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Royal Society of Western Australia

Journal

Vol. 23

1936-37

National Museum of Victoria

FRED. WM. SIMPSON, GOVERNMENT PRINTER, PERTH.

1937.

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JOURNAL

OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA, INC.

Founded 1913 :: :: Incorporated 1937

Vol. XXIII
1936-1937

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

Printed for the Society by
FRED. WM. SIMPSON, GOVERNMENT PRINTER, PERTH.

1937.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

OFFICERS AND COUNCIL, 1936-37.

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His Majesty the King.

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

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T. H. Wilson.

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VOLUME XXIII.

ROYAL SOCIETY OF WESTERN AUSTRALIA.

ANNUAL REPORT OF COUNCIL FOR THE YEAR ENDED 30TH JUNE, 1937.

Ladies and Gentlemen,

Your Council begs to submit the following report for the year ended 30th June, 1937.

Patronage of the Society.—An address has been tendered to His Majesty King George VI. through His Excellency the Lieutenant-Governor of Western Australia, asking him to honour the Society by accepting the office of Patron, formerly held by his late revered father, King George V.

Membership.—There has been an increase in membership during the year, there now being 95 ordinary members, 58 associate members and 17 student members, a total increase of 21.

Owing to the death of Major R. Thynne and Prof. W. Michaelson the number of honorary members has been reduced to 7. The Endowment Fund of the Society was instituted as a result of a generous gift of £100 from Major Thynne to the Society, while Professor Michaelson will always be remembered for his original researches on the biology of Western Australia.

During the year Miss Kathleen Prendergast and Mr. R. T. Prider were elected corresponding members of the Society, thereby bringing the number of corresponding members to 8. The Council has noted with pleasure the election of Miss Prendergast as an 1851 exhibitioner, enabling her to continue her researches on Western Australian paleontology at Cambridge University.

Council.—Eleven ordinary meetings and one adjourned meeting have been held during the year.

During the year it has been found necessary to set aside one night a month adequately to discuss the business awaiting completion, and in spite of the increased claims made on the time of members all Council meetings have been well attended.

In November Mr. W. E. Shelton relinquished the office of Joint Honorary Secretary, Mr. K. R. Norris accepting this position.

Finance.—The satisfactory position disclosed by the balance sheet must be attributed in no small measure to the careful management and supervision of the Society finances by the retiring Hon. Treasurer, Mr. H. Bowley.

The Government Grant has been restored to the former amount of £100 and the Council wishes to express its appreciation of this assistance as, without it, it would not be possible to publish the Journal in its present form.

Journal.—Volume XXII. has now been published and distributed amongst members and scientific institutions with which the Society is in exchange.

The Government Printer and his staff have co-operated whole-heartedly with the Editor, Mr. B. L. Southern, and the Council desires to thank them sincerely. Mr. 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 162 scientific institutions, 48 of which are in Australia, 17 in the United Kingdom, 18 in other parts of the British Empire, 40 in North and South America, 35 on the Continent of Europe, and 3 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.

Award of Royal Society's Medal.—The Royal Society's Medal for distinguished work in science connected with Western Australia has been awarded to Mr. A. Gibb Maitland, F.G.S. The presentation of the Medal will be made in October at a conversazione to be arranged jointly with the University in honour of the visiting members of the Executive of the Council for Scientific and Industrial Research.

Recognition of Services of Mr. W. E. Shelton.—As stated earlier, Mr. W. E. Shelton relinquished the position of Joint Hon. Secretary owing to his appointment as Principal of the Narrogin School of Agriculture. Mr. Shelton's lengthy term of service to the Society during which he has held almost every office in the Society including that of President, has earned the sincere appreciation of members who subscribed an amount enabling a presentation to be made to him prior to his leaving Perth.

Incorporation.—The steps necessary for the incorporation of the Society have now been completed and we anticipate receiving the certificate of incorporation early in the new financial year.

Endowment Land.—Council has been considering the need for acquiring a block of land on which a suitable building might be erected at a later date. A case for a grant of land from the Government has been prepared and a deputation to the Premier is now being arranged.

F. G. FORMAN,
President.

L. W. PHILLIPS,
Joint Hon. Secretary.

It gives me pleasure to place on record my appreciation of the services rendered to me by officers and members of Council, particularly the Honorary Secretary, Mr. L. W. Phillips.

F. G. FORMAN.

Royal Patronage.

Advice has been received that His Majesty King George VI. has been graciously pleased to accept the office of Patron of the Society.

His Excellency the Lieutenant-Governor, Sir James Mitchell, has accepted the office of Vice-Patron.

ROYAL SOCIETY OF WESTERN AUSTRALIA.

Statement of Receipts and Expenditure for the Year ended 30th June, 1937.

General Fund

Receipts.

	£ s. d.
General Fund—	
Balance, 1st July, 1936	97 5 4
Interest, 1935-36	2 14 1
Subscriptions	120 13 9
Government Grant	100 0 0
Authors' Reprints and Refunds for Half Cost of Blocks	26 7 5
Members' Contributions (Presentation Fund)	2 18 0
	£358 18 7

Payments.

	£ s. d.	£ s. d.
Petty Expenses, including Postages, etc.		20 5 3
Clerical Assistance		7 19 9
Annual Meeting, Rent	3 10 6	
" " Catering and Heating	9 15 0	
" " Sundries	0 12 6	
		13 18 0
Ordinary Meetings—Catering		8 7 6
Professor Lloyd's Lecture—Expenses		2 16 4
Museum Trustees, Rent and Attendance		8 16 0
Editor's Honorarium		15 15 0
Presentation		3 0 0
Incorporation Expenses		12 0 0
G.P.O., Box L906—Rent		3 0 0
Transfer to Medal Fund		7 10 0
Government Printer—		
Vol. XXII., completing	71 8 2	
Vol. XXIII., part cost	20 13 3	
Rules, printing	9 3 3	
Miscellaneous printing	7 4 8	
		108 9 4
Balance 30th June, 1937		147 1 5
		£358 18 7

Medal Fund

Receipts.

	£ s. d.
Medal Fund—	
Balance at 1st July, 1936	22 19 0
Interest	0 8 7
Transfer from General Funds	7 10 0
	£30 17 7

Payments.

	£ s. d.
Balance at 30th June, 1937	30 17 7
	£30 17 7

Endowment Fund

	£ s. d.
Endowment Fund—	
Balance at 1st July, 1936	176 4 11
	£176 4 11

	£ s. d.
Balance at 30th June, 1937	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%.

Summary of Funds at 30th June, 1937

	£ s. d.
Credit Balance, General Fund	147 1 5
" " Medal Fund	30 17 7
" " Endowment Fund	176 4 11
	£354 3 11

Perth, 9th July, 1937

H. BOWLEY, Hon. Treasurer.

Unpresented Cheque at 30th June, 1937, No. 104—14s. 8d.
Bank Pass Book at 30th June, 1937—Credit Balance, £147 16s. 1d.

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,
H. P. ROWLEDGE,
Hon. Auditors.

ABSTRACT OF PROCEEDINGS, 1936–37.

16TH JULY, 1936—

Annual General Meeting held at Karrakatta Club. Presidential Address: "Water Supply in the Wheatbelt and Kalgoorlie Regions."

11TH AUGUST, 1936—

Lecture—Held at Burt Memorial Hall—"Carnivorous Plants of the World," Professor F. E. Lloyd, McGill University, Montreal.

8TH SEPTEMBER, 1936—

Papers—"Permian Corals of Western Australia," Dr. Dorothy Hill. "A Note on the Occurrence of Amphipora ramosa in Western Australia," Miss Elizabeth Ripper. Both papers were communicated by Professor E. de C. Clarke.

Lecture—"Mycorrhiza in Relation to Pine and other Plant Growth," Miss N. T. Burridge.

13TH OCTOBER, 1936—

Address—"Some Impressions Gained Abroad, Europe," Dr. Dorothy Carroll.

10TH NOVEMBER, 1936—

Papers—"The Essential Oils of West Australian Eucalypts," G. E. Marshall and E. M. Watson. "Contributiones Florae Australiae Occidentalis." C. A. Gardner.

Lecture—"Notes on Utricularia and Polypompholyx." Professor F. E. Lloyd.

8TH DECEMBER, 1936—

Paper—"Zoological Results of a Trawling Cruise in the Great Australian Bight," D. L. Serventy.

Presentation—Presentation of the Hector Memorial Medal to Professor Weatherburn on behalf of the Royal Society of New Zealand.

Exhibits—

The President—Some Rocks from the Yilgarn Goldfields.

Mr. R. C. Wilson—"The Konimeter used for Dust Counts and Radiographs illustrating Silicosis."

Mr. L. Glauert—"Jewel Beetle of Western Australia."

Mr. Steedman—"Native Flora."

Mr. F. J. Mayne—"Iron Stalactites from Collie Coal Mines."

9TH MARCH, 1937—

Paper—"The Mineralogy and Relationships of Soils from Kalgoorlie, Southern Cross and other Areas in the Western Australian Goldfields," Dr. Dorothy Carroll.

Report—"The Meeting of the Australian and New Zealand Association for the Advancement of Science at Auckland." Dr. E. M. Watson.

13TH APRIL, 1937—

Lecture—"Recent Advances in Atomic Physics," Dr. R. R. Nimmo.

11TH MAY, 1937—

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

Address—"New Zealand," Dr. L. J. H. Teakle.

8TH JUNE, 1937—

Paper—"The Suspensor and Embryo of Actinostrobus."

Address—"Technical Education in Great Britain," Mr. L. W. Phillips

EXHIBITS.

9th March, 1937—Anhydrite from Croesus Pty. Mine and "red rain" which fell in Perth on 10th February; Dr. E. S. Simpson.

8th June, 1937—Meteorites from Gundaring and Yalgoo. Permo-Carboniferous fossils from Mt. Marmion, originally described as sponges. The fossils were more correctly classed as Echinoderms, and not Calceolispongia; Mr. L. Glauert. *Camptostemon Shultzii* Masters from Rev. J. R. B. Love, Kunmunya Mission. This tree constitutes the first record of this genus in Western Australia; Mr. Meadly.

ROYAL SOCIETY OF WESTERN AUSTRALIA.

List of Members as at 1st July, 1937.

HONORARY MEMBERS.

Bird, Mrs. A. M.—The Old Farm, Albany.
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Diels, Dr. Ludwig—Director of Botanical Garden and Museum, Berlin-Dahlem, Germany.
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Alexander, W. B., M.A.—120 Croydon Road, Reigate, England, *or*, Department of Zoology, University Museum, Oxford.
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Gatherer, R. E.—Royal Mint, Perth.
Garner, W. B., F.C.S., M.P.S.—C/o. F. H. Faulding & Co., Murray Street, Perth.
Glauert, L., B.A., F.G.S.—The Museum, Perth.

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Little, R. J.—Government Statistician's Office.
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Adams, A. B., Dip. Agric. (W.A.)—Agricultural College, Muresk.
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Lovegrove, J. A.—9 Riley Road, Claremont.
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Mayne, S. J., B.A.—21 Meadow Street, Guildford.
McLean, K. W., B.A.—84 King George Street, South Perth.
Mulcahy, Miss G. M., B.A.—Biology Department, University, Crawley.
Newton, Miss E. A.—C/o. W.A. Dairy Farmers' Co-op., Stuart Street, Perth.
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Nicholls, T. A.—74 Thomas Street, West Perth.
Pelloe, Mrs. E. H.—78 King's Park Road, West Perth.
Pittman, Mrs. H. A.—C/o. H. A. Pittman, Department of Agriculture.
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Rogers, W. P.—19 Tyrrel Street, Nedlands.
Shelton, Miss K.—20 Kershaw Street, Subiaco.
Shelton, Mrs. W. E.—School of Agriculture, Narrogin.
Samuel, Dr. L. W., B.Sc., A.I.C.—Agricultural Department, Perth.
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Stokle, W.—39 Gloster Street, Subiaco.
Southern, Mrs. M. E.—Applecross.
Southern, Mrs. B. L.—Applecross.
Southern, Miss M.—Applecross.
Tiller, K. C. C.—Kurrawang.
Williams, R. F., B.Sc.—Waite Institute, Glen Osmond, South Australia.
Wilson, Mrs. A. M.—16 Hillview Road, Mt. Lawley.
Wood, W. E.—Arthur Street, Bunbury.
Wood, Miss M. B., B.A.—The University, Crawley.
Wright, Miss H. M. F.—119 Carr Street, Leederville, *or*, Perth Technical College.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

KELVIN MEDALLIST, 1937.

The Royal Society of Western Australia has decided to present its Kelvin Medal to Mr. Andrew Gibb Maitland, formerly Government Geologist of Western Australia.

Mr. Andrew Gibb Maitland, the son of Scottish parents born in Huddersfield, England, on the 30th of November, 1864, was a student and prizeman of the Yorkshire College, Leeds, then one of the constituent colleges of the Victoria University, and which College eventually became the University of Leeds. He received a sound geological training under Professor A. H. Green, F.R.S., and later under W. W. Watts (afterwards Professor of Geology at the Royal College of Science, London) and J. E. Marr (later Woodwardian Professor of Geology, Cambridge), these gentlemen having been appointed to carry out Professor Green's geological classes during his absence in Cape Colony on a tour of investigation of its coalfields for the Government of the day. In addition, Mr. Gibb Maitland received, under Professor G. F. Armstrong (later Regius Professor of Engineering and Science in the University of Edinburgh) a complete and comprehensive training as a Civil and Mining Engineer and Surveyor.

On the completion of his College course Mr. Gibb Maitland geologically mapped a portion of the southern margin of the Yorkshire Coalfield and enlarged his experience by travel in different parts of Great Britain.

In the year 1888 he was appointed to the post of Assistant Geologist on the Geological Survey of Queensland, in which service he spent eight years in pioneer geological work.

During 1891 Mr. Gibb Maitland was, by permission of the Government of Queensland, put at the disposal of British New Guinea, to make a professional examination of the Colony. No serious attempt to unravel and classify the geological formations of New Guinea and investigate mineral resources had been made until his visit in 1891. The geological maps and sections accompanying Mr. Gibb Maitland's voluminous report have formed the basis for subsequent investigations, and competent authorities state that this officer's work was found to be extremely valuable and remarkably accurate considering that the topographical features at that time were for the most part unknown.

Mr. Gibb Maitland came to Western Australia in 1896 as the Government Geologist, a position which he held until 1926—a long life's work.

His services to science and to the State of Western Australia during this period of thirty years may be briefly described under two headings—first, original contributions; second, administrative.

Mr. Maitland has made two particularly notable contributions to the knowledge of Western Australian geology. Soon after assuming office his attention was concentrated on the matter of water supply. He found that there was a tract extending along the coast for nearly 300 miles south of North-West Cape, which promised well as a pastoral area but for the insufficiency of its water supply. From a study of the structure of the region he concluded that artesian water should be available there, and on his advice the Government put down a bore at Pelican Hill, near Carnarvon, to a depth of 3,011 feet, and struck a supply of a little over half a million gallons a day.

As a result of this, over one hundred bores have been put down in this basin, yielding a plentiful supply of good stock water for the many sheep stations amongst which the area is divided. Further study of the structure of the coastal parts of Western Australia led Maitland to predict that artesian water would be found in the country near Derby, in Kimberley, and in the Nullarbor Plains. These predictions, based on facts obtained by arduous work in the field, have been fulfilled. Sir Edgeworth David, in 1932, characterised this work in the North-West Basin as "the greatest economic discovery as yet accredited to any Australian geologist."

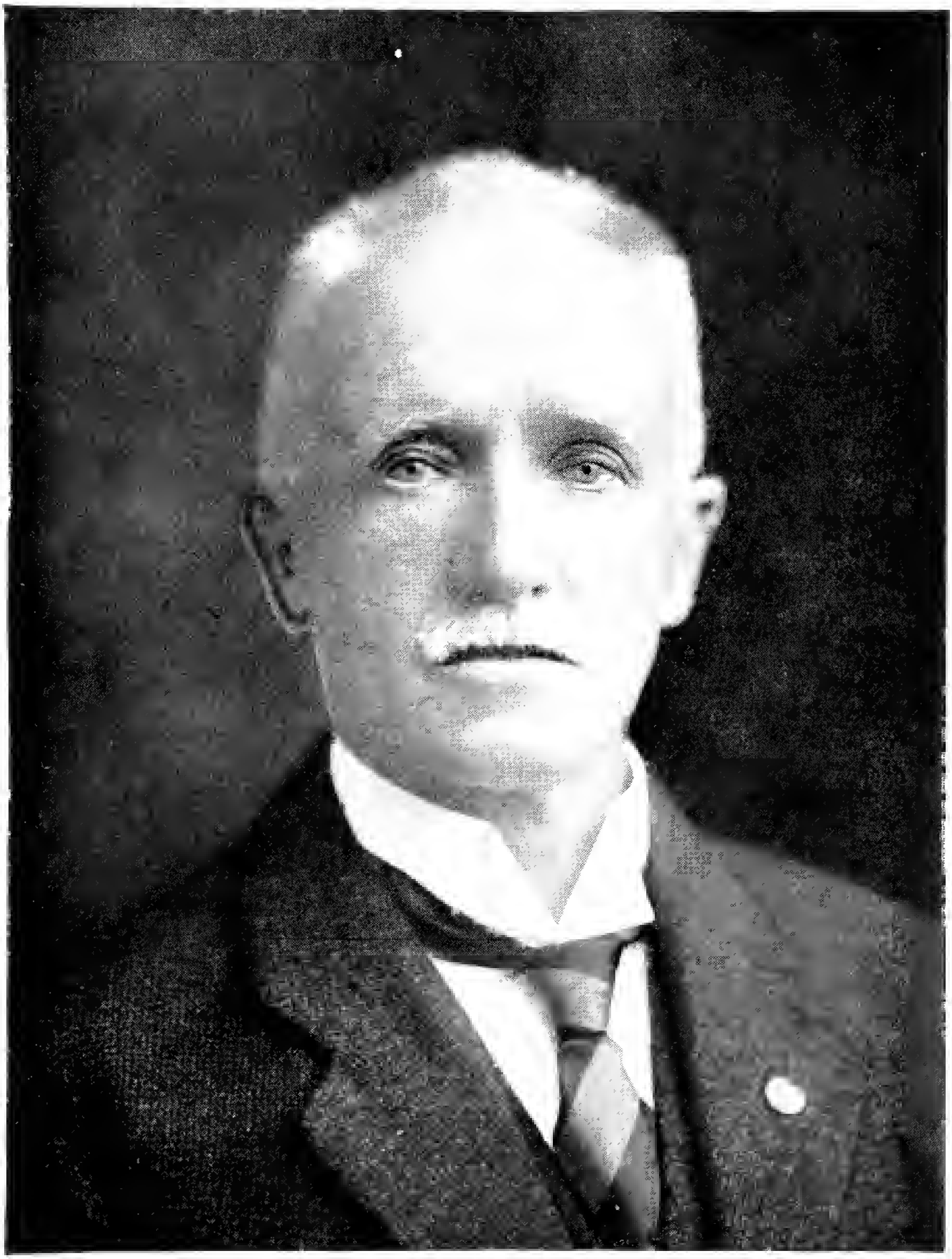
On the other hand, Maitland, after a careful examination of many districts in the Eastern Goldfields and what is now the Wheat Belt, stated that artesian water would not be obtainable in any part of them, and strongly opposed the sinking of an ultimately barren bore through granite to a depth of 3,002 feet at Coolgardie in search of artesian water. It is hard to estimate the amount of wealth which Maitland's work on water supply made and conserved for the people of Western Australia.

Mr. Gibb Maitland's second major achievement was the geological survey of the Pilbara Goldfield. As the result of several seasons of strenuous field work during the years 1903–6, under very trying conditions (it must be remembered that this work was done before motor car, aeroplane, surveyed roads and wireless had come to ease the labours of the man "out back"), Maitland was able to present in Bulletins 15, 20 and 23, subsequently reprinted in one volume as Bulletin 40, of the Geological Survey of Western Australia, a broad account of the geology of an area of 30,000 square miles, including a detailed account of all those centres where mining was being or had been carried out.

The mineral wealth of this region has not yet been fully appraised—partly owing to geological difficulties—but Maitland's work has been of the very greatest practical and scientific value, in that he discovered the order of succession of its immensely old and intensely altered rocks, and this has served as a key for the interpretation of the similar but even more obscure rocks of the chief goldfields of the State, and of their included ore deposits. The recognition of the great extent and antiquity of the group of rocks which he defined as the Nullagine Series will always be associated with his name. To commemorate his pioneer work in this region a rare compound of thorium and uranium, first found at Wodgina, has been named "Maitlandite" in his honour.

During the first decade of his career in Western Australia he built up for the first time in the State a highly organized and thoroughly efficient Geological Survey. His own reports on his field work, and those of the various members of this Survey, he correlated in a series of publications, of which the latest is his "Summary of the Geology of Western Australia." These permanent records have been of the greatest value to scientific workers, both here and in other parts of the world, and would rank as his major achievement, did he not have to his credit the two great pieces of work referred to above.

Mr. Gibb Maitland's greatest service to science in Western Australia lay, however, in the fact that, throughout his long tenure of office, he held steadfastly to the belief that the main function of a Geological Survey is to arrive at a knowledge of the geological structure of the whole of the area assigned to it, and that, unless such broad knowledge has been achieved, detailed acquaintance with small isolated areas is of little value. He was, however,



A. GIBB MAITLAND,
Kelvin Medallist, 1936–37.

fully aware of the value to mining and other industries of detailed local geological knowledge, and, by wisely laying down a firm foundation of extensive regional work, he was able more surely to interpret the detailed examination of important mining centres. This enabled him, towards the close of his term of office, to produce, with his "Summary of the Geology of Western Australia," a geological map of the whole State on which there were very few blanks. It is stated that Australia is greatly indebted to Mr. Gibb Maitland for his sustained efforts in having Western Australia geologically mapped, and for the success with which those efforts have been crowned. A series of summaries of the geology of the many occurrences of economic minerals then recognised within this area of nearly one million square miles has also been prepared and published.

Tact and determination were both necessary to pursue this policy through all the chances and changes of Party Government, and the achievement of his purpose is a service to science even greater than that of recording the results of his personal geological investigations.

Apart from his official duties, Mr. Gibb Maitland has always been a staunch supporter of the cause of Science and the Scientific Method in Western Australia. He was an original member of the Mueller Botanic Society, and of the Natural History and Science Society which succeeded it, and moved the resolution which ultimately led to the formation of the Royal Society of Western Australia. He was for very many years a member of the Council of the Royal Society, and has twice been its president, and also acted for over a quarter of a century as the Local Honorary Secretary of the Australian and New Zealand Association for the Advancement of Science.

His scientific work has been recognised by the bestowal upon him of the Von Mueller Medal by the Australian and New Zealand Association for the Advancement of Science, an honour conferred at other times upon such men as Sir Douglas Mawson and Dr. R. J. Tillyard ; and by the award of the Clark Memorial Medal by the Royal Society of New South Wales.

This award of the Kelvin Medal of the Royal Society of Western Australia—the first honour that has come to him from the State for which he has done so much—is but a tardy recognition of the great value of his work.

CEREMONY OF PRESENTATION.

Arrangements were made, for the presentation of the medal, at the joint reception accorded by the Senate of the University and the Royal Society to visiting representatives of the Australian Council for Scientific and Industrial Research, Sir George Julius and Professor A. E. V. Richardson and Mr. H. E. Wimperis, former Director of Research to the British Air Ministry, in the Winthrop Hall, Crawley on 1st October, 1937.

The President, in introducing Mr. Gibb Maitland to Sir George Julius and asking him to make the presentation, gave the reasons on which the Medal Committee based its recommendation to the Council that the award be made to Mr. Gibb Maitland. First awarded in 1924, the centenary of Lord Kelvin, the medal bears in relief on its obverse the head of Kelvin. It is given "for distinguished work in science connected with Western Australia."

Former medals were struck in gold, but it has been decided that this and all future medals be struck in silver and that a cheque should now accompany the award.

Sir George Julius presented the medal, at the same time congratulating the recipient on his work for science and Western Australia and expressing his personal pleasure in being asked to make the presentation.

Mr. Gibb Maitland in acknowledging the award said:—Mr. President, Sir George Julius, Ladies and Gentlemen,—In receiving from your hands the medal of the Royal Society of Western Australia, the highest token of approbation at its disposal, I beg to thank the Council, through you, for the confidence reposed in and the honour which it confers upon me. If anything could add to the gratifying character of the award, it would be the language in which it has been conveyed. It is such little touches of human interest which warm and light up more or less formal ceremonies like this. For both I tender my sincere thanks, not as a mere *façon de parler*, but as a veritable truth.

When my initial surprise at the award gave way to other thoughts, the first of them was one of gratification at being made the recipient of the medal which bears the honoured name of Kelvin, to whom geologists owe a debt of gratitude for pioneering those investigations which link some of the problems of geology with those of physics.

The second was that the Council upon whom devolved the responsibility of awarding the Royal Society's medal, had been somewhat generous in its estimation of such geological researches as have fallen to my lot. This work has lain in the lesser known portions of Queensland and New Guinea, but principally in large and widely separated areas of Western Australia; much of it has of necessity been something in the nature of a pioneering and exploratory character, carried out in circumstances of isolation from centres of scientific life and thought under the demands made in connection with the development of new and growing countries. Such work, though necessary in the first instance and while possessing the absorbing interest inseparable from the investigation of virgin fields, possibly suffers somewhat by comparison with that relating to detailed geological investigations in relatively small areas, carried out under much more favourable conditions and with more meticulous accuracy. That work, while it has been a duty, has also been a pleasure.

In carrying out the multifarious investigations which have fallen to my lot during nearly half a century, the view that while geological science *is* the interpreter of nature it also claims to be the servant of humanity, has always been in the forefront. I look, Sir, upon this award as an indication that the conception has not been wholly unsuccessful.

Some of my geological work has been carried out in conjunction with others, and it gives me much consolation to think that, though none of my former colleagues in Queensland and several of those on the Geological Survey in Western Australia are now no longer alive, those of the "Old Brigade" who combined scientific enthusiasm with their duty to the State, and who are still on deck, in a measure participate in the distinction which the Society has conferred, and appreciate it.

I greatly regret, Mr. President, that from causes not within my own control, I have been unable of late to take much active share in the manifold work of the Royal Society. While this is so, my interest in its activities is none the less keen than it was, when almost forty years ago I attended some of the first of those meetings which led, despite some opposition, to the Royal Assent being given to the creation of the present Society in 1913.

My feelings in regard to the Society, over which you preside, are tersely expressed in the couplet of that contemplative lover of nature, Wordsworth (who by the way, *did* in one of his poems describe geologists and their activities, in sixteen lines of withering scorn)—

"Yet have my thoughts for thee been vigilant,
Bound to thy service with unceasing care."

WORDSWORTH'S VIEW OF THE GEOLOGIST.

You may trace him oft
By scars, which his activity has left
Beside our roads and pathways, though, thank Heavens,
This covert nook reports not of his hand.
He who with pocket-hammer smites the edge
Of luckless rocks, or prominent stone, disguised
In weather stains, or crusted o'er by Nature
With her first growths, detailing by the stroke
A chip or splinter—to resolve his doubts:
And with that ready answer satisfied,
The substance classes by some barbarous name
And hurries on; or from the fragments picks
His specimen, if but haply intervened
With sparkling mineral, or should crystal cube
Lurk in its cells—and thinks himself enriched
Wealthier, and doubtless wiser, than before.

—*Excursion III.*

———

Congratulatory messages were received from Professor W. J. Dakin, the first President of the Royal Society, and Mr. W. M. Carne, now of Tasmania.

Mr. Gibb Maitland joins the honoured roll of medallists including the late Dr. W. J. Hancock, Dr. E. S. Simpson and Mr. W. M. Carne.

A CONTRIBUTION TO OUR KNOWLEDGE OF THE PRE-CAMBRIAN SUCCESSION IN SOME PARTS OF WESTERN AUSTRALIA.

PRESIDENTIAL ADDRESS.

By F. G. FORMAN.

Read 13th July, 1937; Published 1st November, 1937.

INTRODUCTION.

The principal research of the Geological Survey of Western Australia at the present time is a study of the relationship between the gold deposits and the regional geological structure of the Goldfields of the State. This study has now advanced to a point where we feel confident in making certain recommendations to prospectors in the Yilgarn Goldfield, based on our knowledge of the regional structure of the field, and involving country which, up to the present, has not produced gold. These recommendations will shortly be published in the Annual Progress Report of the Geological Survey.

The working out of structure and the order of deposition of the rocks involved, are so dependent on each other that a previous knowledge of one of these factors is a very big help in working out the other in a new area. As a fuller knowledge of the structure in our goldfields appears likely to be of great economic importance, I feel that I am justified in choosing as the subject for my address to-night, the problem of the Pre-Cambrian succession, and endeavouring to bring together the results of recent workers in the different parts of the State.

KALGOORLIE DISTRICT.

Extensive regional surveys in the Kalgoorlie district were made in 1934–35 by Mr. H. W. B. Talbot (1) of the Western Mining Corporation, who investigated a large area extending north-westwards from Kalgoorlie as far as Black Flag and Kundana; and by Mr. F. R. Feldtmann (2) of the Geological Survey of Western Australia, whose detailed observations were made mainly in the vicinity of the Golden Mile, but who had opportunities of inspecting the more distant areas worked by Talbot. These two investigators have arrived at somewhat similar conclusions.

