis, verrucoso-scabriusculis, apice mucronulato, saepe recurvato; racemis plerumque terminalibus attenuatis, umbellatis; floribus flavis; pedicellis pilosis, crassis; perianthio parvo, angusto, sub limbo globoso recurvato; glandula hypogyna inconspicua; ovario stipitato, pilis adpressis vestitis; stylo glabro, disco obliquo laterali.

An erect shrub leafy in the upper portions, densely and intricately branched, the branches and branchlets glabrous. Leaves linear, tapering into a short petiole, 5-nerved, the margins revolute and nerve-like, the five nerves and the nerve-like margins scabrid with minute tubercles, the apex mucronate-acute, often recurved. Racemes short, sub-umbellate, terminal or rarely in the upper axils, the flowers yellow or greenish; rhachis very short, with appressed hairs; pedicels rather thick, sparsely pubescent with appressed hairs; torus straight; perianth narrow, short, revolute under the globular limb, the tube not dilated, straight, sparsely appressed-pubescent outside, bearded inside in the upper portion with short and dense woolly hairs; hypogynous gland very small and thin, semiannular; ovary distinctly stipitate, appressed-pubescent; style glabrous, short, with an orbicular oblique stigmatic disc. Fruit ovoid-elliptical, pale, smooth, with a long beak formed by the persistent style.

Leaves 3.5-4.5 cm. long, 1-1.5 mm. wide; racemes 1 cm. diameter; pedicels 3-4 mm. long; perianth 2.5 mm. long; style 3.5 mm.; fruit 8 mm. long without the persistent style; base 4 mm. wide.

At the southern boundary of the Austin District, near the northern base of Mount Singleton, in red loamy soil in stony ground, fl. m. July. W. E. Blackall and C. A. Gardner, 9th July, 1931.

This species belongs to the Section Lissostylis, but differs from all other species of this Section in the appressed-pubescent ovary. It is closest to

G. brachystachya Meissn., from which it differs in the shape and vestiture of the leaves, appressed-pubescent perianth, and the presence of the small hypogynous gland.

The Type is Gardner 2210, in the State Herbarium, Western Australia.

Grevillea Blackallii Gardner sp. nov.

Frutex erectus; foliis lineari-teretibus, rigidis, utrinque angusto-sulcatis, junioribus tomentosis, adultis glabris; racemis paucifloris (2-5), sessilibus, axillaribus vel e ramulis lateralibus; pedicellis crassis, tomentosis; perianthio rubro extus albo-tomentosis, intus glabro, fauce breviter pilosa excepta, sub limbo globose-revoluto; toro obliquo; glandula hypogyna semilunari; ovario subsessili; dense tomentoso; stylo glabro; stigmate obliquo laterali; fructu nondum cognito.

A small bushy shrub, the branchlets ± erect, 30-45 cm. in height, and as much or more in diameter. Leaves erect, rigid, linear-terete, narrowly sulcate along each side, otherwise terete and smooth, tomentose when young, but becoming glabrous with age, the apex rigidly pungent. Racemes in the axils of the lowest leaves, or lateral below the leaves, sessile, reduced to clusters of 2-5 flowers; pedicels rather stout, densely tomentose; perianth densely tomentose outside with crisped woolly hairs, the tube somewhat dilated below the middle, revolute under the globular limb, glabrous inside except for some short crisped hairs on the lower side in the throat; torus oblique, the gland side the shortest; hypogynous gland prominent, semilunar, thin; ovary almost sessile, attached near the upper margin of the torus, densely tomentose-villous with white hairs; style glabrous, elongated, the stigmatic disc broad, orbicular, obliquely lateral; fruit not seen.

Leaves 7-10 cm. long, 1 mm. diameter; pedicels 5 mm. long; perianth 9 mm. long; style 1.6 cm. long.

Austin district, in red sand with *Triodia* and *Keraudrenia integrifolia,* near Payne's Find, fl. m. June-July. W. E. Blackall and C. A. Gardner, 10th July, 1931.

The species is named after William Edward Blackall, M.B. M.R.C.S., L.R.C.P., in recognition of his services to Western Australian botany, and to whom the author feels especially grateful for assistance whilst collecting and diagnosing specimens.