Kalgoorlie Series.—The oldest rocks in the district are the Kalgoorlie greenstones (the Older Greenstones of earlier writers) which consist mainly of basaltic dolerite lavas with interbedded thin bands of tuff and some sediments, including banded jaspers or jaspilites. Pillow lavas with features strikingly preserved are common in this series, and were first recognised by Dr. H. E. McKinistry of the Western Mining Corporation who visited Kalgoorlie in 1934.

Black Flag—Tuffaceous Series.—The Kalgoorlie Greenstones are overlain by a series of sediments which are called the Black Flag Series by Talbot, because of the excellent exposures of this series near the Black Flag mining centre. The same rocks have been named the Tuffaceous Series by Feldtmann.

This series consists of grits, quartzites, and mudstones; rhyolite and probably trachyte tuffs, tuff agglomerates, and tuff breccias; and occasional thin bands of lavas and flow breccias. The normal erosion sediments and thin bedded tuffs are the predominant rocks.

Graphitic beds and bands of jaspilite or banded quartzite occur in this series. The term jaspilite has been used by Feldtmann for the usually narrow bands of quartzite; but Talbot prefers to call them banded quartzites, because the red colouration of the common jaspers of the goldfields is rarely present, and they are generally more siliceous.

White Flag—Yindarlgooda Series.—At the western end of White Flag Lake between Black Flag and Kundana, Talbot has indentified a series of volcanic rocks which unconformably overlie the Black Flag sediments. He has named these rocks the White Flag Series; and they include andesite and dacite flows, tuffs, and agglomerates, with some interbedded sediments. These rocks are also reported by Talbot as occurring at Binduli, where the series includes a rhyolite flow. The Binduli rocks referred by Talbot to the White Flag Series, form part of Honman's Porphyrite Series (3), the remainder of that series now being regarded as belonging to Talbot's Black Flag and Kundana Series.

Feldtmann (2) regards Talbot's White Flag volcanics as the equivalents of a series of andesite lavas, flow breccias and flow agglomerates, which outcrop over a considerable area on the western side of Lake Yindarlgooda east of Bulong. These were originally described by him (4) as pebble breccias and named the Yindarlgooda Series.

I have had the opportunity of examining both the White Flag and Yindarlgooda exposures, and am sure that anyone who has seen both would not hesitate to correlate them on the lithological resemblance alone. The correlation is supported by the presence west of Bulong, and beneath the Yindarlgooda Series, of sediments having a general lithological resemblance to the Black Flag Series which underlies the White Flag volcanics in Talbot's type area near Black Flag.

Kundana Series.—Talbot (1) has described an area of generally fresh looking sedimentary rocks consisting of grits, sandstones, shales and a basal conglomerate, which unconformably overlies the White Flag volcanics near Kundana, and has named these rocks the Kundana Series. The boulders of the basal conglomerate are derived from the underlying White Flag volcanics, and are quite unlike the boulders contained in the conglomerates of the Kurrawang Series, next to be mentioned.

Kurrawang Series.—Feldtmann (2) prefers to include Talbot's Kundana Series in the Kurrawang Series, which consists of sandstones, grits and a basal conglomerate. The Kurrawang conglomerate contains a great preponderance of pebbles of banded quartzite and quartz—the former being the more abundant in most localities and, being of exactly the same type as the banded quartzites of the Black Flag Series, are probably derived from them.

The origin of the quartzites in the Kurrawang conglomerates was originally ascribed by Gibson (5) to the jaspers of Edjudina in the Yerilla district, and later by Honman (3) to the jaspers of the Mt. Jackson Range in the north of the Yilgarn Goldfield. It is pointed out by Talbot (1) that neither of these writers knew of the existence of banded quartzites near Black Flag, and that the jaspers of Edjudina and Mt. Jackson are much more ferruginous than the boulders of banded quartzite at Kurrawang.

In addition to the preponderant quartzite boulders there are pebbles of porphyry, greenstone, and granite and a very fine grained grey slatey rock apparently derived from the Black Flag Series.

The following table represents the succession now suggested for the Kalgoorlie district. Where there are differences of nomenclature between the series names given by Talbot and Feldtmann, both are shown in the table.

Dolerite and Gabbro.

Igneous contact.
Kurrawang Series.
Granite and Porphyries.

Igneous contact.
Quartz dolerite-greenstone (Younger Greenstone).

Igneous contact.
Kundana Series.

Unconformity.
White Flag—Yindarlgooda Series.

Unconformity.
Black Flag—Tuffaceous Series.
Kalgoorlie Series (Older Greenstones).

In this table the rocks of the Kurrawang Series are regarded as being later than the Younger Greenstones and the granites and porphyries. No gold-bearing quartz veins have been noted anywhere in the series, although they are said by Talbot (personal communication) to occur in the underlying Kundana Series. The presence of granite pebbles in the conglomerate also suggests that this series is later than the granites. The quartz dolerite-greenstone being the principal host rock of the Kalgoorlie-Boulder belt, and the gold deposits being almost certainly connected with the magma which produced the granite and porphyries, these instrusive rocks have been placed in the table between the Kundana and Kurrawang Series. This arrangement agrees with the succession as described by Honman (3). A fresh quartz gabbro dyke instrusive into the Kurrawang Series near Kundana probably belongs to the same period of late basic instrusive which occur elsewhere in the State.

It has been mentioned that Feldtmann regards the Kundana Series as being part of the Kurrawang Series. The presence of gold-bearing quartz reefs in the former and their absence in the latter, favours Talbot's subdivision.

YILGARN GOLDFIELD.

Detailed field work in the southern portion of the Yilgarn Goldfield south of the Great Eastern Railway (6) by my colleagues Messrs. H. A. Ellis, R. A. Hobson and R. S. Matheson, has resulted in the working out in some detail of the stratigraphy and structural features of this portion of the goldfield.

All recent accounts of the Pre-Cambrian succession in Western Australia are alike in that the Yilgarn Series of metamorphosed sediments have been regarded as the oldest recognisable rock series in the State. The Greenstone Series has now been shown to be older than the Yilgarn Sediments and is the oldest recognisable rock series in the field.

The Greenstone Series consists mainly of coarse and fine-grained amphibolite schists derived by metamorphism from lavas, tuffs and other associated volcanic rocks. Pillow lavas are recognisable in a few places, but the intense development of flow cleavage parallel to the major axes of folds in most of the greenstone areas and deep weathering, prevents their being mapped over the greater part of the area. Interbedded with the greenstones are relatively thin bands of normal erosion sediments. Some intrusive greenstones occur but are difficult to distinguish from the highly altered volcanic rocks.

The metamorphosed sediments called the Yilgarn Series by Mr. T. Blatchford (7), have been demonstrated to overlie the Greenstone Series. They have been renamed the Whitestone Series because they commonly weather to a white or light grey colour, and their new name being suggestive of their weathered appearance is more likely to be understood by miners and prospectors.

The Whitestone Series consists mainly of andalusite, sillimanite, garnet and quartz-mica schist, felspathic grits, quartzites, phyllites and gneisses—all of sedimentary origin. Interbedded with the sediments are relatively thin bands of tuffs, agglomerates and flows. Evidence from bores in the Transvaal Mine near Southern Cross, shows that there are some basic intrusives in the Whitestone Series.

The Greenstone Series and the Whitestone Series have been grouped together in the Yilgarn System. A striking feature of the Greenstone Series is the presence of thin, remarkably persistent, bands of sedimentary jasper or jaspilite which are usually found towards the top of the series. Jaspilites are also associated with the Whitestone Series, having been noted mainly near the Middle and South Ironcap Ranges in the southern extremity of the field.

The granites and gneisses of the district all appear to be younger than the rocks of the Yilgarn system. Amongst the gneisses there are orthogneisses resulting from dynamic metamorphism of normal granite, but many of the gneisses are almost certainly composite gneisses or migmatites and paragneisses formed by alteration of the rocks of both the Greenstone and the Whitestone Series.

The youngest rocks in the Yilgarn field are fresh epidiorite dykes which are seen to intrude the granites and gneisses in a number of places.

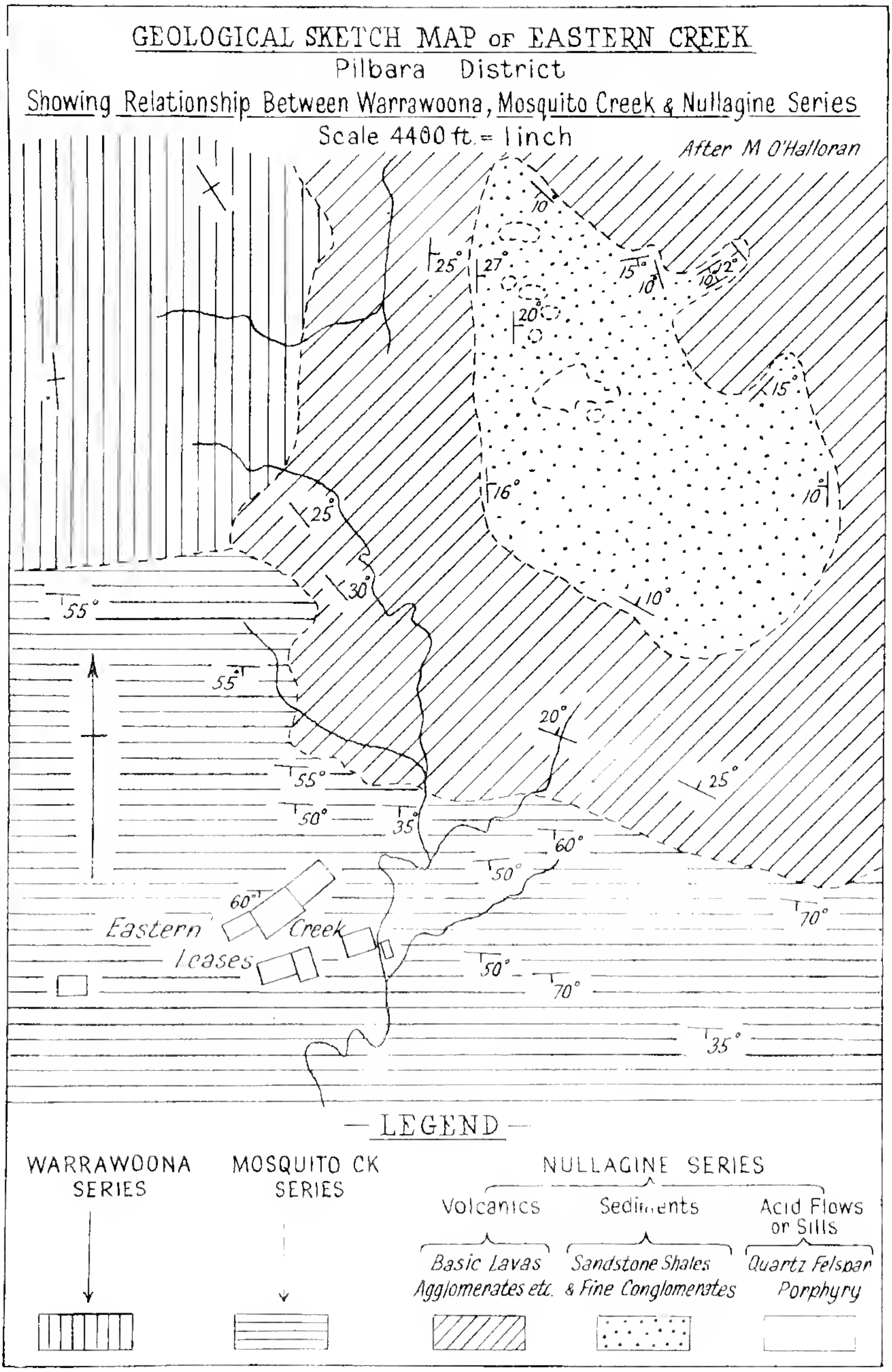
LEONORA.

Observations recently made by myself of the relationship between the greenstones and meta-sediments in the vicinity of Leonora, show that at this centre the greenstones, which include pillow lavas, are the lowest recognisable beds. The sedimentary series consisting of andalusite mica schists and fine-grained grey and green slates overlies the greenstones without any obvious indication of an unconformity. With the order established at this centre, a study of air photographs of the region between Leonora and Laverton suggests that a similar order exists throughout.

PILBARA DISTRICT.

Field work by Mr. K. J. Finucane and his colleagues has added considerably to our detailed knowledge of the geology of the mining centres of the Pilbara Goldfield, but it is pleasing to note that the pioneer work of Mr. A. Gibb Maitland, and the generalisations arrived at by him, still stand the test of time, and are found to be truly descriptive of the broad stratigraphy of the goldfield.

Warrawoona Series. The Warrawoona Series, the oldest recognisable rocks in the Pilbara district, are described by Finucane (personal communication) as consisting mainly of basic and acid lava flows including pillow lavas with interbedded quartzites and carbonated chlorite and chlorite magnetite schists. The dominant trend is N.W.-S.E., and generally they dip at steep angles, the strata being actually overturned in places. They are in many respects comparable to the Kalgoorlie Series of the eastern goldfields.


GEOLOGICAL SKETCH MAP OF EASTERN CREEK
Pilbara District
Showing Relationship Between Warrawoona, Mosquito Creek & Nullagine Series
Scale 4400 ft. = 1 inch
After M O'Halloran
Eastern Creek
Leases
LEGEND
WARRAWOONA SERIES
MOSQUITO CK SERIES
NULLAGINE SERIES
Volcanics
Basic Lavas
Agglomerates etc.
Sediments
Sandstone Shales
& Fine Conglomerates
Acid Flows or Sills
Quartz Felspar
Porphyry

Mosquito Creek Series.—The Mosquito Creek Series consists mainly of tightly folded slates and quartzites with a dominant strike of N. 80° E., and dip S. 80° W. At Eastern Creek the basal beds of the Mosquito Creek Series, consisting at this centre of slates, grits and breccia-conglomerate, strike N. 70° E. and dip south at angles of 35°–55°. Their contact with the Warrawoona Series is obscured, but a short distance north of the supposed position of the contact, the Warrawoona Series strikes N. 30° W. and has almost vertical dips. This suggests an unconformity between the two series with the Mosquito Creek beds as the younger formation.

The possible unconformity at Eastern Creek noted by Mr. Finucanes' party confirms the inference of an unconformity between the two series drawn by Gibb Maitland (8) on the evidence afforded by conglomerates exposed in the North and South Dromedary Ranges, and which appear to be at the base of the Mosquito Creek Series. This conglomerate contains numerous pebbles and boulders of laminated quartz or chert similar to rocks which form a conspicuous feature of the Warrawoona Series.

Granite and Gneisses.—Granite and gneisses of which no detailed study has been made, are intrusive into both the Warrawoona and Mosquito Creek Series.

Nullagine Series.—The Nullagine Series overlies the Mosquito Creek Series with a marked angular unconformity. The rocks consist mainly of conglomerates, grits, basic amygdaloidal lavas and tuffaceous beds. Quartz-felspar porphyries which were originally either flows or sills, have a considerable development in some parts of the Pilbara district and occur mainly in the upper part of the series.

Later intrusives.—The Nullagine Series is intruded in many places by hornblende porphyrite and dolerite dykes.

KIMBERLEY DIVISION.—HALL'S CREEK AREA.

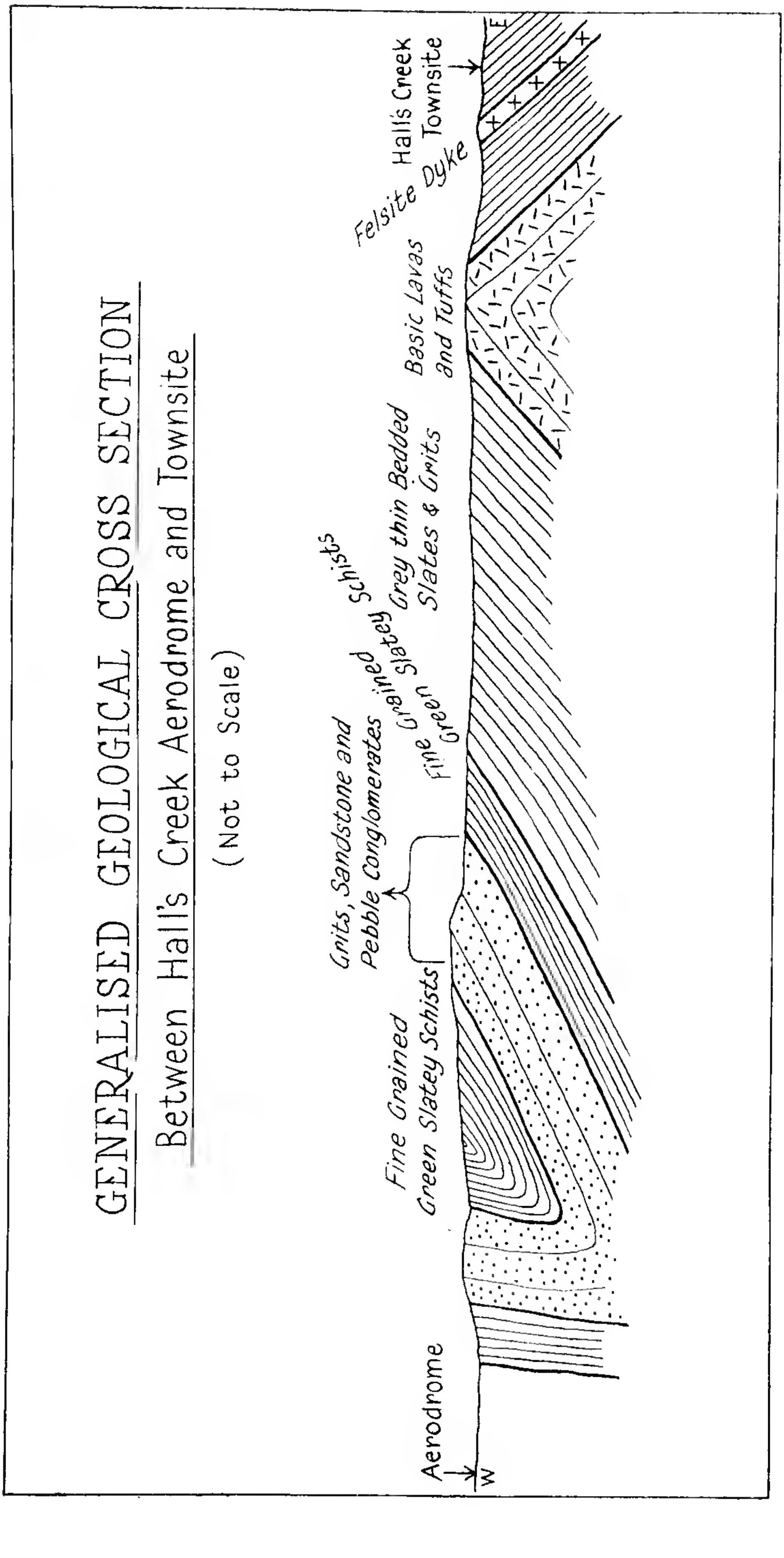
During a recent visit to Hall's Creek I was able to examine a section between the township and the aerial landing ground about 9 miles west. The oldest rocks exposed are basic flows, including pillow lavas, with inter-bedded tuffs. These are overlain by a sedimentary series of grey, thinly bedded slates, fine grained green slates, pebble conglomerates, grits and sandstones.

The rocks of the Greenstone Series are very similar in appearance and degree of folding to the Warrawoona and Kalgoorlie greenstones, and the overlying sediments are in every way comparable to the Mosquito Creek Series of the Pilbara district with which they have been previously correlated. There is no evidence of an unconformity between the two series, but the area of greenstones exposed is so small that one might easily exist and be overlooked. The sediments are intruded by granites some distance west of Hall's Creek, and by numerous dykes and sills of felsite in the vicinity of the townsite.

WARBURTON RANGE AREA.

Following a visit in 1931 to the Warburton Range area near the South Australia border, I wrote an account of the geology of the area which differed materially from the conclusions arrived at by Talbot and Clarke (9) after their expedition in 1916. My full report fortunately remains unpublished, but a summary of the principal conclusions appears in the Proceedings of the Australasian Association for the Advancement of Science for 1932 (10).

Talbot and Clarke's account of the geology (9) describes an older series of greenstones intruded by porphyry dykes which they considered comparable to the greenstones of our central goldfield. These were described as being overlain by volcanic rocks and sediments comparable to the Nullagine Series.


GENERALISED GEOLOGICAL CROSS SECTION
Between Hall's Creek Aerodrome and Townsite
(Not to Scale)
Aerodrome
W
Fine Grained Green Slatey Schists
Grits, Sandstone and Pebble Conglomerates
Fine Grained Green Slatey Schists
Grey thin Bedded Slates & Grits
Basic Lavas and Tuffs
Felsite Dyke
Hall's Creek Townsite
E

My 1931 observations led me to suggest that all the rocks belong to the Nullagine Series, mainly because careful search failed to reveal any sign of an unconformity between the rocks previously referred to a Nullagine age, and the more metamorphosed greenstones and sediments. The porphyry dykes or sills of the Warburton Range were seen to be associated with rocks indistinguishable in appearance and degree of metamorphism from rocks higher in the succession which undoubtedly belonged to the Series referred by Talbot and Clarke to the Nullagines. Further, the porphyries of the Warburton Range were found to be mineralogically and chemically similar to porphyries undoubtedly associated as flows or sills with the Nullagine beds near Bamboo Creek in the Pilbara Goldfield and with beds generally referred to the Nullagine system in the central Kimberleys.

In 1931 I was under the disadvantage of not having a personal knowledge of the Nullagine Series in its type locality—the Pilbara Goldfield—but have since seen large areas of Nullagine rocks in this and other localities. I now feel convinced that I was mistaken in referring all the greenstones of the Warburton area to the Nullagines as many of them are too highly metamorphosed possibly to be regarded as being of Nullagine age, and bear many points of similarity with the greenstones of the central goldfields.

I suggest that, pending further investigation, the basal rocks of the Nullagine Series in this area should be regarded as being the little altered sediments immediately underlying the Warburton Range porphyries, and that some at least of the greenstones, and the altered sediments beneath the porphyries, should be referred to the older Pre-Cambrian.

DARLING RANGE—AVON VALLEY AREA.

During general observations over a large part of the Avon Valley between Toodyay and York, I have been impressed by the frequent occurrence of quartzite bands in the gneiss which is the predominant rock of the area. These quartzites, which are similar to the Jimperding quartzites, conform in dip and strike to the banding of the gneiss, and separate occurrences often have a roughly linear arrangement.

The strikes and dips observed in the Jimperding Series at Toodyay, Wongamine, Clackline and York, and the Cardup Series between Kelmscott and Mundijong, conform to the local structure observable in the gneisses at these places. Both the gneisses and metamorphosed sediments are intruded by massive granites which vary from fine grained to coarse porphyritic varieties. The gneisses include composite gneisses or migmatites and paragneisses, and I suggest that they are, for a great part at least, of the same age as the Jimperding and Cardup Series, and owe their origin to the alteration of these sedimentary rocks by a granitic magma, either the same or an earlier magma to that which provided the massive granites of the Avon Valley and the Darling Range.

A similar origin for some of the gneisses is suggested by field work in the Yilgarn Goldfield (6), and general observations of gneissic areas between Leonora and Lawlers suggest that they also are formed from pre-existing sediments.

Professor Clarke (personal communication) has been unable to discover any unconformity between the sediments and gneisses in the extreme southwest of the State. Both in the Stirling Ranges and at Point Ann, sediments appear to pass downwards without a break into composite gneisses, the banding of which is parallel to the bedding of the sediments.

A SUGGESTED CORRELATION OF THE PRE-CAMBRIAN ROCKS IN SOME PARTS OF WESTERN AUSTRALIA.

Kimberley District.	Pillbara District.	Central Goldfields.			South-West Division.	Eastern Division.
		Leonora.	Kalgoorlie.	Southern Cross.	Darling Range-Avon Valley.	Warburton Range.
Gabbro	Porphyrite and Dolerite dykes	Dolerite dykes	Dolerite and Gabbro	Epidiorite dykes	Epidiorite dykes	Norite, etc.
igneous contact	*igneous contact*	*igneous contact*	*igneous contact*	*igneous contact*	*igneous contact*	*igneous contact*
Nullagine Series	Nullagine Series					Nullagine Series
			Kurrawang Series			
Granite and felsite	Gneisses, granite and porphyry	Gneisses, granite and porphyry	Granite and porphyry	Gneisses, granite and porphyry	Granite and Gneisse	Granite and porphyry
igneous contact	*igneous contact*	*igneous contact*	*igneous contact*	*igneous contact*	*igneous contact*	*igneous contact*
			Younger Greenstones	Younger Greenstones		
			igneous contact	*igneous contact*		
			Kundana Series			
			Unconformity			
			White Flag-Yindarlgooda Series			
Mosquito Creek Series	Mosquito Creek Series	Meta-Sediments		Whitestone Series	Jimperding-Cardup Series	
			Unconformity			
	Unconformity		Black Flag-Tuffaceous Series			
Greenstone Series	Warrawoona Series	Greenstone Series	Kalgoorlie Series (Older Greenstones)	Greenstone Series		Meta-Sediments and Greenstones

CONCLUSIONS.

The following table shows the Pre-Cambrian succession as it now appears to be in those areas dealt with in this paper.

The Greenstone Series which occur at the base of the succession in each district are similar in that they all consist predominately of basic volcanic flows and fragmentals. A strong development of pillow lavas in these series is also a common feature. Although correlation on lithological resemblance must be regarded as uncertain, strength is lent to it in this case because in every district studied, these rocks form the lowest recognisable series and are overlain by a predominantly sedimentary series older in each case than the intrusive granites and porphyries.

Feldtmann (11) describes a greenstone series at Bolgart in the South-West Division, and correlates it with the Kalgoorlie greenstones, but as the relationship between these rocks and the Jimperding sediments has not yet been determined, I have not felt justified in placing the greenstone series at the base of the succession for the South-West Division. There is some evidence, however, which suggests that the Bolgart greenstones lie beneath the Jimperding sediments. In the Darling Range—Avon Valley area the sediments and the gneisses appear to form part of an anticlinal structure with a north-south axis and a regional pitch to the south. If a greenstone series does underlie the sediments it should therefore outcrop along the anticlinal axis somewhere to the north of the Avon Valley. The Bolgart greenstones lie in such a position.

The meta-sediments and greenstones of the Warburton Ranges have been grouped together in the table because we have no knowledge of their relationships. The sediments may be either above or below the greenstones or even interbedded with them. The succession in the Warburton Range district is the least certain of any. This is due, of course, to the inaccessibility of the area and the consequent lack of opportunity for detailed study.

The sediments which in each area overlie the old greenstone series may not all be contemporaneous. Lithological resemblance and the fact that they immediately overlie the greenstones with no sign of an unconformity suggest that the meta-sediments at Leonora, the Black Flag Series and the Whitestone Series can be correlated. Lithological resemblance also suggests a correlation between these rocks and the Jimperding-Cardup Series. The Mosquito Creek Series as seen in the Pilbara and Kimberley goldfields resemble more in appearance the Kundana Series of the Kalgoorlie district. The grey thin bedded slates and grits in the lower part of the Mosquito Creek section seen at Hall's Creek are, however, closer in appearance to the Black Flag Series. These possible correlations have not been indicated in the table because of the uncertainty of correlation merely on lithological resemblance, particularly as the rocks involved lie in such widely separated parts of the State.

A great deal more work will be necessary before it can be determined whether or not the granites and gneisses are all contemporaneous. All recent investigations have shown that these rocks, where they come in contact with meta-sediments, are intrusive or of metamorphic origin, the gneiss in the latter case having been originally a greenstone or a sediment.

Within the gneissic areas themselves it has not been possible to divide the rocks into different age groups, but it is possible that some of the gneisses are really older than the evidence of the gneiss and sedimentary or greenstone contacts suggest, and that the present difficulty of distinguishing an older set of rocks is due to the superposition on them of the structural features of later folding movements with a consequent masking or entire obliteration of earlier impressed structural features.

In the Yilgarn goldfield it seems possible, but satisfactory evidence is not available to support the idea, that some of the gneisses in contact with the greenstones may be of greater age.

It is therefore thought advisable, until satisfactory evidence to the contrary is forthcoming, to group all the gneisses and granites together and regard the granites as intrusive into the Mosquito Creek-Jimperding Series.

The reasons for placing the Kurrawang Series so high in the succession have been given earlier in this paper, but in order not to suggest a definite correlation between the Nullagine Series and the Kurrawang Series, I have placed the Kurrawang Series in a separate horizontal position in this table. There appears to be no reason for suggesting a correlation between the Nullagine Series and the Kurrawang Series, and on the other hand, the greater degree of metamorphism and folding, and the absence of a volcanic phase in the latter series, seem good reasons for not doing so.

I am aware that the material placed before you in this paper contains many uncertainties, and depends a great deal on rather slender evidence which is the best, however, that our present knowledge will allow. If the views I have expressed produce criticism and lead to a widening interest in the problems of our Pre-Cambrian geology, I will feel fully satisfied.

ACKNOWLEDGMENTS.

I wish to express my thanks to Mr. H. W. B. Talbot for discussion on the geology of the Kalgoorlie district, and for his kindness in conducting me over type areas in the field; and to the Management of the Western Mining Corporation which made his reports available; to Messrs. F. R. Feldtmann, H. A. Ellis, R. A. Hobson and R. S. Matheson, my colleagues on the staff of the Geological Survey, and to Professor E. de C. Clarke and Dr. Frank Moss I am indebted for valuable discussions. I have also to thank Messrs. K. J. Finucane and M. O'Halloran of the Staff of the Aerial, Geological and Geophysical Survey of Northern Australia for information on the Pilbara district.