The affinity of this species is with *Grevillea haplantha* and its allies. It approaches *G. haplantha* F. v. M. in its floral structure, but differs in the tomentose indumentum of the perianth externally, and in the paucity of hairs inside, and more particularly in the leaf itself, this being, in *G. haplantha,* broadly channelled or doubly grooved underneath, and distinctly compressed, while the style is pubescent or villous. There are several specimens of *G. haplantha* in the State Herbarium, which show some variation in size and venation of the leaf. The species is a polymorphic one, in which the Avon district forms have a leaf with from 3 to 5 ± distinct nerves on the upper side, while the south coastal and typical form has a nerveless upper surface. The new species is also closely allied to *G. Yorkrakinensis* Gardner, which has a similar torus (described in error as straight), but the leaves of *G. Blackallii* are considerably longer and terete. The three species may be contrasted as follows, including the Avon district form of *G. haplantha* F. v. M.:

A. Leaves distinctly flattened, doubly grooved underneath by the closely revolute margins; style hairy or pubescent.

a. Leaves nerveless above .. .. .. G. haplantha F. v. M. (typical form).

b. Leaves with 3-5 prominent longitudinal nerves on the upper side .. .. G. haplantha F. v. M. (Avon district form).

B. Leaves terete or subterete, narrowly sulcate, style glabrous.

a. Perianth appressed-pubescent, small, sparsely hairy inside with erect hairs; leaves 6-12 mm. long, the sulcae ventral .. .. G. Yorkrakinensis Gardn.

b. Perianth tomentose outside; sparsely hairy in the throat; sulcae lateral, opposite .. .. G. Blackallii Gardn.

The Type is Gardner 2224, in the State Herbarium.

Grevillea stenostachya Gardner sp. nov.

Frutex, ramis intricato-divaricatis; foliis triternato-pinnatis, segmentis teretibus, pungentibus, divaricatis; racemis gracilibus, glabris, elongatis; perianthio erecto, glabro, sub limbo ovoideo revoluto, segmentis angustis; toro plano; glandula hypogyna nulla; ovario sessili, tenuiter piloso; stylo tenui incrassato sub cono stigmatico erecto; fructibus nondum repertis.

An erect bushy shrub of 60-90 cms. in height, with divaricate intricate branches, the bark grey, smooth. Leaves intricate, once, twice, or thrice ternately divided with rigid divaricate pungent pointed segments, the segments terete, smooth. Racemes slender, glabrous, axillary, elongated and comparatively few-flowered, the rhachis slender, glabrous. Pedicels slender, glabrous; perianth erect, the buds clavate, the limb ovoid-elliptical, segments glabrous inside and out, narrow; torus straight; hypogynous gland absent; ovary sessile, nearly globular, sparingly villous; style, obliquely or almost laterally attached, folded above the base, slender, but obpyramidally thickened upwards under the erect stigmatic cone, without any constriction below the cone.

Leaves 2-4.5 cm. long, the ultimate and primary segments about 1 cm. in length; racemes 5-8 cm. long, the flowers scattered or subverticillate; pedicels 2.5 mm. long; perianth 3 mm. long, yellow; style equal in length to the perianth segments.

Austin district: 16 miles west of Meeberrie Homestead on the Murchison River, in red sand in thickets of *Grevillea eriostachya* Lindl., W. E. Blackall and C. A. Gardner, 24th August, 1931.

This species has an affinity to *Grevillea paradoxa* F. v. M., but differs essentially in its few-flowered racemes, slender glabrous rhachis, and absence of the hypogynous gland. Amongst those species of *Anadenia* which do not possess a hypogynous gland it is perhaps closest to *G. stenocarpa,* which has an almost similar floral structure, but the leaves are entire, flattened and striate, while those of *G. stenostachya* are always divided and smooth.

The type is Gardner 2537 in the State Herbarium.

Hakea bucculenta Gardner sp. nov.

Frutex erectus; foliis anguste-linearibus, acutis, erectis, uninerviis, rigidis; racemis elongatis, densifloris, axillaribus; floribus rubris; glabris; pedicellis brevibus; perianthio angusto sub limbo ovoideo revoluto; toro plano; glandula hypogyna ampla semilunari; ovario sessili, glabro; stylo elongato; cono stigmatico angusto, paulum obliquo; fructu ovoideo basi globuloso apicem versus compresso, laeve; seminis ala margine superne decurrente.

A shrub of 1.5-2 metres in height, erectly branched, with the appearance of the narrow-leaved forms of *Hakea multilineata* Meissn., the bark smooth. Leaves sparse, narrow-linear, entire, rigid, erect, acute, flat 1-nerved, the margins thick, tapering towards the base but expanded again at the base itself. Racemes axillary, enclosed before development within imbricate scarious brown bracts, lengthening into narrow spike-like racemes with numerous crowded scarlet flowers, quite glabrous. Pedicels short; perianth-tube narrow, revolute under the ovoid limb; torus straight; hypogynous gland thick, semilunar; ovary sessile, glabrous; style elongated, more than twice as long as the perianth, glabrous, the stigmatic cone narrowly conical and somewhat oblique. Fruit ovoid, the valves flattened in the upper portion, much swollen below into a globular base giving the fruit the appearance of two basal cheeks, smooth, grey, not beaked; seeds black, the wing decurrent only along the upper margin of the nucleus.

Leaves 12-17 cm. long, 1.5-2 mm. wide; racemes 8-9 cm. long; pedicels 1.5 mm.; perianth 5-6 mm.; style 1.7 cm. long; fruit 2 cm. long, 1.7 cm. broad in the lower half, 1.2 cm. wide above the thick base, the valves 3 mm. thick.

Austin district: In red sand in thickets, 30 miles north of the Murchison River to the south of Shark Bay, W. E. Blackall and C. A. Gardner, 29th August, 1931.

The affinity of this species is with *Hakea multilineata* Meissn., from which it differs in the narrower 1-nerved acute leaves, differently shaped hypogynous gland, sessile ovary, and differently shaped fruit.

The Type is Gardner 2571, State Herbarium, Western Australia.

PAPILIONACEAE.

Oxylobium Bennettsii Gardner sp. nov.

Frutex erectus; foliis oppositis oblonge-lanceolatis, coriaceis, reticulatis, mucronatis, basi rotundatis; racemis elongatis plerumque terminalibus; pedicellis tenuibus; calyce glabro, lanato-ciliato; floribus aurantiaceis; ovario villoso, stipitato; stylo brevi, incurvo; legumine lignoso, ovoideo, acuto, glabro, apice dehiscente; seminibus in textura fibroso-spongiosa insertis.

An erect branching shrub 3-12 decimeters in height, glabrous except the margins of the calyces and the ovary, the branchlets terete or slightly angular, purple in colour. Leaves opposite, lanceolate-oblong, coriaceous, obtuse with a small black mucro, prominently reticulate above with raised nerves, lustrous, paler underneath, the secondary nerves anastomosingly reticulate, shortly petiolate, the base rounded and obtuse, sometimes subcordate; stipules linear, straight, rigid, rather prominent. Racemes terminal and sometimes also axillary, elongated, forming leafy panicles, the rhachis angular; pedicels irregularly verticillate, slender, thickened upwards under the calyx; calyx-tube broadly campanulate, the lobes somewhat shorter than the tube, all woolly ciliate on the margins, the woolly hairs extending some distance inside, the upper lobes broad, rounded, united almost to the apex in an almost truncate emarginate upper lip with crenulated margins, the lower lobes rather shorter, ovate-deltoid and sub-acute; standard orbicular-reniform, large, orange-scarlet with a yellow spot near the apex of the claw; wings oblong-falcate; keel obtuse, deep purple. Ovary villous, distinctly stipitate, the stipes lengthening in fruit; style very short, incurved, stout; ovules 6-8. Pod ovoid-oblong, almost woody, hard and glabrous, dehiscing in the upper half only; seeds usually 2, oblong-reniform, black, smooth, embedded in a stringy tissue which traverses the whole interior around the seeds.

Leaves 4-5 cm. long, 1.6 cm. broad near the base; petiole 3-5 mm.; racemes up to 12 cm. long; pedicels 5-7 mm.; calyx 4.5 mm.; upper lip 1.8 mm.; lower lobes 1.5 mm. long; standard 10-12 mm. diameter; pod 1.0 cm. long, 4.5 mm. diameter.

Stony clay soil, Ravensthorpe Range, fl. m. Novem.-Decem. A. J. Milesi and C. A. Gardner, 10th November, 1935.