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JOURNAL OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

VOLUME XXIII.

1.—THE ESSENTIAL OILS OF THE WESTERN AUSTRALIAN EUCALYPTS.

PART IV.

THE OILS OF *E. OLEOSA*, F. v. M., *E. EREMOPHILA*, MAIDEN, AND *E. LEPTOPODA*, BENTH.

By G. E. MARSHALL and E. M. WATSON.

Read 13th October, 1936; Published 14th May, 1937.

EUCALYPTUS OLEOSA.

E. oleosa, a eucalypt widely distributed in Western Australia, is well known for its polymorphism. As a mallee it is found with rough bark in some districts, and with smooth bark in others. In the goldfields area and southwards it occurs both as a giant mallee and as a tree, each having rough trunk bark. In its tree forms, it grades uniformly into *E. longicornis* and also shows great similarity to *E. Flocktoniae*.

The material used in the present investigation was obtained by Mr. G. H. Burvill from the giant mallee of the goldfields, where it is known as "black mallee." It was collected about the middle of October, 1934, from Fitzgerald Location 55, about six miles north-east of Grass Patch. The bark of the black mallee is dark grey in colour, coarse, rough and persistent; the heartwood is reddish; the leaves are coriaceous, freely dotted with oil glands and the venation is of the typical cineol-pinene type.

Baker and Smith (1920) have described the oil obtained from *E. oleosa* from Nyngan, N.S.W., and a comparison of the results of the two investigations is therefore of interest.

	Baker and Smith.	Marshall and Watson.
Yield	1·1 per cent.	1·0 per cent.
Specific Gravity	0·923	0·936
Refractive Index	1·4689	1·4754
Specific Rotation	— 1·5°	— 7·42°
Solubility in 70 per cent. alcohol ...	In 1¼ volumes	In 1⅓ volumes
Saponification value	4·9	7·2
Cineol	52 per cent. (a)	45 per cent. (b)
Volatility	78 per cent. volatile below 183°	65 per cent. volatile below 195°

(a) by phosphoric acid. (b) by *o*-cresol.

The differences between these oils are similar to those between the specimens of the oil of *E. salmonophloia* discussed in a previous communication (Watson, 1935-36), and are due to the larger proportion of high boiling constituents in the present oil. Both oils contained pinene, aromadendrene, high boiling aldehydes and phenols. In addition, the present oil was shown to contain a considerable amount, probably more than 20 per cent., of geraniol. On distillation, the separation of white solid in quantity, as previously described in this series, was again noted. The fact that Baker and Smith make no mention of this phenomenon, although they observed it in the cases of two oils of unknown botanical origin, suggests some fundamental difference between the oils of the Eastern and Western Australian varieties of *E. oleosa*.

The oil does not appear likely to be of any medicinal or mining value.

EUCALYPTUS EREMOPHILA.

E. eremophila also occurs in both tree and mallee form, and is distributed through the forest land of the southern interior. The bark is smooth and thin and is silvery grey in colour, with light brown mottling; the heartwood is pale. The leaves are shiny and are copiously and evenly dotted with oil glands; the venation is indistinct, the submarginal vein removed from the edge and indented to meet the roughly pinnate veinlets.

The material used was collected by Mr. G. H. Burvill from small trees on Esperance Location 523, about four miles west-north-west of Seaddan, in the middle of May, 1935; its identity was verified by Mr. C. A. Gardner.

Distillation proceeded rapidly at first and was completed in four to five hours. The oil was pale yellow in colour, had the characteristic odour of cineol-pinene oils, and was obtained in yield of 1.75 per cent. by weight, calculated on thoroughly air-dried material. It contained 33 per cent. of cineol and a high proportion (probably more than 15 per cent.) of *d*-pinene; free acids and esters were present in very small amounts, but alcohols were present in appreciable quantity. Aromadendrene, high boiling aldehydes and small amounts of phenols were also present. The solubility of the oil in alcohol was very low, showing the presence of large amounts of terpenes.

On distillation the separation of white insoluble matter was again noted as boiling commenced; 34.4 per cent. of the oil was volatile below 165°, indicating a high proportion of pinene; 78.2 per cent. was volatile below 195°.

On standing, both the original oil and the various fractions undergo profound physical and chemical changes. There were marked increases in density, refractive index and viscosity which were accompanied by increases in the amounts of free acid, aldehyde and ester present, and by an apparent decrease in the amount of alcohols. Sufficient information is not yet available to give a satisfactory account of these changes.

EUCALYPTUS LEPTOPODA.

E. leptopoda is a mallee which occurs over a wide area in Western Australia; it is found as far west as Cunderdin, Dowerin and Payne's Find; northwards towards Mt. Magnet; eastwards, a little south of the goldfields railway, to Widgiemooltha and Coolgardie, and thence towards the north and east into the mulga country. It is characteristically rather small, generally five to ten feet high, although occasionally as high as twenty feet, and it inhabits poor sand plain soils in association with wodgils.

The material used was collected by Mr. Burvill from Ninghan Location 1341, about eight miles south of Cleary, in the middle of July, 1936, and its identity was established by Mr. Gardner. The leaves were dull, practically linear in shape, 3 to 3½ inches long and about ¼ inch wide, and they were freely dotted with oil glands; the venation was obscure.

The oil, which distilled rapidly, was obtained in 1.3 per cent. yield and was pale yellow in colour. It contained 68 per cent. of cineol, the odour of which was somewhat obscured by the large amount of volatile aldehyde which was present. Pinene, free acids and esters were present in very small amounts, whilst alcohols, calculated as geraniol, made up nearly 11 per cent. of the oil; aromadendrene was present only in small quantity. Both high and low boiling aldehydes were detected, and, in addition, a phenolic substance, which gave purple coloration with ferric chloride, was present in the higher fractions. The oil contained no phellandrene.

On distillation, insoluble matter again separated as the oil commenced to boil. Little more than 3 per cent. distilled below 162°, but from 162° to 190°, nearly 87 per cent. distilled. The latter material was practically colourless, contained only a trace of aldehyde, had a pleasant odour, and contained 74 per cent. of cineol; its physical properties fall within the required limits of the British Pharmacopoeia and it would therefore make a satisfactory medicinal oil. The scattered distribution of the tree and its sparse foliage, however, would make commercial exploitation perhaps unprofitable.

EXPERIMENTAL.

EUCALYPTUS OLEOSA.

Distillation of the oil was fairly rapid and was complete in from three to four hours. The product was pale greenish-yellow in colour and had, in addition to those already given, the following properties:—Acid value, 1.4: ester value: hot, 5.8, cold, 4.1 (corresponding respectively to 2.0 and 1.4 per cent. of esters calculated as $C_{12}H_{20}O_2$); saponification values of acetylated oil: hot, 85.6, cold, 78.4 (corresponding respectively to 22.2 and 20.7 per cent. of alcohols calculated as $C_{10}H_{18}O$).

Redistillation of the oil gave the following fractions:—

Fraction.	Boiling Range.	Amount.	Specific Gravity.	Refractive Index.	Specific Rotation.
1.	Up to 150° C.	1·5 per cent.	...	1·4645	...
2.	150—170°	16·8 ,, ,,	0·8880	1·4645	+19·2°
3.	170—180°	33·4 ,, ,,	0·9245	1·4638	+ 2·0°
4.	180—195°	13·3 ,, ,,	0·9370	1·4714	— 14·4°

The residue (35 per cent.) was further fractionated at a pressure of 22mms.

Fraction.	Boiling Range.	Amount.	Specific Gravity.	Refractive Index.	Specific Rotation.
5.	94—114°	3·8 per cent.	0·9639	1·4910	— 44·5°
6.	114—125°	6·7 ,, ,,	0·9690	1·4976	— 44·4°
7.	125—160°	5·3 ,, ,,	0·9653	1·4991	— 16·0°
8.	160—172°	6·4 ,, ,,	0·9807	1·5040	— 2·2°

From the residue, 5.15 per cent. of white solid was obtained by adding ether and filtering.

Fraction 1 was colourless and strongly acidic. Fraction 2 contained about 45 per cent. of cineol and, when mixed with fraction 1, yielded an appreciable amount (5 to 6 per cent. of the original oil) of *d*-pinene.

Fractions 3 and 4 were practically colourless and contained the greater part of the cineol.

Fraction 5 was colourless and strongly laevorotatory. Its ester value was 32, corresponding to 11.2 per cent. of esters calculated as $C_{12}H_{20}O_2$, whilst the saponification value of the acetylated oil corresponded to 38.2 per cent. of alcohols calculated as $C_{10}H_{18}O$. Small amounts of aldehydes and aromadendrene were also present.

Fraction 6 was also strongly laevorotatory and contained 4.5 per cent. of esters calculated as $C_{12}H_{20}O_2$, and 69.5 per cent. of alcohols calculated as $C_{10}H_{18}O$. It contained larger amounts of aldehydes and aromadendrene than did fraction 5, and gave a strong orange colouration with ferric chloride.

Fraction 7 showed appreciably less laevorotation and contained the maximum amounts of aldehyde and aromadendrene.

Fraction 8 was only slightly laevorotatory; it contained practically no aromadendrene but still contained an appreciable amount of aldehyde; phenols were present in maximum amount.

EUCALYPTUS EREMOPHILA.

The oil had, in addition to those already given, the following properties:—Specific gravity, 0.9040; refractive index, 1.4724; specific rotation, + 11.1°; soluble in 7 volumes of 80 per cent. alcohol; acid value, 0.5; ester value, 0.8; saponification value of acetylated oil: hot, 56.6, cold, 39.7, the latter corresponding to 10.7 per cent. of alcohols calculated as geraniol. The difference between the hot and cold values corresponds to 6.7 per cent. of alcohols calculated as eudesmol. The aldehyde content was 0.058 milligram mol per gram of oil.

On redistillation of the oil, the following fractions were obtained:—

Fraction.	Boiling Range.	Amount.	Specific Gravity.	Refractive Index.	Specific Rotation.
1	Up to 160° C.	5·3 per cent.	0·8779	1·4645	+30·84°
2	160—165°	29·1 ,, ,,	0·8778	1·4653	+28·6°
3	165—170°	15·9 ,, ,,	0·8889	1·4659	+21·68°
4	170—180°	18·1 ,, ,,	0·9014	1·4659	+ 8·85°
5	180—195°	9·4 ,, ,,	0·9014	1·4698	— 6·16°

The residue (22.2 per cent.) was distilled under a reduced pressure of 30mms.

6	90—125°	4·9 per cent.	0·9510	1·4860	—29·2°
7	125—150°	4·3 ,, ,,	0·9452	1·4984	— 9·81°
8	150—175°	6·8 ,, ,,	0·9579	1·5036	Inactive

From the residue 1.56 per cent. of white insoluble matter was separated.

Fractions 1 and 2, being very similar to one another, were mixed and redistilled; nearly 13 per cent. (calculated on the original oil) distilled between 156° and 158°, and this had physical properties very similar to those of *d*-pinene. It gave pinene nitrosochloride in quantity.

Fraction 3 was colourless, had a pleasant smell, and contained 35.5 per cent. of cineol.

Fractions 4 and 5 were also colourless and contained respectively 52.5 and 28 per cent. of cineol; their ester values were 11.4 and 12.5 respectively, corresponding to 3.9 and 4.4 per cent. of esters calculated as $C_{12}H_{20}O_2$. The saponification value of the acetylated oil of fraction 5 was 88.2, corresponding to 20.8 per cent. of alcohols calculated as $C_{10}H_{18}O$.

Fraction 6 was very pale yellow in colour, gave positive tests for aromadendrene, and contained an appreciable amount of high boiling aldehyde. Its ester value was 15.4 and the saponification value of the acetylated oil was 231 for both hot and cold hydrolysis; the latter corresponds to 59 per cent. of alcohols calculated as geraniol.

Fraction 7 contained aromadendrene and aldehyde and gave a faint purple colour with ferric chloride. Its ester value was 13.3; on acetylation it gave a product which had hot and cold saponification values of 151 and 122 respectively. The latter corresponds to 29.9 per cent. of alcohols calculated as geraniol, whilst the difference between the hot and cold values corresponds to 11.5 per cent. of eudesmol.

The last fraction still contained some aldehyde together with maximum amounts of aromadendrene and the phenol giving the purple colour with ferric chloride. Its ester value was 11.0; hot acetyl value 116 and cold acetyl value 56. The last figure corresponds to 12.4 per cent. of geraniol and the difference between the hot and cold acetyl values is equivalent to 23.7 per cent. of eudesmol.

EUCALYPTUS LEPTOPODA.

Distillation of the oil was completed in three hours and the dried product had the following properties:—Specific gravity, 0.9200; refractive index, 1.4662; specific rotation, — 0.94°; soluble in 1.8 volumes of 70 per cent. alcohol; acid value, 0.8; ester value, 2.3 (corresponding to 0.8 per cent.

of esters calculated as $C_{12}H_{20}O_2$); saponification value of acetylated oil: hot, 41.6, cold, 38.4. The similarity of the last two figures shows that geraniol is the main alcohol present and the hot value corresponds to 10.8 per cent. of alcohols calculated as geraniol.

The aldehyde content, of which much was low boiling, was equivalent to 0.07 milligram mol per gram of oil.

Redistillation of the oil gave the following fractions:—

Fraction.	Boiling Range.	Amount.	Specific Gravity.	Refractive Index.	Specific Rotation.
1	Up to 162° C.	3·3 per cent.	0·9002	1·4575	+ 9·44°
2	162—170°	26·6 ,, ,,	0·9060	1·4630	+ 8·17°
3	170—178°	51·3 ,, ,,	0·9175	1·4638	— 0·30°

The residue (18.8 per cent.) was distilled under a pressure of 28 mms.

4	78— 95° C.	9·4 per cent.	0·9266	1·4682	— 7·02°
5	95—115°	5·0 ,, ,,	0·9640	1·4912	—28·0°

From the residue, 2.1 per cent. of white insoluble matter was separated by means of ether.

Fraction 1 was pale yellow in colour, had a strongly irritant odour, was acidic and contained much aldehyde. Only a very small amount of pinene nitrosochloride was isolable.

Fraction 2 contained a trace of aldehyde. The cineol contents of this and the two succeeding fractions were 66, 78 and 73 per cent. respectively, the last two fractions being completely free from aldehyde. Fraction 2 also contained a small amount of low-boiling ester, having a hot ester value of 4.3 and a cold value of nil; in fraction 3 the hot ester value had dropped to 1.3, but in fraction 4 it commenced to rise as higher boiling esters distilled, and in fraction 5, it had risen to 11.0.

The combined fractions 2, 3 and 4 contained 74 per cent. of cineol and had specific gravity 0.915, refractive index 1.4640, and specific rotation +1.5°.

There was little difference between the hot and cold acetyl values for both fractions 4 and 5. In these fractions, the hot acetyl values were respectively 54.6 and 225, corresponding to 13.5 per cent. and 58.7 per cent. of alcohols calculated as $C_{10}H_{18}O$.

Fraction 5 gave a purple colouration with ferric chloride and contained high-boiling aldehyde; aromadendrene was present in small amount. The residue contained appreciable amounts of high-boiling aldehyde and of the phenol giving the purple colour with ferric chloride; aromadendrene was present in somewhat greater amount than in fraction 5.

The authors are indebted to Mr. G. H. Burvill, of the Department of Agriculture, for the collection of material, and to Mr. C. A. Gardner, Government Botanist, for checking its identity and for the interest he has shown throughout the investigation.

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Perth Technical College.

2.—SOME ASPECTS OF SOIL MINERALOGY,

By DOROTHY CARROLL.

Read: 9th March, 1937; Published: 2nd June, 1937.

In 1933, at the suggestion of Professor Clarke, an examination of the mineral contents of soils from Kalgoorlie, Southern Cross, and several small centres in the Goldfields of Western Australia was started, and a short account of the results was published last year (Geol. Mag. vol. LXXIII., No. 869, p. 503, 1936).

The basis of the investigation is the conception that when solid rock weathers to a soil its more resistant minerals will persist in a fragmentary condition in that soil, and should, therefore, give a definite indication of the nature of the parent material.

During the course of this investigation valuable assistance was given as follows:—First, it was made possible by the award of a Hackett Studentship by the University of Western Australia, to whom grateful acknowledgment is made. Financial assistance was later given by the Western Mining Corporation, and the Council for Scientific and Industrial Research in Melbourne, to whom my best thanks are due, as they are also to the Australian and New Zealand Passenger Conference for the award of a passage from Australia to England to enable the work to be completed at the Imperial College of Science and Technology.

I am greatly indebted to Professor E. de C. Clarke of the University of Western Australia, for the great interest he has shown at all stages in the investigation, for many helpful discussions and suggestions, and for the facilities he has made available for apparatus and field-work.

I wish also to thank the following for assistance at various stages during the investigation:—Inspectors of Mines A. W. Winzar, E. E. Brisbane, L. Gibbons (now in Papua) of Kalgoorlie for help in collecting the soil samples; the Geological Survey of Western Australia, through the courtesy of Mr. F. G. Forman, Government Geologist, for soil samples, rock specimens and for the loan of rock sections from the Survey Collection; the Western Mining Corporation for assistance in collecting soil samples from Southern Cross; Messrs. Prider and Terrill for making rock sections; Dr. C. G. G. Larcombe, Dr. B. H. Moore, and Mr. G. Spencer Compton for the information on the Kalgoorlie district; Mr. T. Blatchford, late Government Geologist, for collecting rock specimens from Southern Cross; Mr. H. Bowley, Assistant Government Mineralogist and Chemist, for help with mineral identifications; and Mrs. H. V. Rowe for transport to Leonora.

My thanks are due to Professor P. G. H. Boswell and Dr. A. Brammall at the Imperial College of Science and Technology at South Kensington, for many valuable suggestions and criticisms. Dr. Brammall gave in addition much invaluable advice on the identification of mineral grains, the description of rock sections, and expression of results.

The soils examined were collected with the view of determining the influence which the parent rock had in their formation. The majority were collected from sites where the soil profile could be seen, in order to obtain standard "heavy mineral" assemblages. ("Heavy mineral" is used for the grains which sink in bromoform of S. G. about 2.9.)

It is not proposed here to enter into a discussion of the technique employed, but to give a few features of interest from the point of view of general geology, for it is becoming increasingly evident that a study of soil mineralogy is an important branch of geology and pedology.

That most of the soils examined were directly derived from the weathering of the underlying rocks cannot be doubted from even the most casual examination of the residues. More detailed work confirms this finding, especially when not only the actual species of heavy minerals are considered, but also the *varieties* of these minerals. The importance of the recognition of varietalism of mineral species was brought to my notice by Dr. A. Brammall, who realised that correlation of soil and rock residues in any area would depend not only on the species present but also on the varieties of these species. Thus, in the Kalgoorlie soils, several types of zircon and rutile were recorded and a search of the heavy residues, obtained by crushing and sepation, of rocks in the district was instituted so that the actual "home" of these species was found. *Plate I.* illustrates several types of rutile and zircon, as well as the general appearance of the heavy residues of soils obtained in this area. *Plate II.* illustrates similarly the residues of the Southern Cross soils.

At Kalgoorlie the soil residues nearly always contain a few grains of andalusite, a mineral which had not previously been recorded from this locality. Most of the soils are known to be residual, so that it is unlikely that andalusite alone would have been introduced from some outside source. Some soils occurring above greenstones at Marvel Loch, south of Southern Cross, are very similar to those at Kalgoorlie with regard to the presence of andalusite. In the neighbourhood of Marvel Loch the greenstones, partly of sedimentary and partly of igneous origin, occur as bands in beds of light-coloured meta-sedimentary rocks. These sedimentary rocks contribute the andalusite grains to the surrounding soils. The Older Greenstone series of Kalgoorlie is apparently, in some localities, interbedded with white sedimentary rocks, so that possibly the greenstones and sediments are in the same relationship to each other as are the greenstones and meta-sediments at Marvel Loch, the suggestion being strengthened by the presence of andalusite.

Another source for the andalusite at Kalgoorlie suggests itself: that it was formed by the action of intrusive porphyry on aluminous rocks. But from its widespread occurrence the first suggestion is the more likely to prove correct.

Thus a study of the soil minerals may lead to suggestions regarding further lines of investigation in the geology of any district, and brings to the fore aspects which had been overlooked or not realised previously.

Similarly any other persistent mineral such as staurolite, kyanite, sillimanite, rutile, or zircon may give a clue to the presence of rocks, which, obscured by soil, had not been known to occur in any particular area. In such investigations a study of the accessory minerals of any exposed rocks must necessarily go hand in hand with that of the heavy residues of the soils.

If the soils in a district have been formed as a result of the mixture of weathered material from several types of rock, the heavy mineral assemblages of the soils will yield the evidence whereby the extent of such mixture can be estimated, e.g., granite-greenstone parentage, or meta-sedimentary-granitic parentage. An example of such mixing, only to be expected near the contact of one type of rock with another where the land is sloping, can be cited from near Corinthian in the Southern Cross district. Two samples were collected, one from either side of a granite-greenstone contact. Both soils contained the same species of minerals in the heavy residues, but in one soil the residue was notably smaller in quantity than in the other, while the amphibole content, an important factor in the "greenstone" soils, had risen in the soil above the greenstone, but fallen in that of granitic origin, where ilmenite and limonite had increased. A word of caution must be given, however, for in dealing with soils formed from greenstones, particularly those from amphibole schists, the heavy residue yielded is very large in amount, much larger than the residue which a granite is capable of forming. Therefore the heavy residues of non-greenstone soils will be masked by the "flood" of released amphibole grains from any nearby area of soil underlain by greenstone. Where such a mixture is suspected it is advisable to remove all amphibole grains from the heavy residue in order to concentrate the minerals peculiar to soils of non-greenstone parentage.

Other features of interest revealed by a microscopic examination of soil minerals are concerned with the clay content and its nature, the colour of soils and how it is held, and the degree of rounding of the soil grains.

The clay minerals, a group of aluminous substances with a fairly wide range in chemical and optical properties, have been found to vary, as is only natural, with the type of material giving rise to the soil. Thus the clay minerals present in a soil derived from a greenstone are quite different from those yielded by a granite and often approach the chlorite group in appearance. The clay minerals of the beidellite-nontronite group (the type usually occurring in soils) are high in their base exchange capacity, and their approximate identification will give a clear indication of the base exchange capacity of the soils as a whole, a factor which is of value to the soil chemist.

Colour in soils may be due to certain minerals but is more often an expression of the influence of climatic conditions on the weathered rock material and vegetation. In some soils the colour is very loosely held, e.g., some intensely red soils from the Marvel Loch district; while in others it is most difficult to remove. When this is so, it is found to be due to a film of aluminous material coating every grain in the soil and holding the ferruginous matter. Such soils are of common occurrence at Kalgoorlie.

The roundness of sand grains is an important factor in deciding the age of some soils. It was at one time considered that the soils in such a district as Kalgoorlie owed their origin to drift by wind. Desert areas develop sand grains which have been well-rounded and are known as the "millet-seed" type. In very few soils in Western Australia have such rounded grains been found. Certainly the soils from Kalgoorlie do not fall into this group, and it is very unlikely that wind has been, in this cycle of erosion, a factor of much importance, for in its natural state, in the areas examined, the land is covered by a thick mantle of vegetation.

The following is a list of the minerals identified as grains in soils from the areas examined:—

Kalgoorlie: Magnetite, ilmenite, limonite, pyrite, leucoxene, amphibole (green and colourless), epidote, zoisite, rutile, tourmaline, sphene, zircon, mica, fuchsite, andalusite, carbonate, chlorite, garnet, gold, quartz, oligoclase, albite, orthoclase, microcline, microperthite, labradorite, micaceous and chloritic grains, clay material (beidellite-nontronite group).

Southern Cross: Magnetite, ilmenite, limonite, amphiboles (green and colourless), epidote, zoisite, rutile, tourmaline, zircon, pyrite, garnet, pyroxene, andalusite, biotite, sphene, kyanite, sillimanite, monazite, staurolite, chlorite, anatase, green spinel, quartz, orthoclase, plagioclase, oligoclase, microcline, kaolinised and chloritic or micaceous material.

Goongarrie: Magnetite, ilmenite, limonite, amphiboles, epidote, zoisite, rutile, tourmaline, zircon, sphene, garnet, biotite, quartz, albite, micaceous grains, clay material.

Comet Vale: Magnetite, ilmenite, limonite, amphiboles, epidote, zoisite, sphene, rutile, tourmaline, zircon, andalusite, quartz, orthoclase, plagioclase, microcline, clay material, micaceous grains.

Niagara: Magnetite, ilmenite, limonite, amphiboles (green, colourless, and brown), epidote, zoisite, rutile, tourmaline, zircon, sphene, garnet, muscovite, biotite, quartz, orthoclase, plagioclase, micaceous grains, clay material.

Kookynie and Tampa: Magnetite, ilmenite, limonite, amphiboles (green, colourless, and brown), epidote, zoisite, rutile, tourmaline, zircon, sphene, sericite, biotite, garnet, monazite, quartz, orthoclase, acid plagioclase, microcline, opal'ne silica, micaceous grains.

Yerilla: Magnetite, ilmenite, limonite, amphiboles, epidote, zoisite, rutile, tourmaline, zircon, sphene, mica, biotite, quartz, orthoclase, plagioclase, clay material, micaceous grains.

Leonora: Magnetite, ilmenite, limonite, amphiboles, epidote, zoisite, rutile, tourmaline, zircon, sphene, andalusite, mica, chlorite, pyrite, corundum, quartz, orthoclase, plagioclase, microcline, clay material, micaceous grains.

Bulong: Magnetite, ilmenite, limonite, amphiboles, epidote, zoisite, rutile, tourmaline, zircon, sphene, andalusite, garnet, kyanite, staurolite, carbonate, chlorite, mica, pyroxene, quartz, orthoclase, microcline, micaceous grains, clay material.

Kanowna: Magnetite, ilmenite, limonite, amphiboles, epidote, zoisite, rutile, tourmaline, zircon, sphene, andalusite, carbonate, kyanite, sillimanite, garnet, mica, fuchsite, quartz, orthoclase, plagioclase, clay material, micaceous grains, sericite.

The examples cited above give some indication of the scope of soil mineralogy in Western Australia. The investigator in this subject must play the part of a detective, for the soils contain numerous grains which act as clues, pointing to some parent rock or some process which is responsible for the soils as they are to-day, whether they be residual, drifted, the remains of superficial deposits since removed, or pure sands of the sand dune type. For the interpretation of the results of the examination of the minerals in soils the investigator must be well acquainted with the geology of the district in which he works, and be alive to all the possibilities revealed by what is seen under the microscope. Mere lists of mineral species from various localities give little of value without some attempt to interpret what has been seen.

It is hoped to publish later an account of the technique employed in obtaining the heavy residues, and a discussion of the methods of expressing results. Details of this investigation, which was accepted as a thesis for the degree of Doctor of Philosophy by the London University, can be obtained from the Department of Geology, University of Western Australia, and the library of the London University.

DESCRIPTIONS OF PLATES I. AND II.

Plate I.—Heavy residues from the Kalgoorlie Fine Sands.

Fig. A.—Assemblage of heavy minerals in the soil collected above the older greenstone at Somerville. No. 11178. t, tourmaline; z, zircon; zo, zoisite; a, amphibole; il, ilmenite.

× 50.

Fig. B.—Typical assemblage of heavy minerals for the Kalgoorlie soils. Soil No. 11166, collected just north of the eastern end of Trans-Australian Railway cutting. a, amphibole; an, andalusite; zo, zoisite; ru, rutile; and ilmenite. Amphibole is less abundant than in A. Many residues from the Kalgoorlie soils are similar to this.

× 50.

Figs. 1-6 indicate the varieties of rutile grains found in these soils. Nos. 1 and 2 from samples collected at the North End; No. 6, a typical mode of occurrence, fine rutile rods in a micaceous base. Sample No. 11163.

× 350.

Figs. 7-15 illustrate the varieties of zircon grains to be found in the Kalgoorlie soils. Nos. 10, 11, and 12 are from the sedimentary rocks; the remainder from various soils.

Plate II.—Heavy residues from the Southern Cross Fine Sands.

Fig. A.—Assemblage of a soil derived from greenstone; consists of a, amphibole; ilmenite, opaque. Sample 15897.

× 50.

Fig. B.—Assemblage from a granitic soil. z, zircon; il, ilmenite; and a little amphibole. Soil collected 9 miles from Southern Cross on the Turkey Hill road. Sample 12164.

× 50.

Fig. C.—Assemblage of heavy minerals from a soil derived from gneiss, Marvel Loch. an, andalusite; t, tourmaline; m, mica; s, sphene; ga, garnet. Sample No. 15899.

× 50.

Fig. D.—Assemblage of heavy minerals from a granitic or gneissic soil; collected near rock outcrops on road between Hope's Hill and Corinthian. Sample No. 12182.

× 50.

Figs. 1-8. Various types of zircon from the Southern Cross soils.

× 300.

Figs. 9 and 10.—Monazite.

× 300.

(From brush drawings by the author.)