This species is closely related to *Oxylobium graniticum* S. Moore, but differs essentially in the shape of the leaf which is always obtuse and broad at the base, whereas in *O. graniticum* the lamina always tapers gradually into the petiole. The branchlets are not prominently angular, the rhachis is glabrous, and the style shorter. The pods of the two species are very different. Those of *O. graniticum*, which have not been described, are coriaceaus, not woody, ovoid, and obliquely mucronate, turgid with an indented upper suture, and without internal pith, while those of *O. Bennettsii* are smaller, acute, and distinctly woody, with a stringy pith.

I have named this toxic species after Harold William Bennetts, D.V. Sc., who has collaborated with me on several investigations made with toxic species, and past President of the Royal Society of Western Australia.

The Type is in the State Herbarium, Western Australia.

DILLENIACEAE.

Hibbertia miniata Gardner sp. nov.

Frutex erectus, ramis tomentoso-pubescentibus; foliis oblanceolatis, obtusis, tomentoso-pubescentibus, adultis supra glabrescentibus; marginibus recurvis; floribus aurantiaco-rubis, terminalibus aut in capitulis simulantibus; pedunculis brevibus; bracteis magnis, acutis, glabro-scariosis; sepalis extus sericeo-pubescentibus; petalis profunde 2-lobatis; staminibus circum carpella dissitis, filamentis tenuibus, antheris atro-violaceis, oblongis, vertice obliquis foraminibus dehiscentibus; carpellis 5, sericeo-villosis, biovulatis.

An erect shrub of 30-45 cm. in height, the branches stout, erect, dense, the branchlets erect, the plant almost globular in outline. Leaves oblanceolate, sessile, tapering towards the base, obtuse, tomentose-pubescent with grey ± appressed hairs, becoming glabrous above in the older leaves, the margins recurved, becoming revolute upon drying, the midrib prominent beneath, impressed above. Flowers large, terminal, solitary or two or three together, shortly pedunculate; bracts broad, scarious, chestnut-brown, ovate to ovate-lanceolate, acute, concave, glabrous, shining; peduncles silky-pubescent, very short; sepals ovate-lanceolate, silky with a white appressed pubescence, acute; petals large, orange-red, obovate, deeply 2-lobed; stamens numerous, situated all round the carpels without staminodia, the filaments slender, white, anthers oblong, purple-black, dehiscing in oblique terminal slits; carpels 5, silky, 2-ovulate.

Leaves 3-3.5 cm. long, 4-7 mm. broad; bracts 1-1.2 cm. long; sepals 1-1.2 cm. long; petals fully 2 cm. long, 1.5 cm. broad, usually lobed to the middle.

Between Chittering and New Norcia, in dry gravelly soil in woodlands of *Eucalytus marginata* and *E. redunca* var. *elata*. fl. m. July-August, E. & C. A. Gardner, July 1934.

This species belongs to the section *Cycladenia*, series *Bracteatae*, but the flowers are scarcely sessile, and the bracts are deciduous, although these features, together with the size of the bracts, would appear to justify this inclusion. It has a close affinity to *H. quadricolor* Domin, *H. Mylnei* Benth., and *H. argentea* Steud. From *H. quadricolor* it is to be distinguished by the absence of staminodia, in habit, the number of carpels, pedunculate flowers and revolute leaves; from *H. Mylnei* (which I have not seen) it can be distinguished by the silky-pubescent sepals, the absence of staminodia and the number of carpels, while the silky carpels, which are 5 in number, and the absence of staminodia serve to distinguish the plant from *H. argentea*. It also differs from all of the above in the colour of the flowers and the purple anthers.

All of the Cycladenia-Bracteatae so far examined have anthers which dehisce by terminal oblique pores, although in some the pores are longer and more oblique than in the species described above. This character, which has not been referred to previously, may be found to be constant for the Bracteatae. It brings the genus *Hibbertia* still closer to *Wormia*, which differs from Hibbertia principally in this character. This feature is not readily noticeable in boiled flowers, since through the action of hot water the pores close, but it is at once apparent in the living and dried specimens, and the writer's attention was directed to it in the living plant of *Hibbertia miniata* by reason of the marked contrast between the deep purple exterior of the anther, and the white interior of the thecae. These deep purple anthers are quite unlike those of any Hibbertia known to me, by reason of their colour.

The type specimen is in the State Herbarium, Western Australia.

VIOLACEAE.

Hybanthus cymulosus Gardner sp. nov.

Frutex erectus; foliis lanceolatis, flaccidis; cymis divaricatis; floribus magnis, violascentibus; petalis supernis quam sepala brevioribus, petala infima multo longiore ad basin saccata; antherae appendice lata aurantiaca.

An erect shrub of 60-90 cms. in height, with erect and spreading stems and almost divaricate branches, the bark pale, thin, but corky. Leaves mostly alternate, narrow-lanceolate to almost linear, soft, acute, tapering towards the base, uninerved, entire; stipules minute. Flowers large in axillary divaricate cymes consisting of from three to several flowers, the terminal flower soon deciduous; bracts similar in outline to the leaves but smaller; bracteoles small, linear, with recurved apices. Sepals united at the base, lanceolate, acuminate, three-nerved, the two lower sepals smaller and narrower than the three upper ones. Petals pale violet, the four upper ones ovate-oblong, obtuse, shorter than the sepals, fimriate-ciliolate; lowest petals cuneate-obovate with a broad claw, retuse, saccate or gibbous at the base and bearded above the cavity, with two folds or callous ridges united into one above the claw of the petal; anthers subsessile, the filaments very short, the connective produced into an orange-coloured obovate retuse appendage as long again as the anther cells; style flattened, somewhat falcate, slightly exceeding the connective appendages. Capsule globular, black, slightly exceeding the calyx, with usually one flat minutely granular seed.

Leaves 2-4 cm. long, 2-3 mm. wide; cymes 3 cm. long; flowers 1-1.3 cm. long; sepals 3-4 mm. long; upper petals slightly shorter; lowest petal 1-1.3 cm. long.

Austin district, at the northern base of Mount Singleton, in red stony soil, fl. m. July, in shady spots. W. E. Blackall and C. A. Gardner, 9th July, 1931.

The species is close to *H. floribundus*, from which it differs in the much larger flowers (the lowest petal being quite as large as that of *H. calycinus*), the lanceolate-acuminate sepals, and the absence of spurs to the lower stamens, as well as in the distinctly cymose inflorescence. It differs from *H. enneaspermus* in the lateral and upper petals being all similar and shorter than the sepals, and in the inflorescence.

The type is Gardner 2212, in the State Herbarium.

MYRTACEAE.

Eucalyptus Stoatei Gardner sp. nov.

Arbor erecta; ramulis acuto-angulatis; foliis alternis obtusis, mucronatis, ovato-oblongis; pedunculis angulatis axillaribus, floribus solitariis anthesim pedicellis non manifestis; calycis tubo costato; operculo conico-hemisphaerici; staminibus ante expansionem incurvis; fructu coccineo pyriforme profunde sulcato, valvis 3, inclusis.

An erect tree of 7-10 metres with smooth green-grey thin bark, the branches erect, dense, the branchlets acutely angular. Leaves mostly ovate-oblong, almost symmetrical, thickly coriaceous and rigid, dark green and shining, drying pale, alternate, obtuse but mucronate, the midrib distinct, the secondary nerves irregular, forming an angle of 45 degrees with the midrib, the intramarginal nerve 1.5 mm. from the margin, petiolate, the petioles angular. Peduncles axillary, solitary, recurved, angular, broadened and thickened upwards, bearing a solitary flower, the pedicel not evident before anthesis, the calyx tube gradually tapering towards the base; calyx-tube turbinate-pyriform in outline, deeply and irregularly ribbed, four of the ribs usually more prominent than the others, straight or curved, scarlet when in bud, flower and fruit, but drying brown; operculum widely and obtusely conical, ribbed, the broad umbonate apex smooth, constricted at the commisural line; filaments rich yellow in colour, incurved, but not inflected in the bud, angular, smooth; anthers ovoid-oblong, opening in longitudinal slits, the filament attached near the base, the gland dorsal; style very short and thick. Fruit pyriform, decumbent, tapering into an angular pedicel, deeply and irregularly ribbed, the number of ribs usually about 12, of which the principal are often branched towards the summit and rounded over the top, smooth between the ribs; disc narrow, capsule deeply sunk with three deeply included subulate valves; fertile seeds black, angled, ± pyramidal, with an irregular wing.