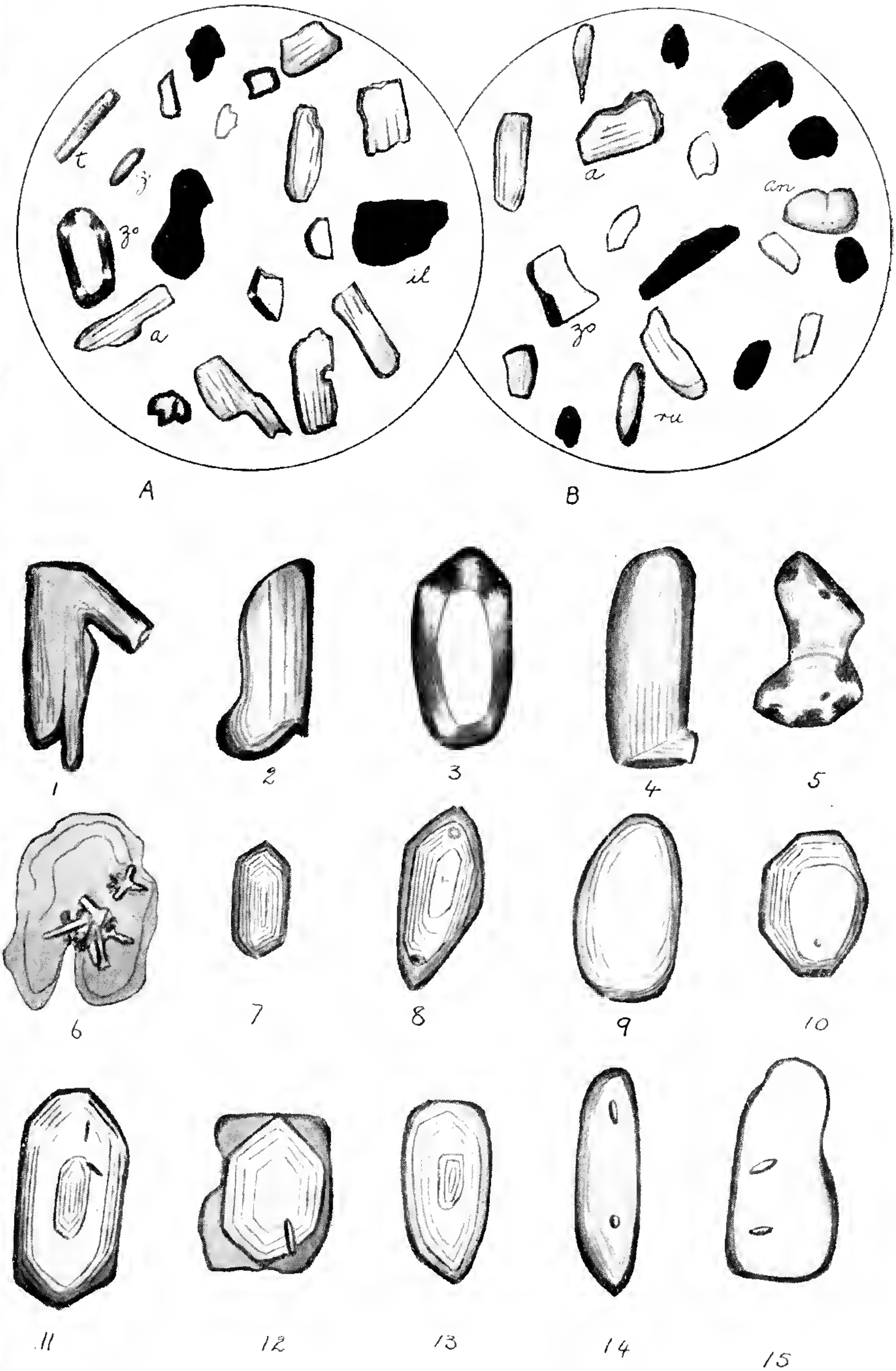

PLATE I.

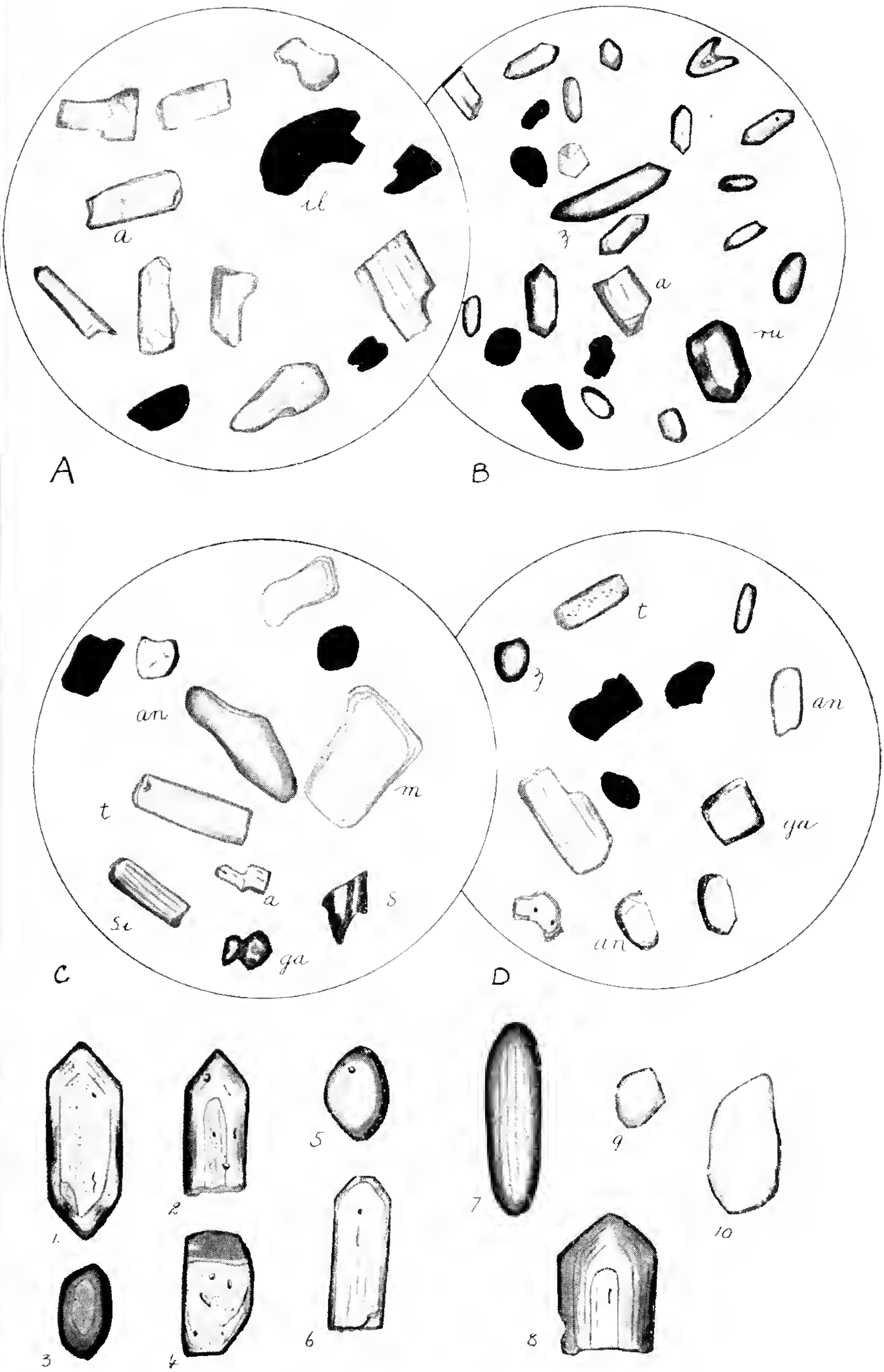

PLATE II.

3.—CONTRIBUTIONS TO THE MINERALOGY OF WESTERN AUSTRALIA.

Series X.

By Edward S. Simpson, D.Sc., B.E., F.A.C.I.

Read: 11th May, 1937; Published: 9th June, 1937.

CONTENTS.

(1)—ALMANDINE, MARVEL LOCH, Cen.

The recent detailed geological survey of the South Yilgarn area, and the keenness displayed in mineralogical problems by the field staff, has enabled the writer to examine in detail four specimens of almandine from different matrices in the one small area. For the specimens described he is indebted to the Government Geologist, Mr. F. G. Forman, and Mr. H. A. Ellis.

The rock mass in the vicinity of the gold mining centre of Marvel Loch is a Precambrian complex of highly tilted and foliated sediments with metamorphic greenstones, both interbedded and intrusive, and occasional pegmatite veins. There are granite outcrops a few miles distant both to north-east and south-west (*1*) (*2*). Almandine occurs freely in bands of metasediments, greenstones and pegmatites.

The workings of the Mountain Queen G.M. are in more or less graphitic mica schist, including some bands in which andalusite is plentiful, and others thickly seeded with garnets. The latter are invariably well crystallised in rhombic dodecahedra, usually quite symmetrically developed, but not uncommonly distorted by elongation along a crystallographic axis, or in other cases along the axis of the zone [022]. The diameter is commonly 3 to 4 mm. The crystals are usually black and almost opaque, probably from minute inclusions of graphite, but in some cases have a translucency of 1 to 2 mm. with a brownish red colour. Several carefully selected uncontaminated crystals from the 280ft. level were analysed with the results given in Col. 1. They prove the mineral to be a manganiferous almandine.

On the east side of Agricultural Loc. 405 there is another bed of dark grey graphitic mica-schist carrying about 5 per cent. of reddish brown almandine in 1 to 3 mm. rhombic dodecahedra. The composition of this is given in Col. (2), showing it to be a magnesian almandine, differing considerably in composition from that first described, though taken from a similar matrix.

Close to No. 2 is an almost black garnetiferous hornblende schist, probably a metasomatic eclogite, which carries many precisely similar looking garnets, forming in the specimens examined about 30 per cent. of the whole rock. The cleanest concentrate that could be obtained for analysis was still contaminated with about 4 per cent. of felspar and hornblende. The composition of this concentrate is given in Col. 3. The principal subsidiary molecule present is spessartite, as in No. 1, but the pyrope, grossularite and andradite molecules are also prominent.

Finally in the Comet G.M. there is a fine grained quartz-albite-microcline pegmatite, carrying a little muscovite, and thickly studded with small red grains of garnet, mostly 1 mm. or less in diameter. These were concentrated by vanning and then with heavy solutions, and finally analysed with the results given in Col. 4.

A comparison of the proportions of the different isomorphous molecules in the four garnets, reveals by far the greatest proportion of spessartite in that occurring in the pegmatite vein. This is in keeping with experience elsewhere, most pegmatite garnets being either manganiferous almandines or spessartites. Of the two garnets found in metasediments, the chief associate of the almandine molecule is spessartite in one case, pyrope in the other, a difference which must be due to differences in composition of the original sediments. The garnet from the schistose amphibolite contains almost equal proportions of spessartite, pyrope, grossularite and andradite co-crystallised with the preponderating almandine, corresponding to the wider range of metallic oxides available for garnet building in the original basic igneous rock. In only one case viz., that from the pegmatite, was any of the skiagite molecule present.

References :(*1*) 1915, T. Blatchford, Geol. Surv. Bull. 63, pp. 3-64.
(*2*) 1937, H. A. Ellis, W.A. Mining and Commercial Review, Apr., pp. 52-4.

Analyses of Almandine, Marvel Loch.

No. ...	1	2	3	4
Matrix	Mica schist.	Mica schist.	Amphibolite.	Pegmatite.
SiO_2	36·22	36·44	39·44	36·20
TiO_2	·08	·72	1·04	n.d.
Al_2O_3	20·38	21·70	19·08	20·76
Fe_2O_3	3·26	·61	2·05	1·08
FeO	27·57	32·89	27·90	27·19
MnO	6·40	·49	3·91	13·34
MgO	1·93	4·03	1·72	1·22
CaO	4·40	2·08	4·34	·56
H_2O+	Nil	·87	n.d.	Nil
	100·24	99·83	99·48	100·30
G. ...	4·17	4·16	4·15	4·20
Analyst	E. S. Simpson	H. P. Rowledge	H. P. Rowledge	H. P. Rowledge.
Molecules per cent.				
Alm.	64	77	67	61·5
Sps ...	15	1	10	30·5
Pyr ...	8	16	8	5
Grs.	4	4·5	8	Nil.
And	9	1·5	7	1·5
Ski ...	Nil	Nil	Nil	1·5

(2)—ANTHOPHYLLITE, MT. PALMER AND MARVEL LOCH, Cen.

Anthophyllite and kupfferite are two rare members of the amphibole group differing from one another only in crystalline form, the former being orthorhombic, the latter monoclinic. Both are characterised by an absence of calcium and sodium, and a preponderance of magnesium over iron, the common formula being $H_2(Mg,Fe)_7Si_8O_{24}$. The practical distinction between them is not easy as the following table shows:—

	Anthophyllite.	Kupfferite.
Composition	$H_2(Mg,Fe)_7Si_8O_{24}$	$H_2(Mg,Fe)_7Si_8O_{24}$
Crystal Group	Orthorhombic	Monoclinic
Sp. Gr.*	3·0	3·05
Hardness	5½	5½
Ref. Indices *	1·610, ·601, ·590	1·615, ·603, ·590
Elongation (optical)	+	+
Extinction, c ∧ Z	0° on every prism face	0° (100) to 20° ± (010)

*Increase with iron content.

The only important distinction of assistance in practical determination is the oblique extinction of kupfferite on all faces in the prism zone except a(100).

The occurrence of several dykes of an almost pure anthophyllite rock in the South Yilgarn goldfield is of unusual interest, because of its rarity. My attention was first drawn to these unusual looking rocks by Mr. H. A. Ellis, of the Geological Survey, who kindly supplied me with typical specimens for determination and with the permission of the Government Geologist placed his field observations at my disposal.

The Archæan complex from Southern Cross southwards beyond Marvel Loch is made up of alternating belts of rock predominantly sedimentary and predominantly igneous (granite and greenstone). The anthophyllite rock appears in several long narrow parallel dykes in three greenstone belts. Further to the east, between Mt. Palmer and Meiers Find, is another small outcrop of similar rock.

Two specimens of this rock type have been analysed. No. (1) is from N.E. of the May Queen G.M.L. 3459, four miles N.N.W. of Marvel Loch, and is slightly weathered. No. (2) is from 3½ miles S. of Mt. Palmer, and is practically fresh. The analytical results obtained are shown in the accompanying table with those of several other rocks of similar composition.

As rocks there are several unusual features to note in them, viz.:

(a) The unusually low proportions of alumina, lime and alkalis amongst the major constituents; and of phosphorus, sulphur and titanium amongst the minor.

(b) The preponderance of magnesia over all other common bases, and of chromium over other minor elements.

These features are characteristic of the hypersthenites, peridotites, serpentines and talc schists, to one or more of which the rock must therefore be related. In looking for other Western Australian rocks of similar composition it was found that the serpentines invariably had a much lower silica percentage, viz. 37 to 42. Even when allowance is made for the extra water in the serpentines, and a comparison is made on the basis of equal water content, the silica in the serpentines is only raised to 40 to 45 per cent., as against 52 to 58 in the anthophyllite rocks. On the other hand, there is a close resemblance as shown in the table to a hypersthenite, and to certain talc rocks which have been thought to be derived from hypersthenites. It would appear, therefore, that the South Yilgarn anthophyllite rocks are derived from hypersthenites, either by direct hydration, or in two stages, viz., by hydration to a talc rock, followed by recrystallisation under heat and pressure to an amphibole rock.

In hand specimens the rocks are of an almost uniform neutral grey colour, and appear to be made up almost entirely of equidimensional crystals, 3 to 5 mm. across, of anthophyllite of that colour. Scattered at rare intervals over the fractured surface are green crystals of tremolite of similar size, whilst a lens reveals a rather uniform distribution of small black specks of chromite and magnetite.

Microscope mounts of rock slices and powder show that the apparent coarse grains of anthophyllite are really each composed of an aggregate of almost parallel but slightly undulating and intertwining colourless fibres of extreme fineness, viz., ½ to 4 microns. There are also many small felted bunches of unoriented fibres. In both forms it is impossible to measure a true extinction angle owing to the overlapping and twisting of the fibres. When, however, the rock is reduced to a fine powder, about 95 per cent. of the single fibres give a straight extinction characteristic of anthophyllite. The remaining fibres, as well as some coarse splinters, give extinctions $Z \wedge c$ up to 13° and are almost certainly tremolite. In the rock slides this tremolite is visible as rare, and usually non-fibrous, colourless crystals. The black iron ores chromite and magnetite are scattered irregularly over the slide.

Anthophyllite Rock and Related Rocks. Western Australia.

No.	1	1	2	2	3	4	5	6
	%	Mols.	%	Mols.	%	%	%	%
SiO_2	57·60	47·63	52·31	43·98	55·27	61·00	57·37	47·44
Al_2O_3	1·90	·94	3·95	1·96	3·67	·68	1·14	6·23
Fe_2O_3	1·56	·50	3·26	1·03	·45	n.d.	·51	·76
FeO	5·45	3·86	5·37	3·77	7·17	6·14	6·52	6·78
MnO	·31	·22	·16	·11	·03	·20	n.d.	n.d.
MgO	26·35	33·21	26·39	33·05	28·36	27·88	26·98	26·68
CaO	1·60	1·42	3·17	2·85	2·93	Nil	·53	3·39
Na_2O	·01 }	·03	·12	·10	·86	Tr.	·25	·33
K_2O	·04 }		·06	·03	·18	Tr.	Nil	Tr.
H_2O +	4·22	11·91	4·57	12·81	·30	4·72	6·17	5·68
H_2O −	·66	—	·70	—	·04	·12	·87	·78
TiO_2	·09	·06	·23	·15	·16	·01	n.d.	·20
Cr_2O_3	·57	·19	·31	·10	·46	·01	n.d.	·22
P_2O_5	Nil	—	Nil	—	Tr.	·10	n.d.	Tr.
CO_2	Nil	—	·05	·06	Nil	Nil	Tr.	2·06
FeS_2	·07	·03	Nil	—	·17	n.d.	n.d.	n.d.
	100·43	100·00	100·65	100·00	100·05	100·86	100·34	100·55
G	2·81 (approx.)	...	2·94	...	3·25	2·83	2·82	2·82
Analyst	H. P. Rowledge.		C. R. Le Mesurier.		C. C. Williams.	E. S. Simpson.	A. J. Robertson.	E. S Simpson.

(1) Anthophyllite rock, near May Queen, G.M., Marvel Loch.
(2) Anthophyllite rock, 3½ miles S. of Mt. Palmer.
(3) Hypersthenite, Norseman, G.S.M. 5646.
(4) Talc Schist, Mt. Taylor.
(5) Talc rock, Meekatharra. G.S.M. 11579.
(6) Talc-chlorite rock, Kalgoorlie. G.S.M. 3391.

(3)- CHLORITE, MT. SATIRIST, N.W. AND KALGOORLIE, CEN.

In my last Contribution (*1*) emphasis was laid on the paucity of mineralogical data regarding West Australian chlorites, and this was remedied to some extent by a description of three specimens from different places. Data are now available regarding two further ones.

Daphnite, Mt. Satirist, N.W.

In the ridges six miles S. of this hill, masses of microscaly greenish black chlorite have been obtained. These are sufficiently dense and tough to be sawn and polished into trinkets. As a little vitreous quartz is intergrown with the chlorite, it appears probable that the specimens have come from a vein or segregation in the local Precambrian greenstone. The composition of carefully selected material is:—

Daphnite, Mt. Satirist.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
21·17	20·02	9·88	33·48	·45	3·40	·10	·06	·12

H_2O+	H_2O-	TiO_2	Total	G	Ng	Nm	Np
10·63	·57	·07	99·65	3·18	1·681		1·681

Analyst, C. R. Le Mesurier.

The mineral molecules present are:

Daphnite	Cronstedtite	Antigorite	Amesite	
65·1	23·2	6·0	5·7	per cent of total molecules.

After calculating these molecules, there remained 3.31 per cent. by weight of silica, probably present as intergrown quartz or opal, and 0.91 per cent. of excess water mostly adsorbed.

By these figures the mineral is shown to be the aphrosiderite variety of daphnite, a variety best defined as that which contains about 20 per cent. of the cronstedtite molecule. The type aphrosiderite from Weilburg, Germany, has the molecular composition Daphnite 71.6, Cronstedtite 11.8, Amesite 11.1, Antigorite 5.5. The Mt. Satirist mineral is greenish black in mass, with the following pleochroism under the microscope; X, very pale yellow; Y = Z, rich green, with slightly bluish tinge. The mineral is optically negative with Ng = Nm 1.684, and birefringence very weak making Np 1.681. The considerable increase in N over the normal (Nm 1.651) with increase in Fe_2O_3 from 5.18 (Weilburg) to 9.88 (Mt. Satirist) is notable, and in accordance with experience.

Daphnite, Kalgoorlie.

From small cavities in a quartz vein crossing the Lake View lode in the Perseverance G.M. some beautiful specimens of a greenish black vermiform chlorite were collected by G. S. Compton in 1935. The bundles of crystals resemble a confused mass of intertwined worms of uniform diameter (about 1.5 mm.), emplanted on quartz and ankerite, and in turn occasionally supporting isolated crystals of ankerite. Cross sections of the rods reveal a rosette of small plates, radiating from the centre at right angles to the surface and to the axis of the rods. The composition of this chlorite is as follows:—

Daphnite, Kalgoorlie.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
23·32	17·45	4·09	38·90	·01	4·54	·24	Nil	Trace

H_2O+	H_2O-	TiO_2	Total	G	Ng	Np
10·89	·80	·03	100·27	3·10	1·662	1·659

Analyst, C. R. Le Mesurier.

The mineral molecules present are:

Daphnite	Ferantigorite	Antigorite	Cronstedtite	
60·0	17·3	13·7	9·0	per cent of total molecules.

Excesses of 0.89 per cent. of SiO_2, and 0.59 of H_2O are indicated by the analysis, and are probably extraneous to the chlorite. This mineral is practically identical in composition with the type metachlorite variety of daphnite found at Elbingerode in Germany (2).

The following optical data were determined under the miscroscope:—

X = c, pale yellow; Y = Z, rich bottle green.
Ng = Nm, 1·662, Ng — Np, small, about ·003. Optical sign, negative.

In similar cavities between the 1,300 and 1,700 feet levels of the same lode in the same mine, there are dense, friable masses of a greenish black chlorite, which has similar optical properties to the above, the colour scheme being the same, and Ng = Nm, 1.657; Np, 1.655. It has almost the same specific gravity, viz., 3.15, and iron content, viz., FeO 38.22, Fe_2O_3 2.93 per cent. Sifted specimens of this chlorite were found to contain a considerable proportion of micro-vermiform particles, with prism diameters from 0.02 to 0.20 mm.

This chlorite is evidently one of the latest minerals to develop in the lode channel.

References: (1) 1936, E. S. Simpson, Jour. Roy. Soc., W.A., 22, p. 2, 3.
(2) 1896, Dana, System VI., p. 656.

(4)—CHLORITOID, MT. MAGNET, MUR.

Chloritoid has already been recorded from two places in the State, viz., in an altered sediment (mica schist) at Collier Bay, 18 miles E.S.E. of Yampi Sound, and in a series of metasomatic dolerites at Kalgoorlie. In 1935 several deep bores were put down in the Precambrian complex on the Hill 60 G.M.L. of the Mt. Magnet Gold Mines, and in the cores from two of them R. W. Fletcher recognised chloritoid. In the No. 1 Bore four different bands of chloritoid rock were recognised, in each of them the mineral being in minute discs, usually well under one millimetre in diameter, set in a ground mass of quartz, sericite, and chlorite.

A similar rock met with at 542 feet in the No. 3 Bore has been analysed for me by Mr. C. R. Le Mesurier. The results he obtained were as follow:—

Chloritoid Mica-schist, Mt. Magnet.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
66·68	20·21	·37	2·46	·01	·54	·31	1·07	4·18

H_2O+	H_2O-	TiO_2	CO_2	P_2O_5	FeS_2	Total	G
2·97	·10	·92	·17	·22	·04	100·25	2·76

The rock is grey in colour with appreciable schistosity. On the fractured surfaces many minute black specks are visible, which prove under the microscope to be discs of chloritoid from 0.2 to 0.5 mm. in diameter. By calculation they form approximately 8 per cent. of the whole rock, finely granular quartz and scaly sericite each forming about 40 per cent. The other minor constituents are chlorite, rutile, and apatite. The rock is plainly a metamorphic sediment. Of the three known varieties of chloritoid, the normal variety, the magnesian (sismondine) and the manganiferous (ottrelite), the last cannot be that present, since manganese is practically absent from the rock. The poor intensity of colour in the sectioned mineral and the molecular ratio of FeO to MgO in the whole rock, viz., 2.6 to 1.0, points to the mineral being sismondine. Its form is typical, the basal planes being sharply defined, whilst the prism faces are as usual absent and replaced by ragged edges. There are innumerable dusty inclusions of quartz, etc., in each crystal.

(5)—COLUMBITE AND MANGANOCOLUMBITE, McPHEE'S RANGE, N.W.

McPhee's Range is an area of Precambrian greenstone projecting from the granite plain of the Turner River, and lying about 20 miles to the east of Wodgina. First known as an auriferous area of no great importance, it has for many years past been chiefly noted for its alluvial and lode deposits of commercial tantalum ore, first discovered and worked by Bonnor in 1905. This has consisted mainly of manganotantalite, but has included also a little ferrotantalite, tapiolite, and microlite. A considerable quantity of manganocolumbite has been found there, much of it very beautifully crystallised. Ferrocolumbite is comparatively rare. The last two minerals, rich in niobium, have been valueless in the past, but are now in considerable demand.

The greenstone of the range, as well as the granite immediately to the west of it, is traversed by a large number of pegmatites characterised by a preponderance of albite and quartz, and genetically connected with the granite. A small amount of tantalum and niobium ore has been obtained from the "lodes," which are albite pegmatite veins, mainly in the greenstone country, but also to a less extent in the granite. The main part of the ore won in the past has, however, been found in the alluvium derived from the pegmatites.

The four compounds $FeTa_2O_6$, $MnTa_2O_6$, $FeNb_2O_6$ and $MnNb_2O_6$ are completely isomorphous and are found in nature cocrystallised to an infinitely varied extent. It is evident from the examination of commercial parcels of ore and prospectors' samples, that the tantaliferous minerals at McPhee's Range, whilst predominantly rich in manganese as base, vary greatly in the relative proportions of tantalum and niobium, even at times in the various pebbles constituting a single sample. This is very noticeable in alluvial ore derived from the disintegration of more than one pegmatite vein. There is very little evidence available regarding the uniformity or otherwise of the ores in a single vein, but in one at least the Ta and Nb contents cover a wide range. There is practically no evidence of the stage of pegmatite development at which they were deposited, but the frequent perfect crystallisation would suggest an early stage.

The percentages by weight of Ta_2O_5 and Nb_2O_5 in a mineral of the tantalite group are hyperbolic functions of the specific gravity of the crystal.* For example—

$$Ta_2O_5 \text{ per cent.} = 251.6 - \frac{1308.5}{G}$$

This follows from the specific gravities of pure tantalite (7.90) and pure columbite (5.20), and their identical molecular volumes in the crystalline state. A graph showing the relations between these two factors is reproduced in Plate 1. It has been repeatedly checked in the Government Laboratory against analyses of actual crystals. The difference in molecular weight between the corresponding iron and manganese compounds is so slight, that the curves for the two series $FeTa_2O_6$—$FeNb_2O_6$ and $MnTa_2O_6$—$MnNb_2O_6$ are practically coincident.

The specific gravity being an easily determined factor, the graph can be used as a means of determining rapidly and closely the composition of a crystal or pebble of a mineral of this series in respect of the metallic acids. For many years it has been so used with great advantage in the Government Laboratory in Perth. It has been calculated that the mineral with equal molecules of $FeTa_2O_6$ and $FeNb_2O_6$, or of $MnTa_2O_6$ and $MnNb_2O_6$, has a specific gravity of 6.55. As the tantalum compounds are the heavier it follows that all fragments of mineral with G over 6.55 are properly classified as tantalite or manganotantalite, and those with G under 6.55 as columbite or manganocolumbite. In the past only tantalites have been in commercial demand; the tantalum being utilised and the niobium wasted. Recently, however, a use has been found for niobium in the steel industry, and consequently a demand for columbites with a high percentage of niobium has arisen.

The richest tantalum ores found in McPhee's Range have been nearly pure $MnTa_2O_6$ with G 7.80 and 7.74. These came from workings one mile N. of M.C. 80 and from Thelemann's claim at Pilgangoora.

The richest niobium ores, judged by the specific gravities, were ones having G 5.21, 5.35 and 5.42, representing 99.5, 94.2 and 88.4 per cent. by weight of $(Mn, Fe)Nb_2O_6$ or 78.3, 74.2 and 69.6 per cent. of Nb_2O_5. The first of these was a recent specimen from 2 miles N. of M.C. 80, the other two were amongst the earliest specimens from Bell's and Macbeth's claims "near Green's Well."

Examples of parcels of ore from here with a narrow range of specific gravity, and therefore a fairly uniform ratio of Ta to Nb are as follow:

No.	Locality.	G Range	Nb_2O_5 %	G Mean.	Nb_2O_5 Mean %	Ta_2O_5 Mean %	FeO %
1.	5m. N. of Green's Tank	6·18–6·47	42·5–32·3	6·33 (M/8)	38·0	44·6	3·53
2.	Pilgangoora	5·90–6·04	51·8–47·0	6·01 (M/7)	47·8	33·8	5·80
3.	Do.	5·77–6·31	55·5–38·5	5·98 (M/17)	49·0	32·4	6·39
4.	Hooley's M.L. Pilgangoora	5·58–5·79	63·0–55·5	5·70 (M/4)	58·8	21·6	15·99

The first three of these consist of manganocolumbite; No. 4 is columbite (ferrocolumbite).

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* This law of course holds good in regard to the components of all isomorphous series with two variables, e.g., ferberite-huebnerite, mimetite-pyromorphite, spinel-hercynite, etc. The general formula is:—

$$H\% = \frac{100\, G_H(G_M - G_L)}{G_M(G_H - G_L)}$$

Where H is the heavier component, *e.g.*, $FeTa_2O_6$, G_H, G_L and G_M are the specific gravities respectively of the heavier component, the lighter component and the mineral under experiment. The percentage of $FeTa_2O_6$ multiplied by $Ta_2O_5/FeTa_2O_6$, *i.e.*, by 0·860, gives the percentage of Ta_2O_5.

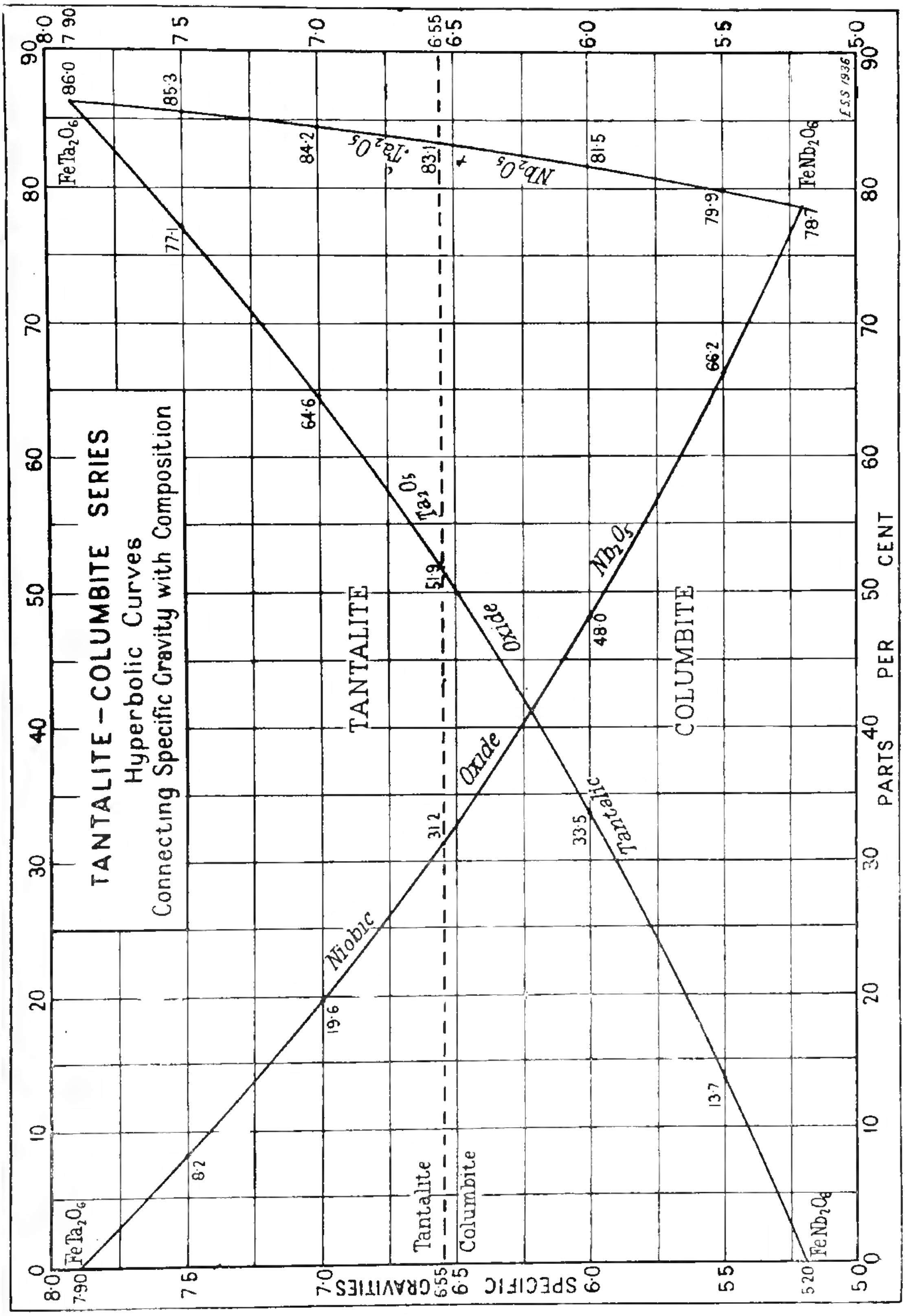
TANTALITE - COLUMBITE SERIES
Hyperbolic Curves
Connecting Specific Gravity with Composition
TANTALITE
COLUMBITE
Niobic Oxide
Tantalic Oxide
Ta_2O_5
Nb_2O_5
$FeTa_2O_6$
$FeNb_2O_6$
Tantalite
Columbite
SPECIFIC GRAVITIES
PARTS PER CENT
E.S.S. 1936

Plate 1.

Two examples of a wide range of grade in the pebbles of one parcel are worth quoting:—

No.	Locality.		Range.	Mean.	FeO
5.	$1\frac{1}{2}$m. N.E. of M.L. 80	G	6·05–7·69	6·73 (M/7)	3·38
		Nb_2O_5	46·5– 4·2	26·7	
		Ta_2O_5	35·3–81·5	57·0	
6.	Bell's M.L. "Green's Well" ...	G	7·35–6·84	6·45 (M/8)	<MnO
		Nb_2O_5	72·2–23·9	34·2	
		Ta_2O_5	7·1–60·0	48·7	

These obviously are mixtures of manganocolumbite and manganotantalite. Another similar mixture from Pilgangoora contained 1.69 per cent. of FeO, with a high MnO content. The only true columbite analysed contained 15.99 per cent. of FeO, whilst other parcels of manganocolumbite in addition to those recorded above carried only 3.26 and 5.22 per cent. of FeO.

Both alluvial and lode concentrates are contaminated with a little cassiterite, ranging from less than 0.5 per cent. up to 20 per cent. One very exceptional sample, from Houston's workings on the east side of Pilgangoora, carried 40 per cent. The majority, however, carry less than 10 per cent.

Other associated minerals noted were albite, quartz, muscovite, lepidolite, spessartite, beryl, spodumene, kaolin, calcite (travertine), limonite, hæmatite, magnetite, tapiolite and microlite.

The fragments of columbite examined (mostly alluvial) ranged in weight from about 165 grammes (6 ozs.) down to 0.1 grammes ($1\frac{1}{2}$ grains) or even less. A fairly typical alluvial parcel yielded the following grades:—

Over 4 mesh, 11.6%. Over 10 mesh, 80.7%. Under 10 mesh, 7.7%.

On a fresh fracture the mineral is opaque and pure black in colour. The surface, however, is usually stained red or brown by ferruginous soil, and possibly at times by decomposition products of the mineral itself.

Much of the manganocolumbite and ferrocolumbite from this place is well crystallised but usually single ended. The lower end is often missing, either through the crystal being an outgrowth from a pre-existing solid surface, or owing to breakage during denudation. The forms noted were, in approximate order of frequency:—

a(100) b(010) c(001) u(133) m(110) k(103) e(021) y(210)
g(130) z(530) q(023) f(102) n(163) o(111).

The crystals of columbite and manganocolumbite are either tabular, flattened parallel to (100), or columnar, and vary in size from 0.1 gramme up to many grammes in weight. The largest crystal of manganocolumbite seen was much chipped, but still weighed 165 grammes. It was composed of the forms a b c u m, and had G 5.95. The next largest, also fragmentary, weighed 30 grammes, and had G 5.78. Occasionally simple combinations of a b c are seen, but mostly these faces are associated with u(133) (See Figs. 1, 2), the habit varying considerably with varying development of the four forms. The u faces are often unevenly developed in the one crystal u^1u^4 being large and u^2u^3 small, or u^1u^3 large and u^2u^4 small. In an extreme case $u^2u^1u_1u_2$ were present, but $u^4u^3u_3u_4$ were entirely missing. Faces of m(110) and y(210) may be moderately broad (Fig. 1), but usually these and other prisms, such as g(130) and z(530), are only narrow chamfers on edges of the pinacoids. e(021) is a fairly common form (Fig. 1) and well developed, but the domes k(103), f(102) and g(023), and the pyramids n(163) and o(111) are rare and poorly developed. In one very unevenly developed crystal $a^2m^1m^4k^1$ were large, $a^1b^1b^2g^4u^3u^4$ were small, whilst $cm^2m^3g^1g^2g^3u^1u^2$ were entirely missing. Tabular twins on e(021) are extremely rare.

Some complex combinations observed were:—

a b c u e y m g   a b e u n e k y
a b e u n o k m   a b e u n f e

Goniometer measurements were made of a crystal of ferrocolumbite with G 5.55. The readings were:—

Face	a^1	z^1	m^1	g^1	b^1	m^2	z^2	a^2
ϕ	0°0′	26° 35′	39° 46′	67° 51′	90° 0′	140° 59′	153° 51′	180° 0′
ρ	90° 0′	89° 31′	89° 7′	90° 0′	90° 0′	89° 41′	89° 41′	90° 0′

Face	z^3	m^3	g^3	b^2	g^4	m^4	z^4	c^1
ϕ	206° 22′	219° 22′	247° 36′	270° 4′	290° 45′	320° 40′	333° 30′	...
ρ	90° 12′	90° 34′	90° 34′	90° 0′	90° 0′	90° 25′	90° 17′	0° 0′

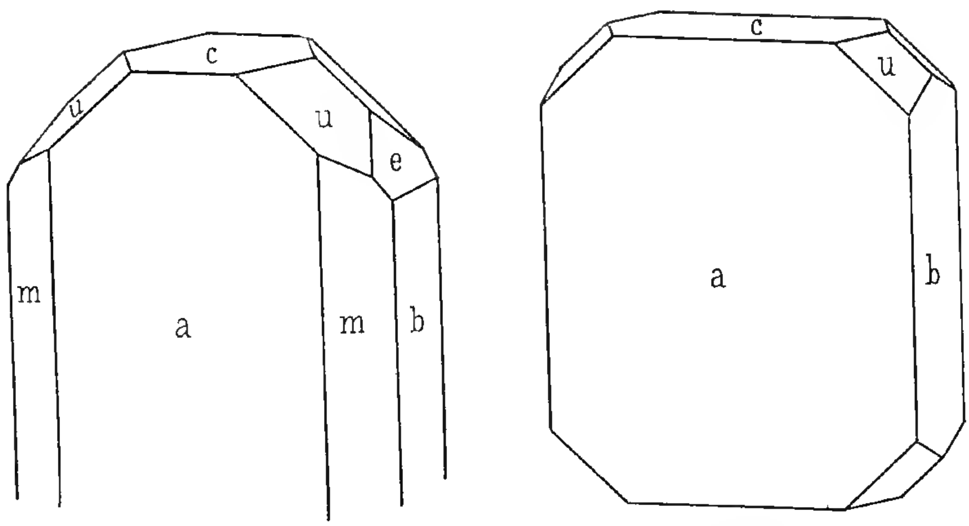

Fig. 1.   Fig. 2.

Crystals of Manganocolumbite, McPhee's Range.

No sharp reading could be obtained for the forms n and e. From the mean reading for az, the ratio a : b was calculated to be 0.82976.

The (100) faces are not uncommonly complicated by small bas-reliefs of parallel crystals. In other cases this face is striated. Fan shaped aggregates of tabular crystals were noted, in which the individuals were attached by a face vicinal to (100) whilst all the (010) faces were in two parallel planes. Still rarer were "Mushroom" forms, in which a large number of small prismatic individuals were combined in the form of a conical segment of a sphere. Four of these had G ranging from 6.38 to 6.55.

(6)—DUFRENITE, GINGIN, S.W.

This bright green basic ferric phosphate, $Fe_2(OH)_3PO_4$, was found in large quantities in the Cretaceous coprolite beds at Dandaragan in 1906. Although similar strata extend southwards to Gingin, the only dufrenite previously found at the latter place was in the form of slight green stains in boulders of glauconite sandstone, which were collected by the writer in 1926 in a creek bed half a mile S.S.E. of Molecap Hill. Last year Mr. J. E. Wells drew my attention to an important occurrence of the mineral with coprolite at Poison Hill, four miles N. of the town.

Owing to two landslips on the western face of the hill, good fresh sections of about 50ft. of the upper greensand are exposed. A typical section here, illustrated in the Fig. 3, is as follows:—

Top (A) Weathered (partly limonitised) greensand, with rare coprolite	30 ft.
(B) Greensand with many large coprolites	2 to 4 ft.
(C) Fresh greensand mostly impregnated with dufrenite and carrying thin lenses very rich in it	8 ft.
(D) Rich dufrenite band	0.5 to 1 ft.
(E) Glauconitic clay	1 ft.
(F) Greensand with abundant small coprolites ..	8 ft.

Bottom about 59 to 70 feet above chalk bed.

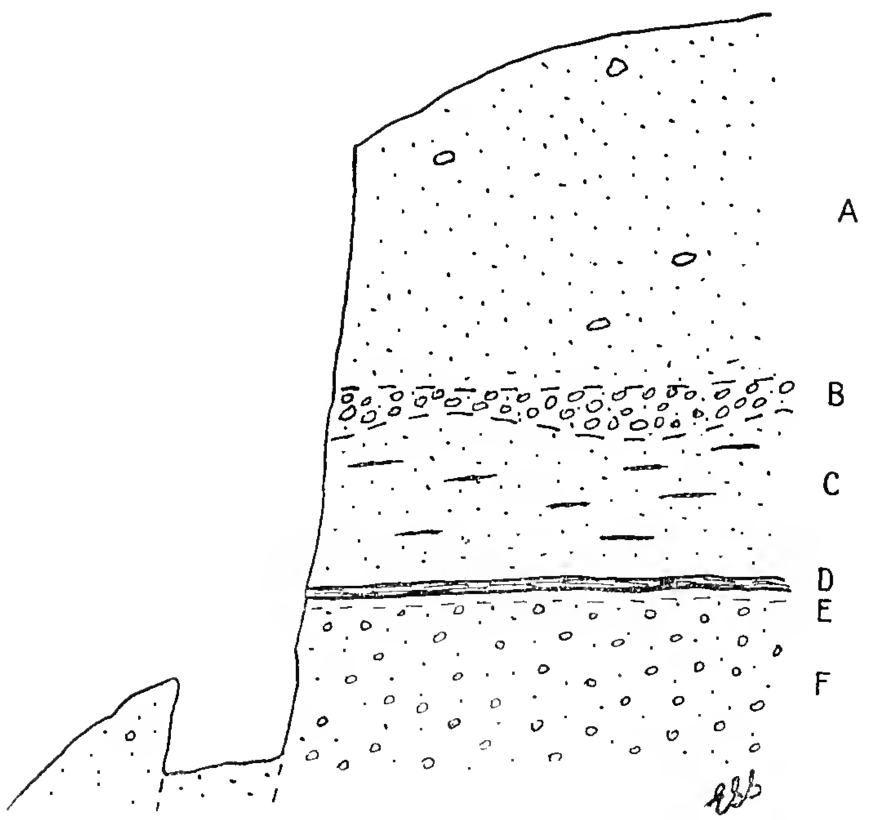

Fig. 3.

Section of Cretaceous Beds west side of Poison Hill, Gingin.

The rich dufrenite horizon (D) is a mixture of dufrenite, glauconite, quartz sand and kaolin, the whole bright green in colour or mottled with brown limonite and iron-stained clay. Immediately beneath it the thin layer of glauconitic clay seems to be almost impervious to water. The lowest coprolitic greensand extends below the ground level at the foot of the cliff. No dufrenite is visible in it.

My impression of the origin of the dufrenite is that the richest bed (D) was originally a layer of clayey greensand with abundant marcasite or pyrite and possibly apatite, concretions. The sulphides were oxidised by air and oxygenated water as the country became eroded, giving rise to solutions of sulphuric acid and iron sulphates. In contact with coprolite, or lime phosphate solutions derived from them, ferrous and ferric phosphates would form, and ultimately be precipitated and fixed in position as diffusions and concretions of the very stable compound dufrenite, the main concentration being immediately above an impervious layer of clay. In support of this theory, whilst the coprolites in some bands are hard and compact, averaging 22.7 per cent. of P_2O_5, in others they are porous and friable, being evidently leached, and carry only 10.2 per cent. P_2O_5. Furthermore, a distinct odour of SO_2 emanates from the face of the smaller landslide, indicative of oxidising marcasite or pyrite.

No crystallised mineral is to be seen here, all of it being earthy and massive. Even the apparently purest pieces are heavily impregnated with grains of quartz, glauconite and kaolin, the dufrenite acting as a cement. Some of the richest looking material from horizon (D) was found to contain: Fe_2O_3 23.31, P_2O_5 7.09 per cent. This is equivalent to about 25 per cent. of dufrenite.

The impregnated greensand of horizon (C) would probably average 5 to 10 per cent. of dufrenite.

(7)—ELBAITE, RAVENSTHORPE, S.W.

As far back as 1909 (*1*), the presence of pink and green tourmaline at Ravensthorpe was noted by L. Glauert and the writer. The pink was obviously the rubellite variety of elbaite, but the green might well have been either that species or dravite. The result of recent chemical and physical investigation has proved that both are elbaite.

The two colour varieties are closely associated with one another in a quartz-microcline-albite pegmatite in Precambrian greenstone a short distance to the north-west of the town. Spodumene and muscovite are abundant in the same vein, whilst rarer constituents are lepidolite, beryl, manganocolumbite, black dravite, and montebrasite.

Although no gem material has been obtained, some very handsome specimens of alkali tourmaline have been collected. Specimens often show only the pink variety in bunches, frequently radiated, of fine (1 to 2 mm.) prisms. In some specimens there is a pronounced crustiform structure, one such having a dense layer of radiating rubellite 10 to 20 mm. thick on one face, then a sharply outlined central band of albite 5 to 10 mm. thick, succeeded in turn by a third layer, 3 to 5 mm. thick, of lepidolite. The colour of the rubellite ranges from "phlox pink" (R. 65f) through "pale rosolane pink" (69′d) to "vinaceous lilac" (69^{5}). The translucency is of a low order, about 1 to 3 mm. The specific gravity is 3.00 to 3.02, refractive indices No. 1.637, Ne. 1.619; and dichroism, E. colourless, O pale pink when over 0.5 mm. thick, colourless in thinner sections. A partial analysis yielded the figures given below.

Closely associated with the rubellite is a green elbaite with G 3.02 to 3.04; refractive indices No 1.634, Ne 1.619; and dichroism, E colourless, O pale green when over 0.5 mm. thick, colourless in thinner sections. The colour in mass is a series of tints of greyish green which are hard to match, but approach Ridgways 33^{3}, 33^{5}i and lighter tints of the same, with rarely

41‴i. Only one crystal showed any high degree of translucency, and this, because of lack of fluid inclusions, and somewhat higher iron content, had G 3.06, and colour olive green. A partial analysis given below showed that the green variety had considerably more iron, manganese and magnesium in it than the pink variety. The figures were:—

Elbaite, Ravensthorpe.

	SiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Li_2O	Na_2O	K_2O
Pink	39·07	41·25	·19	·54	·10	·29	1·28	2·32	·20
Green	37·92	39·18	2·14	1·34	·40	·22	1·24	2·64	·42

* Equivalent to total Fe.

In habit both types form hexagonal or curved triangular prisms (a, m), the green ones being stouter, having a diameter of 3 to 10 mm. They occur, in the case of the green, in parallel or unoriented groups with interstitial albite or quartz. In one specimen the mineral is embedded in spodumene.

Green monochrome elbaite is rare at Ravensthorpe, but a layer of the green variety enveloping a core of pink is comparatively common. Stout prisms of rubellite appear in many cases to have grown outwards from the walls of a fissure or from a tabular mass of spodumene, and at an advanced stage in their growth the composition of the precipitating thermal solution has suddenly changed, with the result that a final layer of green elbaite has been deposited on them in parallel position. Such overgrowths of celandine to artemisia or American green (R 33‴-33‴b-33‴i) on a core of lilac elbaite make very handsome specimens. The greatest rarity is a core of milk white elbaite covered with the green.

The black dravite occurring occasionally in the same vein has G 3.10 with dichroism E colourless, O cobalt blue.

Reference: (*1*) 1909, E. S. Simpson and L. Glauert, Geol. Surv. Bull. 35, p. 22, 46.

(8)—GAHNITE, GOYAMIN POOL, S.W.

Quartzites are not so prominent amongst the Precambrian metasediments of the Chittering Valley as they are in the same series further north between Moora and Three Springs, or further south about Bullsbrook. In the more common rock type a quartz biotite schist, gahnite has been found at Gillingarra, 45 miles north of here, and been previously described (*1*). About three-quarters of a mile east of Goyamin Pool is a thin bed of slightly sillimanitic quartzite, interbedded with the prevailing quartz-biotite schists, and close to an intrusive or interbedded amphibolite and garnet amphibolite. In section the quartzite shows small interstitial bunches of microscaly white mica and occasional prisms of sillimanite, apatite and zircon. In hand specimens it is seen to be traversed by a network of small quartz veins carrying grains of green gahnite and pale brown staurolite, both of which have also penetrated the rock on either side to a slight depth. In places they are evenly and sparsely distributed through the vein or rock, in others there are considerable concentrations of gahnite in the veins, forming as much as 50 per cent. of the whole.

The grains of gahnite range from a fraction of a millimetre up to 5 mm. in diameter, the average being a little over one millimetre. The shade of green varies from about R 35″i to 35″k. The grains are moderately translucent in mass and completely transparent in thin section (about 0.05 mm.) when the colour ranges from colourless to rather strong bluish green.

A number of pieces of rock showing the mineral were crushed and concentrated, first by vanning, then by sinking in methylene iodide solution. The concentrate weighed 14 per cent. of the rock and contained about equal quantities of gahnite and staurolite, the latter in well formed 1 mm. or smaller crystals. By further treatment with Clerici solution (G 4.2) an almost pure concentrate of gahnite was obtained. Examination under the microscope proved the mineral to be vitreous, transparent, green in colour and isotropic, and only contaminated with a little iron stain, quartz and mica. Deducting 0.39 per cent. of Fe_2O_3 soluble in weak HCl and 0.05 of water combined with it, the analytical figures were:—

Al_2O_3	Cr_2O_3	ZnO	FeO	MnO	MgO	CaNi	SiO_2	Total
57·72	Nil	29·46	8·88	·02	2·79	Nil	1·08	99·95

Analyst C. R. Le Mesurier.

The specific gravity was 4.38. The composition of the Goyamin Pool mineral is almost identical with that of the Gillingarra gahnite (*1*).

Reference: (*1*) 1930, E. S. Simpson, Jour. Roy. Soc., W.A., 16, p. 30, 31.

(9)—GROSSULARITE, MELVILLE, Mur.; TOODYAY, S.W.; AND MEIER'S FIND, Cen.

Melville, Mur. Reference was made to the occurrence here of two species of garnet, andradite and spessartite, in two previous contributions (*1*), (*2*). A third species, grossularite, remains to be described. Garnets, often well crystallised and of fairly large size, up to 2 cm. diameter, are found in several places in the amphibolite area. Analyses and specific gravity determinations indicate that there is a complete series ranging from almost pure andradite, containing only 0.22 per cent. alumina and having G 3.87, to a ferriferous grossularite with 13 per cent. of alumina and G 3.62. A single crystal was found with G 3.60, indicating more alumina still, whilst garnets of intermediate composition had G 3.81, 3.78 (N 1.895), 3.71, 3.69, 3.65. Pure grossularite contains 22.7 per cent. Al_2O_3 and has G 3.55 and N 1.730. Pure andradite, which is fully isomorphous, has no Al_2O_3 but in place of it 31.5 per cent. Fe_2O_3, with G 3.85 and N 1.900.

On Elliott's gold prospecting area, about one mile north of the townsite, a shear zone in amphibolite traversed by many veinlets of quartz has been exploited for gold. The quartz veins were remarkable for containing a number of beautiful crystals of brown garnet, ranging from 0.5 to 2.0 cm. in diameter. Some of these occurred in single isolated crystals, but more often they were in parallel or unoriented groups. The form is the rhombic dodecahedron d(110) modified by more or less narrow faces of n(211) and s(321). In most cases the faces have a very brilliant lustre; whilst the surface colour of the freshest and brightest is about hessian brown (R 5′m), bleaching of some bring them near snuff brown (R 15″k). Their identity as ferriferous grossularite is proved by their composition given below. The calculated molecular composition per cent. is: grossularite, 58.0; andradite, 36.8; almandine, 4.1. spessartite, 0.9; pyrope, 0.2. In addition there are 3.25 per cent. by weight of included quartz.

Groups of almost equally perfect crystals with G 3.65, 3.69 have been found associated with massive garnet in a quartz reef near the Victoria G.M. 1½ m. N.E. of the Basin, i.e., 3 miles N. of Melville township. These are slightly darker in colour than the previous ones, and whilst some are almost unmodified dodecahedra, others have very broad faces of n(211), with only narrow bevels of s(321).

The same mineral too, in crystals up to 3 cm. in diameter lacking the form (321) and with only rare faces of (211), has been found half a mile W.N.W. of the townsite. Its G is 3.60.

Grossularite, Melville and Toodyay.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO
(1) Garnet, Melville	40·08	·58	13·18	11·16	1·74	·34	·06	32·68
(2) Rock, Toodyay	50·68	·96	12·63	3·79	2·13	1·02	1·71	26·81

	Alks.	H_2O+	H_2O-	Total	G	Analyst.
(1)	Nil	Trace	Nil	99·82	3·62	D. G. Murray
(2)	Trace	·35	·26	100·34	3·27	H. P. Rowledge

Toodyay, S.W. A garnet hornstone has been found in the Precambrian series a little to the south-east of Key Farm, two miles S. of Toodyay. Its composition is given above, from which the following approximate mineral composition has been deduced:—

Grossularite	Quartz	Diopside	Sphene	Chlorite & Actinolite	
68.3	16.8	11.6	2.3?	1.0	per cent. by weight.

The titanium here calculated to sphene may form part of the garnet.

The molecular composition of the garnet is:—

Grossularite	Andradite	Almandine	Spessartite	
77	16	4	3	mols. per cent.

The rock is an indistinctly bedded, semivitreous hornstone of a general yellowish green colour, not far from Ridgway's grape green (25[b]). Thin short lenses of transparent quartz follow the bedding plane, and there are occasional small splashes of greenish black amphibole and chlorite which are more freely developed on the contact.

A thin section shows that by far the most abundant constituent is colourless garnet in closely compacted crystals and grains, 0.05 to 0.20 mm. in diameter. More or less perfect rhombic dodecahedra are plentiful. The garnet forms broad bands associated with rare prisms of colourless diopside. There is also a little cloudy chlorite and rare actinolite. Between the garnet bands are bands of vitreous quartz, coarsely crystalline. The quartz encloses a little fine dust, and occasional crystals of garnet and diopside are completely embedded in it.

This rock is most probably a highly metamorphosed siliceous and argillaceous limestone.

Meiers Find, Cen.—At this new gold find in South Yilgarn pale pink to pale brown masses of grossularite are plentiful in a quartz vein. With one exception, which yielded a dodecahedral angle of 60°, no crystal forms are visible, the masses having rough boundaries and reaching 2 or 3 cm. in length. There are occasional small intergrowths of a greenish grey amphibole, probably actinolite. The garnet is isotropic, with G 3.55, N 1.740 approximately. A rough analysis of a small fragment gave the following figures:—

SiO_2, 39; Al_2O_3, 25; Fe_2O_3, 0.5; CaO, 34.5; MgO, 1.5.

The mineral is obviously an almost pure grossularite.

References: (1) 1928, E. S. Simpson, Jour. Roy. Soc. W.A., 14, p. 52-3.
(2) 1934, E. S. Simpson, Idem 20, p. 55-6.

(10)—HAEMATITE (HYDROHAEMATITE), INGLEHOPE, S.W.

In recent years the system Fe_2O_3-H_2O has been subjected to intensive study, one of the objects in view being to solve the constitution of the long series of supposed individual minerals in which the ratio of Fe_2O_3 to H_2O varies from infinity to 1 2.

The older school of mineralogists treated all the following minerals as independent species:—

(1) Haematite	Fe_2O_3
(2) Hydrohaematite	$Fe_2O_3 . \frac{1}{2}$ (or less) H_2O
(3) Turgite	$Fe_2O_3 . \frac{1}{2} H_2O$
(4) Lepidocrocite	$Fe_2O_3 . H_2O$
(5) Goethite	$Fe_2O_3 . H_2O$
(6) Limonite	$Fe_2O_3 . 1\frac{1}{2}$ (±) H_2O
(7) Hydrogoethite	$Fe_2O_3 . 1\frac{2}{3} H_2O$
(8) Xanthosiderite	$Fe_2O_3 . 2 H_2O$
(9) Limnite	$Fe_2O_3 . 3H_2O$.