Leaves 8-11 cm. long, the lamina 6-8 cm. long, 2.2-3.6 cm. wide; peduncles 2-3 cm. long in flower, 4-5 cm. long in fruit; calyx-tube 3-3.3 cm. long, the operculum 1 cm. long; fruit 4-4.5 cm. long (including the pedicel), 3 cm. diameter in the broadest part, the orifice 9 mm. wide.

Eyre District: Bandalup Creek, near Kundip. K. F. Dureau and J. E. Harrison, June, 1935.

The species is a very distinct one, having no close affinities, and belongs to the Section Macrantherae, Series Incrassatae. It appears to be closest to *Eucalyptus Forrestiana* Diels, from which it differs essentially in the irregular ribs of the calyx and fruit which are indefinite in number. It also shows an affinity to *E. angulosa* Schau, differing amongst other features in the pyriform fruit and solitary flower on the long pendant peduncle, and the shorter operculum. The plant is of considerable decorative value because of its habit, deep glossy foliage, and strikingly scarlet buds and fruits, in which it bears a certain resemblance to *E. Forrestiana* Diels.

I have named this species in honour of Theodore Norman Stoate, Senior Assistant Conservator of Forests in Western Australia, whose interest in the forest flora of South-Western Australia has resulted in the acquisition of several interesting specimens for the State Herbarium, and who first collected fruits of this tree.

The type specimen is in the State Herbarium.

Eucalyptus mitrata Gardner sp. nov.

This name is proposed in place of *Eucalyptus coronata* Gardner, described in this Journal, vol. xix 86 (1933). The name E. coronata was used by Tausch, in Herb. Bauer, Ferd, Bauer in Herb. Vind. ex Maiden, Bull. L'Her. Boiss ii. 570 (1902). It is a synonym for *E. tereticornis* Sm.

NOTES ON THE TYPES OF *Spirifer rostalinus* HOSKING.

By K. L. PRENDERGAST, B.Sc. (Hons.).

INTRODUCTION.

The following notes have been submitted to avoid any possible confusion due to the fact that no particular specimens were named as types in Miss Hosking's description of *Spirifer rostalinus*.

Spirifer rostalinus Hosking.

1931.—*Spirifer rostalinus* Hosking. Fossils from the Wooramel River District, Western Australia: Journ. Roy. Soc. W.A., Vol. XVII., p. 24, Pl. VIII., fig. 3, Pl. VIIIA., fig. 4.

The author of this species has now selected as the holotype a specimen of the Geological Survey of Western Australia No. 1 4949x, figured in the original paper on Pl. VIII., fig. 3.

Spirifer rostalinus var. auritus Hosking.

1931.—*Spirifer rostalinus* var. *auritus* Hosking. Fossils from the Wooramel River District, Western Australia: Journ. Roy. Soc. W.A., Vol. XVII., p. 24, Pl. VIIIA., fig. 5-7, Pl. X., fig. 1a-c.

As indicated in the text (p. 24) the holotype (G.S.W.A. No. 1 4949y) is figured on Pl. VIIIA., fig. 7a-c, and the paratypes on Pl. VIIIA., fig. 4-7, and Pl. X., fig. 1a-c.

Spirifer rostalinus var. tumidus nom. nov.

1931.—*Spirifer rostalinus* var. *crassus* Hosking. Fossils from the Wooramel River District, Western Australia: Journ. Roy. Soc. W.A., Vol. XVII., p. 24, Pl. VIII., fig. 1-2, Pl. VIIIA., fig. 8, Pl. IX., fig. 1a-d, Pl. XI., fig. 1-2. (not. *Spirifer crassus* de Kon, 1842, Description des foss. de Belg., p. 262, Pl. 15, fig. 5).

Mr. F. Chapman, the Commonwealth Palaeontologist of the National Museum, Melbourne, very kindly pointed out that the name "crassus" having been used previously to distinguish a species of Spirifer (*Spirifer crassus* de Kon.) it is necessary to rename this variety.

The holotype is figured in the original paper on Pl. VIII., fig. 2, and Pl. IX., fig. 1a-d, and the paratypes on Pl. VIII., fig. 1, Pl. VIIIA., fig. 8, Pl. XI., fig. 1-2.

Holotype No. G.S.W.A. 1/4949z.

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