The result of the latest investigations, including X-ray examination of minerals and the study of dehydration curves of both minerals and artificial ferric hydroxide gels, is to define as species the following only (Ref. *1-5*):—

(A) Haematite α	Fe_2O_3. Rhombohedral.
(B) Haematite γ, or Maghemite	Fe_2O_3. Cubic, magnetic.
(C) Goethite (of which Limonite is the massive form)	$Fe_2O_3 . H_2O$ = Fe(OH)O. Orthorhombic. 0.92 : 1 : 0.64.
(D) Lepidocrocite	$Fe_2O_3 . H_2O$ = Fe(OH)O. Orthorhombic. 0.43 : 1 : 0.64.

The other five supposed species are either intimate intergrowths of A or B with C or D, or imperfectly analysed minerals in which undetermined Al_2O_3 has been weighed with and counted as Fe_2O_3, and organic matter with H_2O; or specimens carrying adsorbed and occluded water.

Of these alternatives probably the most serious cause of error is imperfect analysis, no proper search or allowance having been made in many cases for intimately admixed kaolin, halloysite and gibbsite. For this reason there is a need for the accumulation of a number of modern accurate analyses of these common minerals. Opportunity was therefore taken of analysing some very pure specimens of crystalline "hydrohaematite" received recently from Inglehope in the Darling Range south of Perth. The mineral forms the inner layer of hollow ovoid concretions found a few chains north of the railway siding. The concretions reach a foot or more in diameter. The outermost layer, averaging one centimetre in thickness, is composed of very cellular brown limonite. It is succeeded by a layer of dense brown to black iron ore of undetermined character. The innermost layer has a brilliant metallic lustre with mammillary surface, at right angles to which the mineral cleaves in a series of slightly curved and radiating faces with brilliant lustre typical of "goethite" and "hydrohaematite" elsewhere, and somewhat reminiscent of a series of tightly packed flowerbuds.

This mineral on analysis proves to agree with descriptions of "hydrohaematite." Its composition is:—

Hydrohaematite, Inglehope.

Fe_2O_3	Al_2O_3	Mn_2O_3	SiO_2	H_2O	Mg, Ca	Ti, V, P	Total	G
96·86	1·26	·19	·41	1·73	Nil	Nil	100·45	4·48

Analyst, D. G. Murray.

At first sight the molecular ratio of Fe_2O_3/H_2O is 6.3/1.0, but if the Al_2O_3 and SiO_2 are first calculated as halloysite and gibbsite, half the water disappears, whilst the small remainder might well be present as occluded moisture or remnants of pre-existing goethite.

In view of what has been stated, the Inglehope mineral is to be considered as a pseudomorph of haematite after crystallised goethite, still retaining some small cores of unaltered goethite, and a little admixed halloysite (or kaolin) and gibbsite.

It is to be noted that Weiser and Milligan (*4*) recently found that ageing of the brown hydrated gel precipitated from solutions of ferric salts shows X-ray proof of the normal alpha-haematite after a few months in the cold, or after a few hours near 212° C.

References: (*1*) 1919, Posnjak & Merwin, Amer. Jour. Sci. 47, p. 311.

(*2*) 1925, Gaubert, Comp. Ren. Ac. Sci. 181, p. 869.

(*3*) 1929, Boehm, Zeit. Kryst. 68, p. 567-585.

(*4*) 1935, Weiser and Milligan, Jour. Phy. Chem. 39, p. 25-34.

(*5*) 1935, Goldsztaub, Bull. Soc. franc. Min. 58, p. 6-76.

(11)—PISANITE, RAVENSTHORPE, S.W.

Pisanite is a well defined monoclinic double salt bearing the same relationship to the isomorphous minerals melanterite, $FeSO_4.7H_2O$ and boothite, $CuSO_4.7H_2O$, that dolomite does to calcite and magnesite. Other isomorphous compounds cocrystallised in small proportions in some occurrences are the monoclinic forms (unknown as independent minerals) of the corresponding compounds of magnesium zinc and nickel, and the manganese salt occurring naturally as mallardite.

Pisanite is a greenish blue mineral, stable in moist air, such as is found in damp mine workings, its customary situation, but efflorescing superficially in dry air, to a white granular salt of less degree of hydration, probably the rather stable pentahydrate, as in a dessicator the water content is rapidly reduced by two molecules. On warming in air to a temperature of 100° C. disintegration sets in, not only by further dehydration, but by slow oxidation of the ferrous iron.

A unique cobaltiferous pisanite with an appreciable cocrystallisation of $CoSO_4.7H_2O$ (bieberite), was found in 1934 forming crusts on the timbers and walls of the abandoned Surprise C.M. (ML 114) at Ravensthorpe. It is in rather finely crystalline crusts a few millimetres thick as well as in small stalactites. It is translucent in thicknesses up to 5 mm. and is of a greenish blue colour, which could not be matched in Ridgway's index, the nearest approach being 43′ i or k. This is the commonest tint, but there is a slight variation due probably to some specimens containing a little more or less copper than the normal amount. The mineral is readily soluble in cold water.

A preliminary analysis of a small fragment yielded CuO, 14.0; FeO, 12.1 per cent. Theory requires CuO, 14.11; FeO, 12.74 per cent. For a complete analysis some fragments of uniform and normal colour were selected and kept in a vessel with a little moist cotton wool to avoid dehydration. The specific gravity of several of these fragments was shown to be 1.95. The results of the analysis were:—

Pisanite, Ravensthorpe.

	CuO	FeO	NiO	CoO	MgO	CaO	Al_2O_3	SO_3
Per cent	13·09	11·00	·16	·57	·97	·27	·39	28·52
Mols	1633	1531	21	76	240	48	38	3562

SiO_2	Zn, Mn, As, Sb, Ti	H_2O (a)*	H_2O (b)	Total
·11	Nil	14·23	30·69	100·00
·18	—	7899	17034	—

Analyst, C. R. Le Mesurier.

* Water. (a) Loss in desiccator. (b) Remainder by difference.

The loss of water after 7 hours at 50° was 27.12 per cent., and an extra 0.60 vaporised at 100°, at which stage oxidation of FeO began to be apparent. The mineral then still contained 17.20 per cent. of water, or a little over 5 molecules out of 14.

Previous analyses of pisanite (*1*) to (*6*) have shown the presence of isomorphous magnesium in two cases (Leona Heights and Isabella, both U.S.A.) zinc in three cases (Huelva, Spain, and Rico and Bingham U.S.A.) manganese in one case (Huelva, Spain) and nickel in two cases (Lading, Austria, and Huelva, Spain). The presence of cobalt in the Ravensthorpe mineral is unique. It is interesting to note also the presence of nickel and magnesia, and the absence of zinc. Up to the present no zinc minerals have been detected at Ravensthorpe, but cobaltite occurs in small quantities in several of the copper-gold mines. The pisanite obviously originates in the oxidation of chalcopyrite intergrown with a little nickeliferous cobaltite and occurring in a shear zone in amphibolite, whence the magnesia.

No exact calculation of the molecular ratios can be made owing to the uncertainty regarding the form in which the lime and alumina occur. Allowing, however, small amounts of SO_3 and H_2O to be combined with them, the remaining ratios Cu + Ni + Co : Fe + Mg : SO_4 : H_2O come out very close to the theoretical ratios 1 : 1 : 2 : 14.

References: (*1*) 1923 Collins, Minl. Mag. 20, p. 32.
(*2*) 1927 Vavrinecz, Zeit. Kryst. 66, p. 167-8.
(*3*) 1929 (Abs. 1931) Vavrinecz, Minl. Abs. 4, p. 381-2.
(*4*) 1929 Doelter, Handb. der Mineralchem. 4 (2), p. 290-1.
(*5*) 1930 Hintze, Handb. der Mineralogie, 1 (3) p. 4375.
(*6*) 1933 Eckel, Amer. Minl., 18, p. 449-454.

ACKNOWLEDGMENTS.

I desire to express my indebtedness to the Government Geologist (Mr. F. G. Forman), Mr. H. A. Ellis, Mr. G. S. Compton and Mr. R. W. Fletcher for specimens, and for permission to publish the results of my examination of them. I am also deeply indebted to Messrs. H. Bowley, H. P. Rowledge, and C. R. Le Mesurier for assistance in analytical and optical investigations.

4.—A NOTE ON THE OCCURRENCE OF *AMPHIPORA RAMOSA* (PHILLIPS) IN WESTERN AUSTRALIA.

By ELIZABETH A. RIPPER, M.Sc. (Melb.), Sedgwick Museum, Cambridge.

Read 10th September, 1936; published 23rd June, 1937.

(Communicated by Professor E. de C. Clarke.)

INTRODUCTION.

A collection of Devonian and Permian fossils from various localities in the Kimberley District, Western Australia, sent by Dr. Arthur Wade, of the Freney Kimberley Oil Company, for examination by Miss D. Hill, of the Sedgwick Museum, Cambridge, contains a number of specimens which may undoubtedly be identified with *Amphipora ramosa* (Phillips), a stromatoporoid occurring abundantly at various horizons within the Devonian of Europe. The Western Australian localities at which this species occurs, and its associates, as far as determined, are as follow:—

A397. Northern end of Bugle Gap. No associates.

A412. Mountain Home Spring Valley. Associated with *Prismatophyllum brevilamellatum* Hill.

A422. Near Little Mt. Pierre. Associated with *Disphyllum depressum* (Hinde), *Atrypa aspera* Schlot. and *A. desquamata* Sow.

B89. 1½ miles South of Station K, Rough Range. No associates.

Two other stromatoporoids, *Actinostroma clathratum* Nicholson and *Stachyodes verticillata* (M'Coy) occur at Loc. A251, Palm Spring George, Oscar Range; the associated fauna is not known. The horizon given by Miss Hill from the evidence of the corals occurring at Locs. A412 and A422 is Givetian or Frasnian (Upper part of the Middle or lower part of the Upper Devonian).

Dr. Wade's collection is at present in the Department of Geology, University of Western Australia.

AMPHIPORA SCHULZ.

1883—*Amphipora* Schulz, Jahrb. der Königl. preuss. geol. Landesanstalt (1882), p. 89.

1886—*Amphipora* Nicholson, Mon. Brit. Stromatoporoids, Gen. Introd., p. 109.

Stromatoporoids in which the coenosteum consists of slender, sometimes branching, cylindrical stems, which are usually provided with tabulate axial canals. Skeletal fibre apparently compact; skeletal mesh usually completely reticulate, pillars and laminae not being recognisable as distinct skeletal elements. Astrorhizae absent.

Genotype: *Caunopora ramosa* Phillips. Palaeozoic Fossils of Cornwall, etc., p. 19, pl. VIII., figs. 22a.-e., 1841.

Horizon and localities (of type material): Middle Devonian of Chudleigh and Babbacombe, South Devon.

Amphipora ramosa itself is probably confined to the Devonian, but *A. socialis* Romanowski has been recorded from the Upper Carboniferous of the Timan by Stuckenberg (1895), and a form occurring in the Gotlandian of Turkestan is compared with this species by Riabinin (1928). Another species, described under the name of *A. asiatica* by F. R. C. Reed (1927, p. 180) and considered to be closely allied to *A. socialis* Romanowski, is at present in the Upper Carboniferous of Yun-nan. A form similar to this is described by Yabe and Sugiyama (1933) as occurring in the Permian of Japan. The form occurring in the Glen Bower Series of the Murrumbidgee Beds of Boambalo Crossing, Murrumbidgee River, New South Wales, and described by R. Etheridge, jun. (1917) as *A. australica*, is very similar to, and may even be identical with *A. ramosa* (Phill). The genus *Amphipora* has therefore a comparatively long range in time, being found in various forms, whose limits of variation are rather ill-defined, in Gotlandian, Devonian, Carboniferous and Permian faunas.

Amphipora ramosa (Phillips).

1841—*Caunopora ramosa* Phillips. Palaeozoic Fossils of Cornwall, etc., p. 19, pl. VIII., figs. 22a.-c.

1883—*Amphipora ramosa*; Schulz, Die Eifelkalkmulde von Hillesheim, p. 90, pl. XXII., figs. 5-7; pl. XXIII., fig. 1.

1886—*Amphipora ramosa*; Nicholson, Mon. Brit. Strom., Gen. Introd., p. 109, pl. IX., figs. 1-4.

1892—*Amphipora ramosa*; Nicholson, Mon. Brit. Strom., p. 223, pl. XXIX., figs. 3-7.

1919—*Amphipora ramosa*; Vinassa de Regny, Pal. italica, vol. XXIV., p. 109, pl. IX. (IV.), figs. 14, 15.

1934—*Amphipora ramosa*; Le Maitre, Mém. Soc. Géol. du Nord, XII., p. 202, pl. XVII., figs. 2, 3.

Diagnosis.—Coenosteum built up of cylindrical stems, usually parallel, sometimes branching in a dichotomous manner. Skeletal mesh reticulate; radial pillars sometimes distinct; skeletal fibre apparently compact. Tabulate or non-tabulate axial canals and marginal vesicles may be present.

Description and Remarks.—The specimens from Western Australia are much weathered and show clearly the characteristic fasciculate form of the coenosteum of this species. The stems are from 3 to 5 mm. in diameter, are usually simple, and sometimes have an irregularly roughened exterior, produced by the weathering of the marginal vesicles. Weathered transverse sections frequently show the presence of an axial canal.

Transverse sections show an irregularly reticulate skeletal mesh which makes up the greater part of the stem. Small axial canals, 1mm. or less in diameter, are frequently present. Some specimens, which may also be provided with an axial canal, have well-defined marginal vesicles of greater diameter than the interspaces of the normal skeletal mesh (see Text-figure 2). These two characters are not necessarily connected, however, since many cross-sections show either one or the other, developed to varying extents. Nicholson (1892), in his description of the species, refers to this variation in the appearance of transverse sections, but his material seems to have contained two prominent types of specimens: the first having a large axial canal, dense reticulate tissue and large marginal vesicles, and being enveloped in an epitheca, and the second having a loosely reticulate structure, with small marginal vesicles, and an imperfect axial canal. Some examples of the second type lacked an axial canal, and all lacked the epitheca. Le Maitre (1934), on the other hand, notes that the epithecate specimens with the large vesicles lack axial canals, and that those having a finer skeletal mesh and no vesicles are provided with axial canals. Both writers agree that these forms are probably different conditions of the same species, and Le Maitre notes that it is impossible to identify as *A. ramosa* (Phill.) only those specimens which show at once the axial canal and the marginal vesicles. No systematic variation like that described by Nicholson and Le Maitre has been observed in the specimens from Western Australia.

The appearance of longitudinal sections varies considerably with their position in the coenosteum. Those passing through the periphery of a branch show an irregularly reticulate skeletal mesh similar to that seen in transverse sections. A section passing through the centre of a branch reveals the axial canal, if present, and shows in some specimens a rather regular skeletal mesh which builds up the larger part of the coenosteum and usually terminates against the zone of marginal vesicles. This central zone of regular structure has well-defined radial pillars which pass obliquely outwards from the neighbourhood of the axial canal (when present), and which are connected by irregular processes. These sometimes occur at similar levels in neighbouring interspaces, but definite laminae are not present. This type of skeletal mesh is very similar to that seen in the longitudinal sections figured by Schulz (1883 pl. XXII., figs. 5, 6), and in those of Le Maitre (1934, pl. XVII., fig. 2). It must be noted, however, that this structure in the Western Australian specimens is not restricted to those which lack an axial canal, but occurs quite independently of the presence or absence of this latter character.

Amphipora ramosa (Phillips) occurs at a number of horizons within the Devonian. The specimens described by Phillips came from Chudleigh and Babbacombe, South Devon; the main mass of the limestone at the latter locality has been referred by Shannon (1928, p. 113) to his C1 horizon (top of the Givetian). Schulz (1883) describes the occurrence of the species in banks, forming a definite horizon (Bänke mit *Amphipora ramosa*) in the upper part of the Middle Devonian of Hillesheim in the Eifel. Nicholson (1892) in describing the British occurrence notes the presence of the species in the Devonian limestones of Shaldon, Newton Abbot, Teignmouth, etc., but as most of the specimens come from the pebbles of the Permian (New Red Sandstone) conglomerate, no evidence of the horizon within the Devonian can be obtained. Vinassa de Regny (1919) has described the species from the Middle Devonian of the Carnic Alps. Later work has extended the geological range of the form: Le Maitre (1934) has described the occurrence of typical specimens in banks in the Chalonnes Limestone of Maine-et-Loire, of Coblenzian-Eifelian (Lower-Middle Devonian) age, and Riabinin (1932) records its occurrence in the Frasnian (Upper Devonian) of the Timan. It is probable that this species ranges at least throughout the Devonian, but has met with conditions favouring the formation of banks only at certain horizons, notably the Coblenzian-Eifelian in the Maine-et-Loire region and the Givetian in the Eifel district. The Western Australian form has apparently formed banks under similar conditions, though the exact horizon at which these conditions prevailed has not yet been determined.

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1928—Shannon, W. G.: The Geology of the Torquay District. *Proc. Geol. Assoc.*, XXXIX., pp. 103-136.

1928—Riabinin, V.: Notes on Silurian Stromatoporoids. *Bull. Com. Géol. Leningrad*, vol. xlvii., pp. 1041-1054.

1932—Riabinin, V.: Devonian Stromatoporoidea of Timan. *Bull. United Géol. and Prospecting Service*, U.S.S.R., vol. li., fasc. 58, pp. 855-870.

1933—Yabe, H., and Sugiyama, T.: Discovery of *Amphipora* and *Clathrodictyon* in the Permian of Japan. *Journ. Geol. & Geog.*, vol. XI., pp. 19-23.

1934—Le Maitre, D.: Etudes sur la Faune des Calcaires Dévoniens du Bassin d'Ancenis. *Mém. Soc. Géol. du Nord*, XII.

EXPLANATION OF FIGURES.

Plate 1.

Amphipora ramosa (Phillips). A specimen showing the external form of the coenosteum. Natural size. Loc. A422, near Little Mt. Pierre, Kimberley District, Western Australia.

Text-Figure 1.

Amphipora ramosa (Phill.). Longitudinal section of a specimen possessing an axial canal (a), radial pillars (p) and marginal vesicles (v). x 8. Loc. A412, Mountain Home Spring Valley, Kimberley District, Western Australia.

Text-Figure 2.

Amphipora ramosa (Phill.). Transverse section of a specimen possessing an axial canal (a) and large marginal vesicles (v). Those parts of the section shaded diagonally represent cavities within the skeletal mesh which have become filled with a substance darker in colour than the skeletal fibre. x 8. Loc. A422, near Little Mt. Pierre, Kimberley District, Western Australia.

Text-Figure 3.

Amphipora ramosa (Phill.). Transverse section of a specimen possessing an axial canal (a), but lacking large marginal vesicles. x 8. Loc. A422.

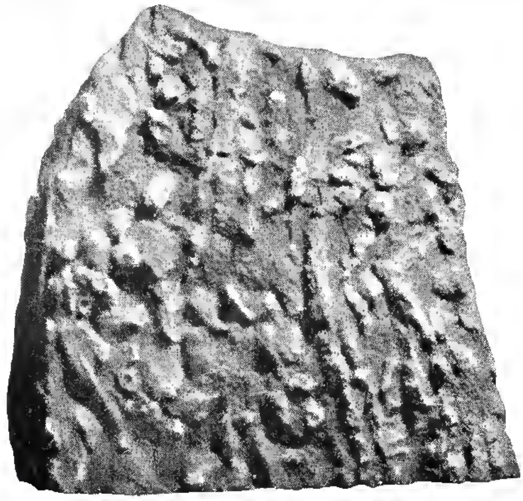
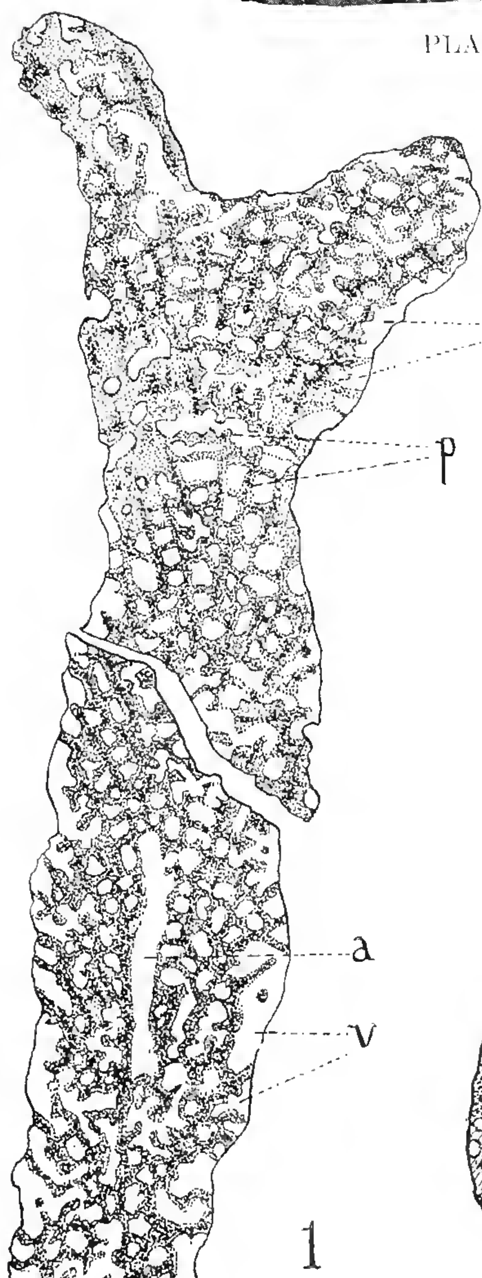
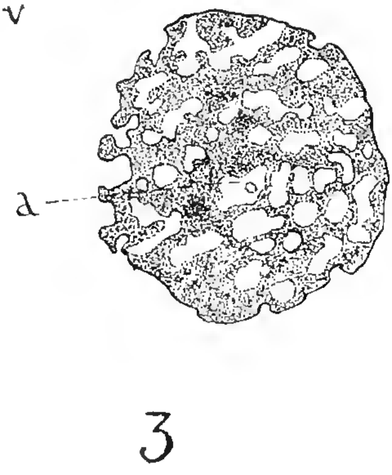
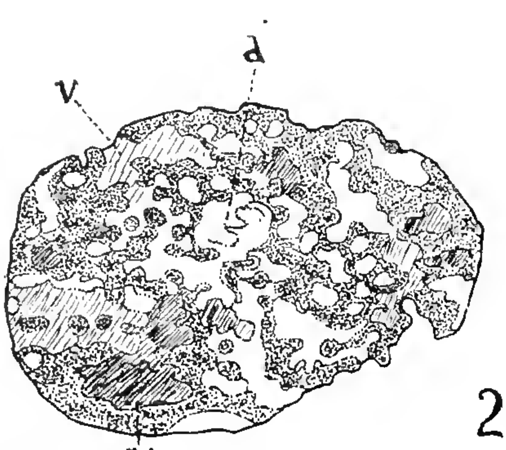


PLATE I.







TEXT FIGS.

5.—THE PERMIAN CORALS OF WESTERN AUSTRALIA.

By DOROTHY HILL, Ph.D.,
Associate of Newnham College, Cambridge.

Read 10th September, 1936; Published 30th June, 1937.

(Communicated by Professor E. de C. Clarke.)

INTRODUCTION.

This paper revises those species of Rugose Corals already described from the "Permo-Carboniferous" strata of Western Australia, and describes three new species and one new genus. It investigates a type of septal structure characteristic of Permian Rugosa. It also re-describes the Tabulate Corals reported from the "Permo-Carboniferous" of Western Australia, includes a new species, and investigates the arrangement of their calcareous fibres. All the localities involved are shown to be Permian.

The table gives the localities and the species in the order of their description:—

	Fossil Range, North of Lyons River, Gascoyne River.	Fossil Range, near junction of Gascoyne and Lyons Rivers, Lat. 25° S.	Gascoyne River.	Fossil Cliff, Irwin River.	Locality 1, Callytharra Limestone, Wooramel River [Wade.]	Creek half-mile west of Callytharra Spring, Wooramel River.	Callytharra Limestone, Wooramel River.	Two miles south-east of Christmas Creek Homestead, Kimberley.	Mt. Marmion, Kimberley.	Two miles east of Selection Homestead, Kimberley.	Liveryuga Beds, North of Hill, Kimberley.	8½ miles north of Nerrima Homestead, Kimberley.
Amplexus ? pustulosus Hudl.	×	×	×									
Gerthia sulcata (*Hinde*) ...	—	—	—	×								
Plerophyllum australe Hinde	—	—	×	×	—	—	×					
Euryphyllum trizonatum sp. nov.	—	—	—	×	—	—	—	—	—	—	—	?
E. minutum sp. nov. ...	—	—	—	—	—	×						
Tachylasma densum sp. nov.	—	—	—	—	—	—	—	—	—	—	×	
Tachylasma sp.	—	—	—	—	—	×						
Verbeekia talboti (Hosking)	—	—	—	—	×	×						
Monilopora ? nicholsoni Eth.	—	—	—	—	—	×	—	—	×			
Thamnopora marmionensis (Eth.)	—	—	—	—	—	—	—	—	×			
Thamnopora wimensa sp. nov.	—	—	—	—	—	—	—	×	—	×		

Age of the Coralliferous Beds.—Workers on Upper Palaeozoic stratigraphy and faunas have not yet reached unanimity of definition for the term Permian. The lower limit of the Permian has been placed at many different horizons, and when dealing with any fauna it is necessary to indicate which terminology is being followed. In this paper I shall follow the terminology of Haniel (1915), modified by Miller (1933). Both these workers have dealt with ammonoid faunas and their results agree reasonably well. The table shows their interpretation of Permian horizons:—

	Haniel, 1915, p. 19.		Miller, 1933, p. 425
Neodyas	Amarassi ... Oberer (Timor) ... Mittlerer	Productuskalk (Salt Range)	= Upper Permian
	Basleo (Timor)		= most of Sosio beds (Sicily). Delaware Mts. Formation and Word Formation of Texas = Middle Permain
Palaeodyas	Bitauni (Timor) ...	Obere Artinsk, Sosio, Wichita	= Artinskian, and some of Sosio beds = Lower Permian.
	Atsabi (Timor) ...	... ...	
	Somohole (Timor)	Unterste Artinskstufe	
Obercarbon	... ...	... (Uralian)	= Upper Pennsylvanian.

Schuchert (1928) and Heritsch (1934) regard the Artinskian as the upper part of the Lower Permian; they include the underlying *Schwagerina* beds of the Urals in the Lower Permian, and place the Gshelian *Cora-* and *Omphalotrochus* beds at the top of the Upper Carboniferous. Ting and Grabau (1934) regard the Artinsk as Middle Permian, and place the whole of the Uralian (*Schwagerina-*, *Cora-* and *Omphalotrochus*-beds) in the Lower Permian. Fredericks and Emeljantzev (1934 p. 18), also regard the Artinsk as Middle Permian, but place the Uralian in the Upper Carboniferous, stating that in Lower Permian times there was an orogenic phase in the Urals. They differ from other authors also in considering the *Schwagerina* beds to be below the *Cora-* and *Omphalotrochus* beds.

The geological range of the genera and species described in this paper is given under their description. All the Rugose genera (excepting *Amplexus* Sowerby, to which our species is doubtfully referred) are confined to the Permian; none occur in the Upper Carboniferous (Uralian): both Tabulate genera are very long ranged, but the species resemble Permian species. All the Australian localities mentioned are therefore Permian. Whether they are Lower or Middle Permian cannot be deduced with certainty from the corals, owing to the insufficiency of our knowledge. Permian corals have been described from very few places, such as Timor, the Northern Urals, the Oufimskoe Plateau, and China.

GENUS **AMPLEXUS** SOWERBY.

Amplexus Sowerby, 1814, vol. I., p. 165.

Genotype (by monotypy): *Amplexus coralloides* Sowerby, *loc. cit.*, pl. lxxii., Black Rock (Lower Carboniferous Limestone), Limerick, Ireland.

Diagnosis.—Simple cylindrical Rugose corals with distant, flat, complete tabulae, and short septa which are fully developed only on the upper surfaces of the tabulae, but above these positions extend progressively a shorter distance from the epitheca; there are no dissepiments.

Remarks.—The simple structure of this genus may be a morphological end-point for many lineages. Some of the Permian amplexoids seem to me to have important differences in the septa and their structure; thus many have continuous club-shaped septa; some have dissepiments.

Amplexus? pustulosus Hudleston.

(Plate 1, fig. 1: text-fig. 1.)

Amplexus pustulosus Hudleston, 1883, p. 591, pl. xxiii., figs. 1a, 1b, 1c. "Fossil Range," Gascoyne River [Permian].

Amplexus pustulosus; Hinde, 1890, p. 194 (partim), Gascoyne River [Permian].

Amplexus pustulosus; mentioned Etheridge, 1903, p. 8, from Williambury Station, Minilya River, Gascoyne District. Specimen not examined by me.

Amplexus pustulosus; Glauert, 1910, p. 82; 1925, p. 45.

Amplexus coralloides Sow. var. *pustulosus* Hudleston; Gerth, 1921, p. 96.

Material: Lectotype (here chosen) and figured R. 2275, British Museum; Forrest collection; figured Hudleston *loc. cit.* fig. 1a.; Fossil Range, near junction of Gascoyne and Lyons Rivers, north of Western Australia.

The other syntypes are lost. They were presented, in the Forrest Collection, to the Geological Society, whence specimens collected outside the British Isles were transferred to the British Museum in 1911. I understand from Miss Hosking that none of Hudleston's type material is in Western Australia. Other Specimens, R. 13972-3 and R. 13977-8, British Museum, were collected by H. P. Woodward and mentioned by Hinde, 1890, p. 194, as from the "Carboniferous" [Permian] of the Gascoyne River, Western Australia. R. 13974-6 also described by Hinde *loc. cit* as *A. pustulosus*, are *Plerophyllum australe* Hinde, from the Gascoyne River [Permian]. R. 13979, in the British Museum, said to be a paratype, is, however, much smaller than the holotype, with coarse longitudinal ribbing, and has the tip broken off, showing 5 prominent septa; so it also is probably *Plerophyllum* sp.

Diagnosis.—Erect, turbinate Rugose corals with the septa dilated and laterally contiguous, leaving a wide axial area free of septa.

Description.—The five incomplete specimens (B.M.R. 2275, R. 13972-3, 13977-8) on which this description is based are much crushed. They are erect and turbinate, the largest having a height of 60 mm., and a diameter at the calice of 40 mm. The nature of the crushing suggests that the calice was deeper than the diameter of the corallite. The epitheca and probably also the minor septa are eroded away, but curious pustules, which appear not to be part of the coral tissue, are seen on the surface of the holotype. Their exact nature is not known, owing to the poverty of material. The specimens show longitudinal striation, but this is due to weathering, the extremely narrow interseptal loculi showing as narrow grooves.

A transverse section of 15 mm. diameter taken from the broken base of the specimen shows 34 major septa only, dilated so that they are laterally contiguous, extending two-thirds of the way to the axis. Each shows a very distinct "median dark line," but re-crystallisation prevents any description of the grouping of the fibres. The transverse section suggests that the peripheral parts of the coral, where possibly minor septa were present, have been eroded away.

Of the tabulae nothing is known. The calcite in the empty axial part of the section is strongly re-crystallised, and the acicular crystals are arranged in groups.

Remarks.—Only the holotype of the type material can be traced, as above mentioned; while, of the specimens referred to the species by Hinde, only four are possibly conspecific, and these are too crushed for accurate determination. The material is so poor that it cannot be referred with certainty to any genus. Until other specimens are found, the species is best referred doubtfully to *Amplexus*, in which it was first placed, and under which it appears in the literature. Gerth (1921 p. 96) considers that it may be only a variety of *Amplexus coralloides* Sow. [Lower Carboniferous], but with this

I cannot agree. He describes, under the genus *Amplexus*, six species from the Permian of Timor, with short septa and distant, flat tabulae; one of these, *A. abichi* Waagen and Wentzel, occurs also in the Permian of the Salt Range. But in none of these forms are the septa so dilated as to be laterally contiguous throughout their length, and the Australian species does not appear to be closely related to them.

Amplexus cf. nodulosus Phillips.

Amplexus cf. *nodulosus* Phillips; Hudleston, 1883, p. 591; Glauert, 1910, p. 82; a specimen in the Forrest Collection marked 1, believed by Hudleston to be from "Fossil Range," north of the Lyons River, Gascoyne District, Western Australia. This specimen was recorded by name only and has not been traced; it can hereafter be omitted from faunal lists.

GENUS **GERTHIA** GRABAU.

Gerthia Grabau, 1928, p. 29.

Genotype: *Polycoelia angusta* Rothpletz, 1892, p. 69, pl. xii., figs. 23, 31, 32. Upper Permian of Ajermati, Timor.

Diagnosis.—Simple, ceratoid, rugose corals with a peripheral stereozone, with the cardinal, counter and two alar septa more prominent than the remainder, and with septal insertion accelerated in the counter quadrants. There are no dissepiments, and tabulae are not known.

Remarks.—The genus is known from Timor, at Ajermati, Amarassi, and Basleo. From their ammonoids Haniel (1915, p. 19) regarded the two former localities as Upper Permian, and the last as between Upper and Lower Permian; Miller (1933, p. 425) called the Basleo beds Middle Permian. It is represented in the Lower Permian (Soschkina, 1928) of the western parts of the Northern Urals. Grabau *loc. cit.* has tentatively placed in it *Astrocyathus incisus* Ludwig and *Astrocyathus compressus* Ludwig, both from the Lower Zechstein of Posneck in Thuringia. The marked acceleration of the insertion of the septa in the counter quadrants distinguishes the genus from *Polycoelia* King, in which, according to Grabau, insertion is equal in all four quadrants.

Gerthia sulcata (Hinde).

(Plate 1, fig. 2.)

Pterophyllum sulcatum Hinde, 1890, p. 197, pl. viii. A, figs. 2, 2a [Permian], Irwin River, Little Champion Bay, Victoria District.

Pleurophyllum (sic) *sulcatum*; Glauert, 1910, p. 83.

Gerthia (?) *sulcata*; Grabau, 1928, p. 34, pl. i., fig. 4 (a reproduction of Hinde's fig. 2a., *loc. cit.*).

Holotype: British Museum R. 2274 (figured Hinde *loc. cit.* and Grabau *loc. cit.*) the only specimen known, locality and horizon as above.

Diagnosis.—Large *Gerthia* with the septa so dilated as to be laterally contiguous and to fill the lumen.

Description (based on the holotype only).—The fragment of corallum is subcylindrical and regularly curved, 4 cm. high and 1·1 cm. in diameter. It shows repeated but not very evident cone-in-cone rejuvenescence, and well-marked interseptal ridges and septal grooves, the grooves for the minor septa being present from the beginning. The calice is not known.

There are 28 slightly rhopaloid[1] septa, all dilated and laterally contiguous, filling the lumen at least in the proximal parts of the corallite. But the cardinal and counter septa and the two alar septa are longer and more dilated than the remainder, and show a stronger tendency towards swelling near the axial edges. The counter septum is longer than the cardinal septum. There are seven or eight septa in the counter quadrants, and four or five in the cardinal quadrants. Minor septa are not seen in the transverse section. The septal structure seems to be similar to that described below for *Plerophyllum australe* Hinde, but owing to the scarcity of material this must remain uncertain. The nature of the tabulae is unknown.

Remarks.—In the great dilatation of its septa this species resembles those from the Lower Permian of the western parts of the Northern Urals described by Soschkina (1928) more closely than those described by Gerth (1921) from the Upper and Middle Permian of Timor. The above description will need expansion when more specimens are found. The acceleration of the septal insertion in the counter quadrants is marked. As Grabau has already observed (1928, p. 34) Hinde mistook the counter septum for the cardinal septum. In this species, as in the majority of Permian simple corals, the counter septum is the largest, extending beyond the axis.

GENUS **PLEROPHYLLUM** HINDE.

Plerophyllum Hinde, 1890, p. 195.

Pleurophyllum (sic.): Etheridge, 1903, p. 8.

Plerophyllum; Gerth, 1921, p. 87.

Plerophyllum; Grabau, 1928, p. 45.

Genosyntypes: *Plerophyllum australe* Hinde, 1890, p. 196, pl. viii. A., figs. 1a.-1f. [Permian] Gascoyne River, Irwin River; Western Australia.

Plerophyllum sulcatum Hinde, 1890, p. 197, pl. viii. A., figs. 2, 2a.

Genolectotype (chosen Grabau, 1928, p. 46); *Plerophyllum australe* Hinde *loc. cit.*

Diagnosis.—Small, curved, ceratoid rugose corals in which the two counter-lateral septa, both alar septa, and the cardinal septum (and sometimes the counter septum also) are larger and more dilated than the others, but equally developed among themselves, and are swollen near their axial edges. Septal insertion is accelerated in the counter quadrants.

Remarks.—The genus (*sensu stricto*) occurs elsewhere in the Lower Permian of the western parts of the Northern Urals, and at Hatu Dame in Timor, and in the Middle Permian at Basleo in Timor. It is not known from Eastern Australia. Gerth (1921, pp. 87 seq.) placed in the genus a number of species from Timor, but most of them have since been removed by Grabau (1928). Grabau defined two other genera according to which of the six protosepta[2] are longer and more dilated than the other septa. Thus in *Tachylasma* the two counter-lateral and the two alar septa are predominant, and rhopaloid, but the cardinal septum is extremely short, and the counter septum thin. In *Gerthia* the cardinal, counter and two alar septa are predominant and rhopaloid. As Grabau has shown (1928, p. 34, p. 46) *P. sulcatum* Hinde has the septal arrangement characteristic of the genus *Gerthia* Grabau, to which it must therefore be transferred.

[1] Rhopaloid septum Hudson, 1936, p. 90. "A septum increasingly thickened towards a rounded axial edge and club-shaped in transverse section, as in *Plerophyllum* Hinde."

[2] Grabau, like Edwards and Haime, recognises only 4 primary septa—the cardinal and counter and two alar septa. He regards the two counter-lateral septa as accelerated meta-septa. Most British authors recognise 6 proto-septa, the cardinal, counter, two alar and two counter-lateral septa. See Hill, 1935, p. 504.

The Devonian genus *Oligophyllum* Pocta and the Carboniferous genus *Cryptophyllum* Carruthers both have the two counter-lateral, the two alar, and the cardinal septa better developed than the other septa, but *Plerophyllum* can be readily distinguished from these by the clubbed axial ends of the septa, and the much greater length and dilation of all the septa.

Structure of the rhopaloid septum of Plerophyllum and other Permian Rugose Corals (Text-fig. 2a-c): A rhopaloid septum (Hudson) is a continuous septum swollen near its axial edge so that it is club-shaped in transverse section. Rhopaloid septa are characteristic of the Permian Rugose genera *Plerophyllum* Hinde, *Tachylasma* Grabau, *Gerthia* Grabau and *Sinophyllum* Grabau, of some Permian amplexoids, of the Tournaisian *Rhopalolasma* Hudson, and of many Hexacorals.

Rhopaloid septa have a characteristic appearance in transverse section. In the middle portion there is usually a median dark band merging without definite boundaries into the outer tissue, which consists of fibres directed at right angles to the median dark band. In the swollen axial portion this dark band may or may not continue; as the axial edge is approached, fibres in the median plane may be seen to lie parallel to the median plane; they curve out in the outer portions so as to cut the margin of the septum at right angles: usually, in the swollen axial portion the median dark band appears to break up into crescentic patches, curved parallel to the axial edge of the septum. Close examination shows that these patches are parts of the divisions between the growth layers of the septum. The median dark line, in this as in other septa, is due to the junction of two differently directed sets of fibres, laid down by the opposing sides of a septal invagination.

My sections indicate that a clubbed septum is formed as follows:—

The septum consists, as described for *Palaeocyclus* (Hill, 1936) of a single vertical series of laterally contiguous monacanths; but in *Plerophyllum* their axes are extremely close together. They arise at the periphery of the corallum and are at first directed steeply upwards, curving towards the axis at a gradually increasing rate so that they cut the axial edge of the septum at right angles. They are formed at the extreme top of the septal invagination. If they were not dilated laterally by sclerenchyme laid down by the sides of the septal invagination, the septum would be attenuate. But the sides of the septal invagination secrete layer after layer of sclerenchyme, consisting of fibres continuous with the fibres of the trabeculae, and at right angles to the surfaces of the layers. The growth lamination of this dilating sclerenchyme is usually emphasised in Permian corals by a separation along the divisional planes, or a deposition of some impurity there; the layers may be traced on the sides of the septum as fine raised lines curving down towards the axis from the periphery (*i.e.*, at right angles to the course of the trabeculae). Lateral growth of the septa is greatest near their axial edges, where the invagination swells, and the septum becomes very dilated; vertical growth of the septa is greatest at their peripheral ends.

The meta-septa in *Plerophyllum* are usually not rhopaloid, and in transverse section the median dark plane usually continues to the axial edge. The fibres of the dilating sclerenchyme are directed at right angles to the median plane of the septum, but slightly upwards, since in transverse section they are at right angles to the median plane, and in vertical section they are pinnately arranged with regard to the median plane.

Plerophyllum australe Hinde.

(Plate 1, figs. 3-6; text-fig. 3.)

Plerophyllum australe Hinde, 1890, p. 196, pl. viii. A., figs. 1a.-1f.; [Permian] Gascoyne River; Irwin River, Little Champion Bay, Victoria District.

Pleurophyllum (sic) *australe*; mentioned Etheridge, 1903, p. 8, Williambury Station, Minilya River; Fossil Hill, Wyndham River (both in the Gascoyne District).

Pleurophyllum australe; Etheridge, 1907, p. 27, pl. vii., fig. 1, pl. viii., fig. 10, from the Irwin River.

Pleurophyllum australe; Glauert, 1910, p. 83; 1925, p. 45.

Pleurophyllum australe; Etheridge, 1914, p. 13, Mt. Marmion, Kimberley District.

Plerophyllum australe; Grabau, 1928, p. 46, pl. i., figs. 5 and 6.

Plerophyllum australe; Hosking, 1931, pl. 11, pl. iii., figs. 4-6, [Permian] of creek half mile west of Callytharra Springs, Wooramel River, and south bank of the Wooramel River, below Callytharra Springs, Western Australia.

Syntypes: in British Museum; R. 2273, figured 1890, pl. viiia., fig. 1a., Gascoyne River; R. 13983, figured *loc. cit.*, fig. 1d., Irwin River; R. 13984, figured *loc. cit.*, fig. 1e., Irwin River; R. 13985, Gascoyne or Irwin Rivers.

Lectotype (here chosen): B.M.R. 13984, Irwin River [Permian].

Other specimens examined: Sedgwick Museum A. 4743 from the Permian of Irwin River; A. 4752-4 from the Permian Callytharra Limestone, Callytharra. Three (H. 23) in the Collection of the University of Western Australia, Permian, Irwin River.

Diagnosis.—*Plerophyllum* with the septa dilated throughout and laterally contiguous in the proximal parts of the corallum.

Description.—The corallum is small, ceratoid and straight or curved. The curvature may be regular or slightly irregular, and the direction of growth may change slightly. The average height of the corallum is about 3 cm., and the diameter at the calice varies from 10 mm. to 14 mm. The calice is conical, and very deep, and very small minor septa are observed in its upper parts. The epitheca is striated longitudinally, the septal ridges being rounded, and twice the number of the major septa, so that minor septa are potential even in the distal parts. Transverse striation is faintly marked. The corallum may be buttressed at its base by a talon. The plane of symmetry of the corallum rarely coincides with the plane of the cardinal and counter septa.

The septa are rhopaloid, club-shaped in transverse section. In transverse section only dilated major septa are apparent. In the proximal parts of the corallum they are so dilated as to be laterally contiguous throughout: but towards the calice dilatation may be less marked in a zone half-way between the periphery and the axis, so that there is a peripheral and an axial stereozone. In the calice the septa are free except in the peripheral stereozone. The cardinal septum, the two alar and the two counter-lateral septa are developed to an equal size and are much larger and more dilated and have a more club-shaped section than the counter septum and the metasepta. The size and degree of dilatation of the meta-septa depends on their order of insertion; but occasionally the meta-septum in the middle of a quadrant may be longer than those previously formed.

Tabulae are seldom developed, since the dilatation of the septa fills the interseptal loculi. But where observed they are distant, dilated, and gently inclined downwards from the axis to the periphery.

Remarks.—The species is closer to *P. radiciforme* Gerth from the Middle Permian of Basleo, Timor, than to *P. weberi* Gerth from the Artinskian (Lower Permian) of Hatu Dame, Atsabi, Timor, or *P. hexaseptatum* (Soschkina) from the Lower Permian of the western parts of the Northern Urals. In the two latter species the counter septum also is longer than the metasepta.

As Graban surmised (1928, p. 46) Hinde made an error in assuming that the short septum between two long ones was the cardinal septum. It is in reality the counter septum, as proved by the order of insertion of the septa, deduced from the interseptal ridges on the epitheca, and the relative sizes of the meta-septa. No trace of the minor septa can be seen in transverse sections taken below the calice: but their interseptal ridges on the epitheca are present throughout, and they can be seen at the distal margin of the calice. This is an example of extreme lateness of appearance of the minor septa. The greater length of the meta-septum in the middle of a quadrant may be of significance in a discussion of the manner in which the Hexacoral septal insertion was derived from the Rugose septal insertion.

Three specimens from the Callytharra Limestone (Callytharra) Wooramel River (S.M. A. 4752-4) show a decrease in the dilatation of the septa in a zone of variable width mid-way between the periphery and the axis; and in the interseptal loculi distant, dilated tabulae are developed, inclined from the axis to the periphery.

GENUS **EURYPHYLLUM** GEN. NOV.

Genotype: *Euryphyllum reidi* sp. nov. Permian, Upper Dilly Marine stage, Cabbage Creek, Springsure District, Queensland [= Lower Bowen (Reid, 1930, p. 93)]. Holotype is L. 237a. in the University of Queensland collection.

Diagnosis.—Simple, almost erect turbinate to ceratoid Rugose corals with well-marked interseptal ridges; the major septa are grouped about a narrow closed cardinal fossula, and are dilated and laterally contiguous except in a zone of variable width midway between the periphery and the axis; very short minor septa appear late, and remain buried in a peripheral stereozone. Tabulae are distant, usually much dilated, complete or incomplete, and inclined from the axis to the periphery. There are no dissepiments.

Remarks.—The genus is known only from the Permian of Australia, and of Timor (Wesleo, *Zaphrentis cainodon* Koker, 1924, p. 9, *non* Etheridge), the "Permo-Carboniferous" Maitai Limestone of New Zealand ("*Zaphrentis* sp. cf. *gregoryana*, Trechmann, 1917, p. 61, pl. IV., fig. 7), and the Artinskian of the Western Urals (*Stereolasma minus* Sochkine, 1925, pl. I., figs. 6, 6a). It is common in the equivalents of the upper part of the Lower Marine stage of the Hunter River succession of New South Wales. It is zaphrentoid, but it may be distinguished from all other zaphrentoid coralla by the characteristic dilatation of its tissue. It is quite different from the type species of *Zaphrentis*, *i.e.*. *Turbinolia* (*Zaphrentis*) *phrygia* Rafinesque and Clifford 1820 [= *Caryophyllia cornicula* (Lesueur) 1820 = *Caninia punctata* d'Orbigny 1850 = *Zaphrentis cornicula* (Lesueur) Edwards and Haime 1851] from the Middle Devonian of the Falls of Ohio. In the ephebic stage, *Z. phrygia* has long minor septa, dissepiments, and carinate septa, and has developed much further than the "Zaphrentoid stage."

The Lower Carboniferous *Hapsiphyllum* Simpson [type species *Zaphrentis calcariformis* Hall from the Corniferous limestone (Middle Devonian) of the Falls of the Ohio, Kentucky], has the structure usually called Zaphrentoid, but differs from *Euryphyllum* in dilatation and ontogeny.

Altogether it seems advisable to give this Permian genus a new name, so that its origins need not be confused. The relations of the species described by Etheridge (1891, p. 9) from the Upper Marine group (Permian) of New South Wales as *Zaphrentis* (*Plerophyllum*?) spp. cannot be made out from the figures, and I have no specimens for comparison.

The septa of *Euryphyllum* have throughout the same structure as that described for the meta-septa and for the unswollen portions of the clubbed septa of *Plerophyllum*. The median dark plane is very pronounced, and the growth lamination is emphasised, while the fibres can rarely be seen. Where the fibres can be seen they are at right angles to the median dark plane in transverse section of the septum, and directed slightly upwards from this plane in vertical section. Presumably the arrangement of the trabeculae is as postulated for *Plerophyllum*. The stereozone rarely shows the median dark planes of its constituent septa, but in it the growth layers of neighbouring septa meet in an arch or curve.

Euryphyllum trizonatum, sp. nov.

(Plate 1, fig. 7; text-fig. 4.)

Holotype: H. 22a., Collection of the University of Western Australia, from the Permian of Fossil Cliff, Irwin River, Victoria District.

Syntypes: A. 8643, Sedgwick Museum, and H. 22b., Collection of the University of Western Australia, from the same locality and horizon.

Diagnosis.—*Euryphyllum* with complete dilatation of the septa confined throughout to a regular narrow peripheral stereozone and the axial region.

Description.—The corallites are simple, turbinate, and almost erect. The direction of slight curvature is not quite constant, and the plane of symmetry at any part of the corallum is not always in the fossular plane. The two complete corallites were 20 mm. tall and 13 mm. in diameter at the calice; the third corallite was incomplete, but had a diameter at the calice of 23 mm. The calice is half as deep as the height of the corallum. The epitheca shows coarse longitudinal ribbing, the inter-septal ridges being high, and as wide as the septal grooves. There are septal grooves indicating potential minor septa.

In ordinary transverse section only major septa are seen, and they number 24 at a diameter of 8 mm., and 32 at a diameter of 20 mm., but in a section through the upper parts of the calice short minor septa may be distinguished in the peripheral stereozone. The septa are dilated and in contact peripherally, forming a very regular peripheral stereozone at least one tenth the diameter of the corallum; they are then suddenly much less dilated, and leave interseptal loculi styliform in transverse section; their axial ends are confluent, and thus form a dense axial structure. The length of the septa varies slightly, depending directly on their order of insertion. The fibres forming the septa are directed at right angles to the "median dark line," and the growth lamination of the septa is parallel to the median dark line.

The cardinal fossula is narrow, closed and parallel-sided, extending almost to the axis. The cardinal septum bisects it, and extends from the stereozone to the axis. There are equal numbers of meta-septa in cardinal and counter quadrants.

Tabulae are seen in transverse section, but their nature is unknown in vertical section.

Remarks.—A specimen (B.40) from the fossiliferous limestone 8½ miles north of Nerrima Homestead, Kimberley, has 40 septa at a diameter of 20 mm., and much greater dilatation than the syntypes. Probably, however, it belongs to this species. Some specimens of *Euryphyllum reidi* Hill from the Upper Dilly marine stage of the Lower Bowen beds [=Lower Marine of New South Wales Hunter River succession] closely resemble this species, but they show a much more extensive and far less regular dilatation of the septa. In most Rugose corals dilatation appears to be a primitive character, and it may reasonably be assumed that the Western Australian species has reached a higher stage of development than the Queensland forms, and that it is therefore rather younger.

Zaphrentis postuma Smith (1931, p. 4), from the Upper Carboniferous of South Wales, in its adult stage somewhat resembles the West Australian species, but it has fewer septa, a narrower stereozone, and its septa are never so dilated as to fill the lumen.

Euryphyllum minutum sp. nov.

(Plate 1, figs. 8-11; text-fig. 5.)

Holotype: Sections a., b. on slide H. 24, in the Collection of the University of Western Australia, from the Permian of creek half a mile west of Callytharra Springs, Wooramel River, Western Australia. There are five other fragments. The sections c., d., also mounted on slide H. 24, are doubtfully referred to this species.

Diagnosis.—Minute ceratoid *Euryphyllum.*

Description.—The coralla are ceratoid, and not quite erect. The direction of slight curvature is inconstant, and the plane of symmetry at any part of the corallum is not always in the fossular plane. The coralla are from 8 to 10 mm. tall, attaining a calical diameter of 4 mm. The calice is one-third as deep as the height of the corallum. The epitheca shows coarse longitudinal ribbing, and grooves indicating potential minor septa are present. Fine growth annulation is seen.

In transverse section only major septa are seen; there are 18 at a diameter of 3 mm. They are dilated and in contact peripherally, forming a stereozone 1 mm. wide, in which they cannot be traced individually; their axial ends run together in groups, those of each quadrant uniting together before joining the 6 proto-septa at the axis. The fossula is closed and expanded towards the axis, and is bisected by the cardinal septum.

Tabulae are complete, distant and dilated, and are inclined gently from the axis towards the periphery.

Remarks.—The species differs from *E. trizonatum* in its small size, and the less radial arrangement of its septa. It is very close to the Artinskian *Stereolasma minus* Soshkine (1925, fig. 6, 6a) in size, but its septa are less radially arranged than in the Russian species.

GENUS **TACHYLASMA** GRABAU.

?*Ufimia* Stuckenberg, 1895, p. 187.

Tachylasma Grabau, 1922, p. 34, 1928, p. 44.

?*Rhopalolasma* Hudson, 1936, p. 92.

Genotype: *Tachylasma cha* Grabau, 1922, p. 35, pl. I., figs. 2a., b. and text-fig. 50 on p. 36 [?Carbonic, ?Yunnan, ?South China]. The label of this specimen was lost before the species was described. It seems that Grabau later (1928, pp. 54-147) considered the genus to be Permian only.

Diagnosis.—Simple Rugose corals in which the meta-septa are subequal, the two alar and two counter lateral septa tend to be most prominent, and the cardinal septum is more or less aborted. Typically the septa are dilated and have swollen, rounded axial edges. Septal insertion is accelerated in the counter quadrants. Tabulae are not well developed, and there are no dissepiments.

Remarks.—The genus is one of a Permian group in which various of the proto-septa are more prominently developed than the remaining proto-septa, and the meta-septa. Acceleration of septal insertion in the counter quadrants is noticeable. The genus is widespread. It occurs in the Upper, Middle and Lower Permian of Timor; in the Artinskian (Lower Permian) Trogkofelkalk of the Carnic Alps (Heritsch, 1934); in the Lower Permian (Artinskian) of the Urals and the Oufimskoe Plateau; and in many Permian localities in China.

The genus is probably a synonym of Stuckenberg's Carboniferous (?)genus *Ufimia* (Genotype *Ufimia carbonaria* Stuckenberg, 1895, p. 188, pl. II., figs. 2, 3; pl. III., fig. 3, from the River Ufa, in the Urals), although Grabau (1928, p. 53) considers the two to be separate; since I have no Russian material, I cannot settle the matter. *Rhopalolasma* Hudson (1936, p. 92) from the Tournaisian of England, is also possibly synonymous, although Hudson considers it to be a homeomorph only. There are no important morphological differences between the three genera.

Tachylasma densum sp. nov.

(Text-fig. 12.)

Holotype: B. 126a., in Dr. Arthur Wade's collection, from the third band of Liveryngа Beds, North of Hill C., Freney Oil Area, Kimberley, Western Australia. Permian. Fragments of two other specimens are known from the same locality.

Diagnosis.—*Tachylasma* with septa dilated and in contact until just below the calice.

Description.—The corallum is trochoid, and slightly curved, attaining a diameter of 25 mm. in a height of 30 mm. The epitheca of the syntype is weathered off, and the calice filled with matrix.

At a diameter of 18 mm. there are 37 major septa, and very short minor septa in some of the loculi. The septa are dilated and in contact save for a narrow zone just inside the periphery, and are swollen very little more near their axial edges. The two counter lateral and the two alar septa are the largest and most dilated. The cardinal septum is extremely short, and the counter septum thin and of an intermediate length. There are 10 major septa between counter and alar septa; between alar and cardinal septa there are 7 major septa. The meta-septa are extremely irregular in length. The fine structure of the septa is as described in *Plerophyllum*. The tabulae are not seen owing to the excessive dilatation of the septa, and there are no dissepiments.

Tachylasma sp.

(Plate 1, fig. 12.)

The distal portion of a corallum probably belonging to the genus *Tachylasma* Grabau has been collected from a creek half a mile west of Callytharra Spring, Wooramel River. It is 1/4978 in the collection of the

Geological Survey of Western Australia. It expands in 10 mm. from a diameter of 18 mm. to a diameter of 21 mm., and then rejuvenescence occurs, whereby the diameter is rapidly and evenly reduced. There is coarse longitudinal ribbing of the epitheca, the septal grooves being as wide as the interseptal ridges. Fine transverse striation is present.

In the only section obtainable, taken immediately at the floor of the calice, there are 25 unequal major septa alternating with short equal minor septa. They are dilated and in contact only at the periphery, where they form a stereozone 1 mm. wide. The septa which presumably are the two counter-lateral and the two alar septa, are more prominently developed than either the counter septum or the cardinal septum, and the latter is shorter than any of the others. Of the meta-septa, those first formed are shorter than those immediately following, as in typical *Tachylasma*. None of the septa reach the axis, and their axial edges are only slightly swollen to a club-shape.

Remarks.—Although one cannot be certain that the septa taken for the proto-septa in the above description are correctly named, since the early stages of the corallum are destroyed, I think the assumptions made are reasonable, and that in all probability the specimen belongs to the genus *Tachylasma*. It differs from *T. densum* in the smaller number of septa and in the lack of dilatation. The septal structure of the fragment is that normal in *Tachylasma*, which is the same as that described above for *Plerophyllum*.

GENUS **VERBEEKIA** PENECKE.

Verbeekia Penecke (in Verbeek), 1908, p. 673.

Dibunophyllum (*Verbeekiella* sic); Gerth, 1921, p. 84.

Verbeekia; Soschkina, 1928, p. 385.

Genotype: Verbeekia permica Penecke *loc. cit.* from the Permian of Ajermati, Timor = *Dibunophyllum australe* Rothpletz, 1892, p. 70, pl. XII., figs. 19, 24, 20a (?), non 20, 25, 14; pl. XI., figs. 7, 9 (?), from the Permian of Ajermati, Timor = *Clisiophyllum australe* Beyrich, 1865, p. 85, pl. II., figs. 7a., b., 8a., b., 9.

Diagnosis.—Simple Rugose corals typically with much-dilated skeletal elements: with a clisiophyllidan axial column, with domed tabulae, and without dissepiments.

Remarks.—Gerth has examined Penecke's and Rothpletz's material; he has concluded that Penecke's *Verbeekia permica* is but an elongate form of *D.* (*V.*) *australe* Gerth, with less dilatation, and that it is characteristic of Ajer mati, and is identical with *Clisiophyllum australe* Beyrich from Ajer mati. Gerth has called the Ajermati type *Dibunophyllum* (*Verbeekiella*) *australe forma elongata;* but strictly speaking this type is the genotype, and Gerth's *D.* (*V.*) *australe* should have been made the *forma*. Of Rothpletz's figured specimens, Gerth has concluded that pl. XII., figs. 20, 25 and 14 represent a different species. The narrow peripheral stereozone and the lack of dissepiments is characteristic of most Permian corals. I do not think it likely that this genus is derived from the Clisiophyllidae of the Lower Carboniferous. It more probably represents a new stock. In the proximal part of the corallites, the vertical skeletal elements are so dilated that horizontal elements do not develop, but the dilatation decreases distally, and horizontal elements develop. Such conditions seem to be characteristic of new stocks.

Considerable differences in the arrangement of the septal lamellae are shown by those simple Permian corals with an axial column. These differences are those found within the family Clisiophyllidae of the Lower Carboniferous (*e.g.* in *Dibunophyllum, Aulophyllum and "Centrephyllum"*) and within the species *Symplectophyllum mutatum* Hill from the Lower Carboniferous of Queensland. Until a large amount of the Permian material can be investigated, I propose to include under *Verbeekia* Penecke all such Permian corals, *e.g. Carcinophyllum cristatum* Gerth, *Dibunophyllum rothpletzi* Gerth, *D. tubulosum* Gerth, *Clisiophyllum australe* Beyrich, *C. torquatum* Rothpletz and *C. talboti* Hosking. Mlle. Soschkina (1928, p. 386), has already referred *D. rothpletzi* Gerth to *Verbeekia*.

The genus as thus constituted is known elsewhere from the Lower Permian of the western parts of the Northern Urals, and in the Lower, Middle and Upper Permian of Timor.

Verbeekia talboti (Hosking).

(Plate 1, figs. 13-17; text-figs. 6, 7.)

Clisiophyllum talboti Hosking, 1931, p. 10, pl. III., figs. 1-3 (Permian), creek half a mile west of Callytharra Springs, Wooramel River.

Syntypes: Specimens $\frac{1}{4660}$ and $\frac{1}{4962}$ in the Collection of the Geological Survey of Western Australia. Horizon and locality as above.

Diagnosis.—*Verbeekia* with dibunophylloid axial structure containing few septal lamellae.

Description.—The corallum is simple, trochoid and curved, twisting slightly during growth. Size is variable, but the average height is 35 mm., with a diameter at the calice of 25 mm. The calice is deep, with a boss about one-third the width of the corallum, extending upwards almost as far as the calical margin, separated from the axial edges of the septa by a deep trench which widens suddenly at the fossula. The boss usually shows a median ridge in the fossular plane, and lamellae diverge from the ridge. The calicular platform is steeply sloping, and short minor septa are seen between the major septa. The epitheca shows more or less well-marked interseptal ridges and septal grooves, approximately equal in width indicating that the fossula is on the longest side of the corallum, but not necessarily in the plane of bilateral symmetry of any part of the corallum, and that minor septa are potential throughout. Annulation and low bourrelets are typical.

The septa number 26-34 of each order, but the minor septa seldom appear until just below the calice. They are always more or less dilated; they may be laterally contiguous only at the periphery, forming a narrow peripheral stereozone, or throughout their length; or such complete contiguity may be confined to the septa of certain parts of the corallum only, usually the cardinal quadrants, and a few neighbouring septa. None of the septa are rhopaloid. In transverse section they are seen to consist of fibres directed outwards from a light-coloured medium plane, at first pinnately, but curving gradually or quickly so as to run almost at right angles to the median plane. In vertical section the fibres are directed slightly upwards from the median plane. Growth lamination is never very evident. The septa are believed to consist of monacanths directed distally and towards the axis, as described in *Palaeocyclus* (Hill, 1936), and *Cymatelasma* (Hill & Butler, 1936), but whose axes are very close. There are usually equal numbers of meta-septa in cardinal and counter quadrants. The axial structure consists of a median lamella, which is continuous with the cardinal septum, but may be continuous with the counter septum, septal lamellae numbering from 5-9 on each side, and the axial parts of the tabulae. Dilatation of the skeletal elements may be so great that the structure is quite compact, but usually there are loculi giving the structure a piped appearance. The tabulae are domed, sometimes dilated, and may be represented by tabellae, especially in the axial structure, but these are never very numerous.

Remarks.—The species closest to this is *Verbeekia rothpletzi* (Gerth) from the Lower and Middle Permian of Timor and the Artinskian of the Urals.

Zaphrentis sp. Hudleston.

Zaphrentis sp. Hudleston, 1883, p. 590, in Forrest Collection, specimen marked 1, believed by Hudleston to be from "Fossil Range," north of the Lyons River, Gascoyne District, Western Australia. This specimen was recorded by name only, and has not been traced; it can hereafter be omitted from faunal lists.

GENUS **THAMNOPORA** STEININGER.

Thamnopora Steininger, 1831, p. 10; 1834, p. 337.

Pachypora, Lindström, 1874, p. 14.

Genosyntypes: *Thamnopora madreporacea* Steininger, 1831, p. 11, 1834, p. 338 *Calamopora polymorpha* var. γ Goldfuss, 1829, p. 79, pl. xxvii., fig. 4a, *Calamopora polymorpha* var. δ Goldfuss, 1829, p. 79, pl. xxvii., fig. 5, and specimens Steininger had in front of him. Middle Devonian, Eifel.

Thamnopora milleporacea Steininger, 1831, p. 11, 1834, p. 338, specimens in front of Steininger. Steininger refers to forms figured by Goldfuss, namely, pl. xxvii., fig. 1d, and pl. xxviii., figs. 2a-e as synonyms. Middle Devonian Eifel.

Genolectotype: *Thamnopora madreporacea*, interpreted upon the original of *Calamopora polymorpha* var. γ Goldfuss, 1829, pl. xxvii., fig. 4a = *Alveolites cervicornis* de Blainville, 1830, p. 370; 1834, p. 405 partim. See Steininger 1831, p. 12, where he restricts the species by excluding *Calamopora polymorpha* var. δ pl. xxvii., fig. 5, and he indicates the genotype in the sentence "Ich habe diese Koral von den Alveoliten getrennt und daraus ein besonders Genus mit den Namen Thamnopora gebildet." In case it is contended that this statement does not formally determine the genolectotype, the original of *Calamopora polymorpha* var γ fig. 4a is here chosen as lectotype of *Alveolites cervicornis*, and that species is here selected as genolectotype of *Thamnopora*." (Lang and Smith MS.)

Diagnosis.—Ramose Tabulate corals in which the cylindrical branches may be flattened and coalesced; the corallites are typically polygonal, and diverge from the axis of the branch and usually open normally to the surface; the corallite walls are dilated throughout, and the dilatation increases distally; typically the growth lamination in the sclerenchyme of the wall is obvious, while its fibrous nature is not; septal spines are usually obsolete, and mural pores are large.

Remarks.—This genus, and morphologically similar genera, their synonymy and morphology, have recently been revised by Drs. Lang and Smith, with the result that what was formerly a completely chaotic and useless group may now be used in exact stratigraphical discussions. The importance of the work which Drs. Lang and Smith are doing in clearing up the generic synonymies of Palaeozoic corals, and in describing the genotypes cannot be over-estimated. I am much indebted to them for allowing me to abstract the above synonymies from their unpublished manuscript. Drs. Lang and Smith will show that *Pachypora* Lindström is synonymous with *Thamnopora*.

The corallite walls are dilated throughout, and the dilatation increases distally and is not concentrated in the higher parts of the corallites as in *Striatopora* and *Coenites*.

The genus is rather rare in the Silurian, and very common in the Devonian. It is not known with certainty from the Carboniferous, but is again very common in the Permian, occurring in Timor, India, Japan and Australia. It is rare in the Trias. The four Permian species from Timor, *T. jabiensis* (Waagen & Wentzel), *T. curvata* (Waagen & Wentzel), *T. lobata* (Gerth), and *T. monstrosa* (Gerth) are characterised by dimorphism of the corallites; the three last also show excessive dilatation of the walls.

Thamnopora marmionensis (Etheridge).

(Plate 1, figs. 18-20; text-fig. 8.)

Favosites marmionensis Etheridge, 1914, p. 13, pl. I., fig. 1; pl. II., figs. 2-4; pl. VIII., fig. 2 [Permian], Mt. Marmion, Kimberley District, Western Australia. Figured syntypes in the Collection of the Geological Survey of Western Australia.

Favosites marmionensis; Glauert, 1925, p. 45.

Diagnosis.—*Thamnopora* forming large lobate masses, with corallites of two sizes opening obliquely to the surface, calices frequently with lower lip semi-circular, and with corallite walls becoming very thick distally; with large irregular mural pores, frequent tabulae and without septal spines.

Description (based on two syntypes only).—The corallum is flattened and lobate, and consists of rounded, diverging, but coalesced branches. The larger fragment (text-figure 8) is 55 mm. long, 45 mm wide at its greatest width, and 17 mm. deep. The average diameter of the branches is 13 mm. In its growth habit the corallum is identical with *T. lamellicornis* (Lindström), except that the individual branches are cylindrical rather than compressed.

The calices are of two sizes, indicating dimorphism of corallites. The larger are 2 mm. in diameter and the smaller 1 mm. In the unworn parts of the common wall between two corallites rises a thin median crest; but in the worn parts the common wall appears as a thick partition. The shape of the calice is very variable. Both sizes may be polygonal, but frequently they may be semi-circular, and the upper lip may be bounded by two such semi-circular lower lips of neighbouring corallites. That is, they are like the calices of *Alveolites*, except that the semi-circular wall is the lower lip in *T. marmionensis*, whereas it is the upper lip in *Alveolites*. Very rarely, low septal striae are observed in the calice, but no opercula have been seen.

The corallites arise by intermural increase at the axis of a branch, where they are vertical: they then diverge, the curvature increasing slightly towards the surface, where they open sometimes at right angles, but sometimes obliquely. The crescentic calices correspond to those corallites opening with the greatest obliquity. The walls of the corallites are dilated: dilatation is slight at the axis of the branch, but increases towards the calice, so that the wall may be as much as 1mm. thick. The common wall between two corallites consists of fibres directed pinnately upwards and towards the axes of the corallites, and does not show the growth lamination typical of most species of the genus. Septal spines do not appear in the sections. Tabulae are poorly developed, complete, and horizontal or inclined. Mural pores are numerous, large (diameter 0.1mm.), and not arranged in regular series. Their course through the dilated wall is rather irregular, and suggests that in some cases they may be due to a boring organism, as suggested by Lindström for similar "pores" in the Silurian *T. lamellicornis* and in *T. curvata* (Waagen and Wentzel) from the Permian of the Salt Range.

Remarks.—The species resembles the four species from Timor in the dimorphism of its corallites. In its dilatation it is closest to *T. curvata* (Waagen & Wentzel), from the Middle Permian of Timor, but differs from this in having a ramose and flattened corallum, rather than a finger-like corallum.

Thamnopora immensa sp. nov.

(Plate 1, figs. 21, 22; text-fig. 9.)

Holotype: Specimen here figured, text-fig. 9, H. 25 in the Geological Survey of Western Australia Collection, from two miles east of Selection Homestead, south of Rough Range, Kimberley, from a Permian Polyzoan Limestone.

Diagnosis.—*Thamnopora* of large size, in which the corallites are very long, have excessively dilated walls, and numerous large and regular mural pores.

Description.—The corallum is very large (largest fragment, text-figure 9, 75 x 65 x 45 mm.), and consists of coalescent and approximately cylindrical branches about 40 mm. in diameter. Unweathered calices are not seen, but they are probably polygonal. The corallites are vertical for a very short distance (5 mm.) and then turn sharply outwards to open at the surface of the branch at right angles. The length of this more or less straight part of the corallites may be as much as 30 mm. The corallites vary in size, the diameter from the median dark line of the walls being from 1 to 2.5 mm. It cannot be ascertained with certainty whether they are dimorphic as in *T. marmionensis*, as the surfaces of the coralla are too weathered.

The corallites are almost completely choked by the dilatation of the walls. Fibres are directed pinnately up towards the axes of the corallites from the median dark line of the common wall, but owing to re-crystallisation it is not possible to ascertain whether the walls consist of trabeculae or not. A space about 0.25 mm. wide may be left at the axis of the corallite, and usually seven or eight tooth-like pieces (which may represent septa) of the dilated wall project into it. Rarely, small circular foramina (about 0.1 mm. in diameter) are seen in vertical sections of the walls, and these are probably mural pores. But the corallum is riddled with the straight, spiral or irregular cylindrical tracks (up to 0.5 mm. in diameter) of boring organisms; usually the axis of the corallite has been excavated, either in a straight or a spiral cylinder, and neighbouring corallites are frequently connected by almost horizontal tunnels, which may or may not occupy the site of mural pores. The borings are usually lined by iron oxide, and may be crossed by thin transverse or slightly concave plates.

Neither septal spines nor tabulae have been recognised with certainty.

Remarks.—The species resembles *Thamnopora lobata* (Gerth) and *T. curvata* (Gerth) from the Middle Permian of Timor in filling the lumen of the corallites so completely that they are devoid of true tabulae. It differs from these in forming very large coralla of large coalescent branches.

B. 74, a large finger-like, incomplete branch, from two miles south-east of Christmas Creek Homestead, Kimberley, shows the same spiral tracks of the boring organism. This is in Dr. Wade's Collection.

GENUS **MONILOPORA** NICHOLSON & ETHERIDGE.

Monilopora Nicholson & Etheridge, 1879, p. 293, pl. vii., figs. 2a.-f.

Genotype (by monotypy): *Jania crassa* McCoy, 1844, p. 197, pl. xxvii., figs. 4, 4a. [Nicholson and Etheridge's descriptions were based on specimens from the Carboniferous Limestone of Derbyshire and Lancashire. But McCoy's syntypes were from three localities in the Lower Carboniferous of Ireland; that figured *loc. cit.* fig. 4, from Lackagh, Drumquin; that figured *loc. cit.* fig. 4a., St. John's Point, Dunkineely, Killybegs, Donegal Bay; unfigured, a specimen from the Calp of Abbeybay, Ballyshannon. Of the three syntypes, the only one that is wound round a crinoid stem (a condition typical of Nicholson & Etheridge's specimens) is that figured *loc. cit.* figs. 4a.]

Diagnosis.—Compound reptant coralla, usually encircling crinoid stems; the corallites are applied to the crinoid stem by one side, but the calices are erect and free laterally, and open approximately at right angles to the attached surface; the corallites have a peripheral stereozone, in which the sclerenchyme is typically reticulate in patches. There are no tabulae, and typically neither septal spines nor striae.

Remarks.—The relation between the genera *Monilopora* and *Cladochonus* McCoy is being investigated by Professor L. B. Smyth of Dublin and myself. Our findings are still unsettled, and I shall not anticipate them here.

Monilopora ?nicholsoni Etheridge.

(Plate 1, figs. 23-24; text-figs. 10-11.)

Monilopora nicholsoni Etheridge, 1914, p. 14, pl. I., figs. 2-4; pl. vii., fig. 4. (Permian), Mt. Marmion, Kimberley, Western Australia.

Monipolora nicholsoni; Glauert, 1925, p. 45.

Material here described consists of a number of fragments of coralla in the collection of the University of Western Australia from the Permian of the creek half a mile west of Callytharra Spring, Wooramel River, Western Australia. With it are a number of very slender ceratoid coralla of *Euryphyllum minutum* nov., which might be mistaken for single corallites of *Monilopora ?nicholsoni*, were it not for their coarsely striated epitheca.

Diagnosis of Callytharra specimens.—Slender *Monilopora*, with the proximal corallites reptant and embracing crinoid stems.

Description of Callytharra specimens.—The corallum is reptant proximally where it embraces thin crinoid stems. The corallites in this reptant portion may give rise to slender non-reptant branches, but if so, in my specimens they are broken off just above the point of issue. A trochoid proto-corallite about 3 mm. high and with a calical diameter of 3 mm., is attached by one side to a crinoid stem. It gives rise through its calical walls to an offset on each side. Each offset is applied by one side to the crinoid stem, and creeps round the stem, its calice becoming free. A new offset continues the encircling of the crinoid stem. The calices of these offsets are 2-4 mm. in diameter, usually 3 mm., and the corallites are curved, ceratoid or scolecoid. They may be 6 mm. from their point of issue to the calice, but are usually about 4 mm. Low septal ridges may sometimes be seen in the calice, and there is a faint longitudinal striation on the epitheca, indicating 18-20 septa. The epitheca also shows fine growth annulation.

In transverse section each corallite has a stereozone regularly about 0.75 mm. wide, so that in the narrow necks connecting calice and offset, the axial space is extremely small, but in the calice it expands considerably. The sclerenchyme does not show indications of fibres, but this is possibly due to recrystallisation. It shows growth lamination, the laminae being parallel to the epitheca in transverse section, but in vertical section being parallel to the sloping calical platform. No trace of reticulation of the sclerenchyme such as that described in *Monilopora crassa* and *M. beecheri* has been seen, nor have septal spines nor tabulae been observed.

Remarks.—This species occurs in the same district and on approximately the same horizon as the syntypes of *Monilopora nicholsoni* Etheridge. Of the latter only slender, short and semi-palmate branches have been described, and of the Callytharra specimens only the attached proximal portions are known. It is probable that only one species is represented at both localities. The size of the calice is fairly constant. Nevertheless *M. nicholsoni* as described by Etheridge differs considerably in having much coarser, even semi-palmate branches—whereas the only branches known from Callytharra are extremely slender, 2-3 mm. only. Miss Prendergast informs me that all the types of *M. nicholsoni* are lost, and in their absence it is considered unwise to separate the Callytharra specimens into a new species. Etheridge remarks that the reticulate structure of the sclerenchyme, claimed by him and Nicholson as diagnostic of the genus, was noted in only one section of the topotypes. I have not found it at all in the Callytharra specimens.

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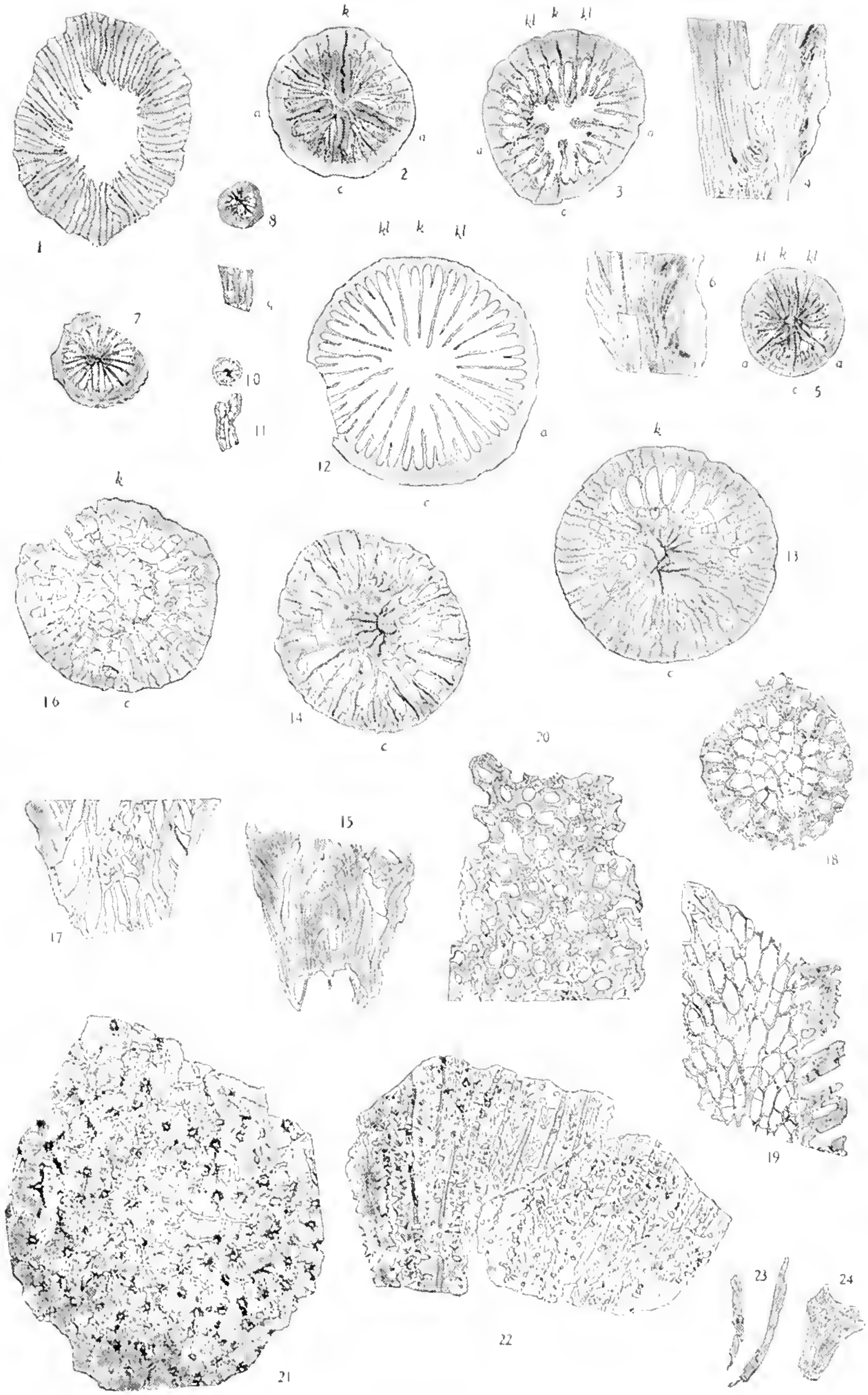

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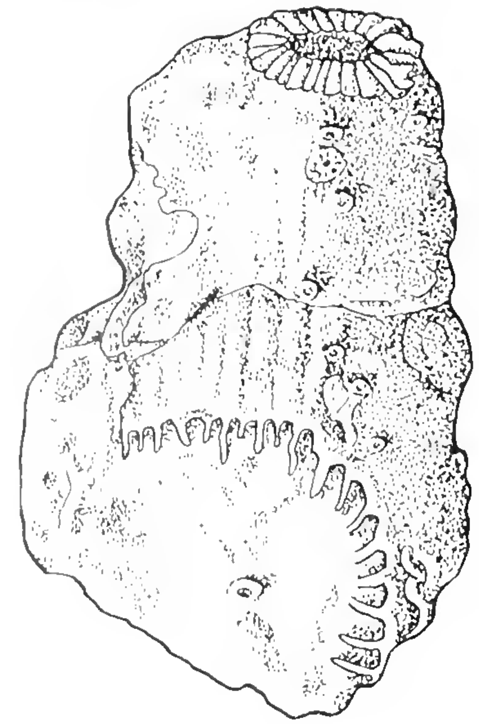

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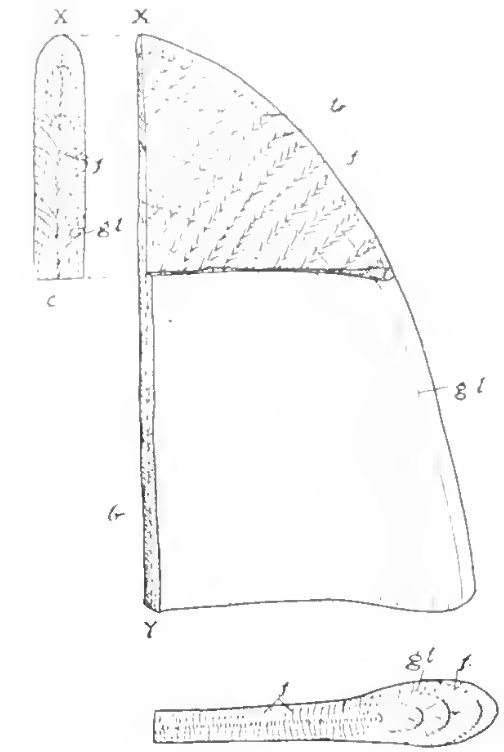

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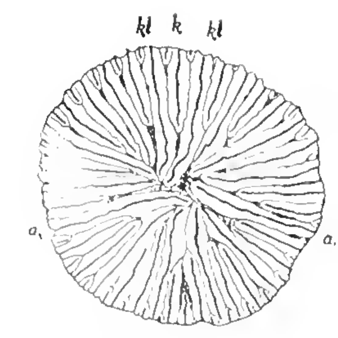

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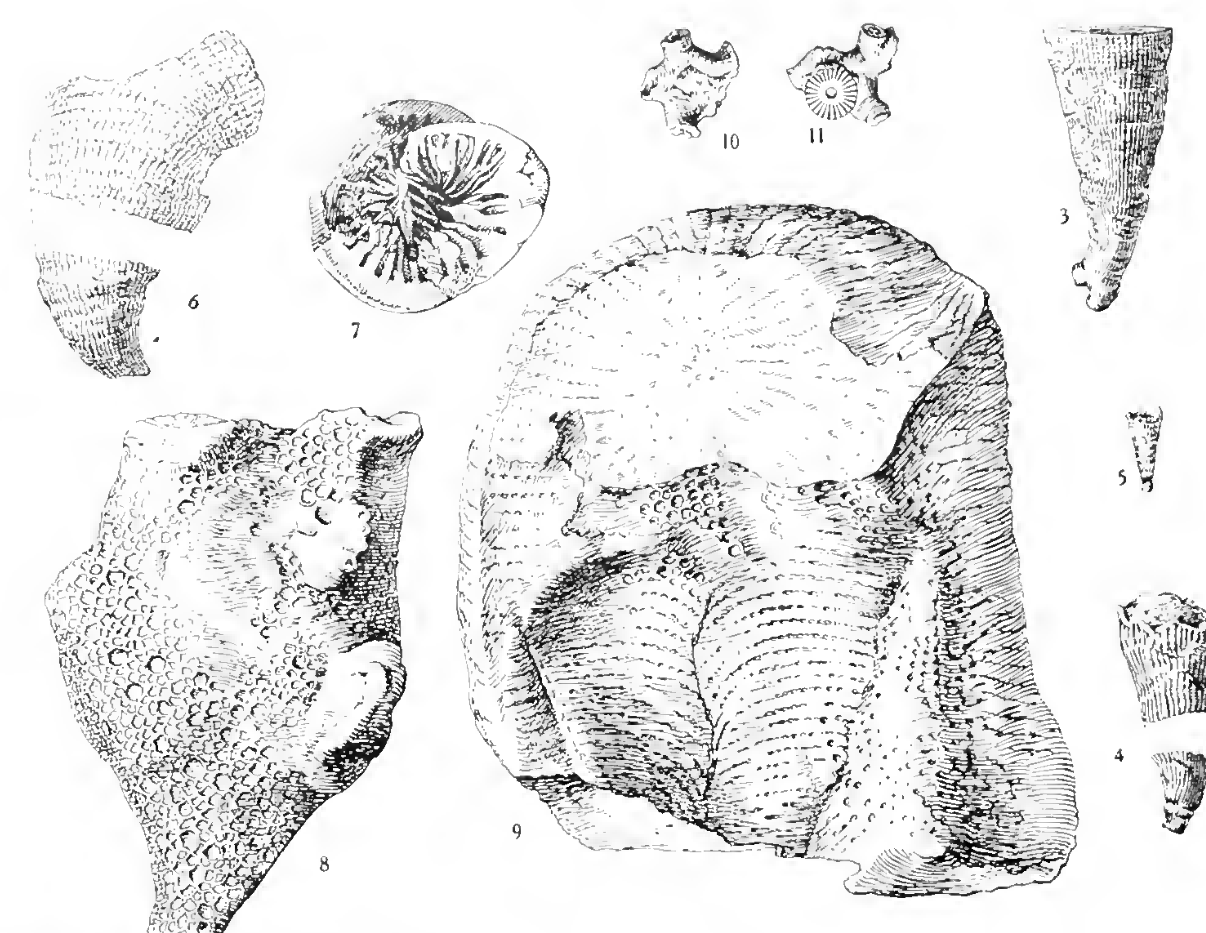

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6.—ZOOLOGICAL NOTES ON A TRAWLING CRUISE IN THE GREAT AUSTRALIAN BIGHT.

By

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Read 8th December, 1936; Published 14th July, 1937.

CONTENTS.

I. INTRODUCTORY.

Fishing in Western Australian waters by steam trawler was first begun as a commercial enterprise towards the end of 1929, the grounds exploited being those at the western end of the Great Australian Bight discovered in 1912 by the Federal Investigation Ship *Endeavour*. This venture, conducted by the Western Australian Trawling Co., Ltd. in the s.s. *Bonthorpe* working from the port of Albany was, however, short-lived (for reasons unconnected with either the supply or marketing of the fish) and the operations lasted only from November, 1929, to March, 1930.

The opportunity offered of forming an acquaintance with the zoology of this otherwise inaccessible region induced the writer to accompany the vessel on one of her cruises, and through the courtesy of the board of directors of the company and of the master, Captain L. W. Claxton, fifteen days were spent at sea, from February 19 to March 5, 1930.

As events turned out only one haul of the trawl was made owing to the failure of the ship's engines while at the fishing grounds, but it was so rich a haul in quantity and quality, that a considerable collection of interesting specimens was preserved from it. From the commercial fisheries point of view it was the biggest single haul made by the *Bonthorpe* during her operations and it was believed to be the largest haul ever secured by trawling in the Bight.

The haul was made at a depth of 93 fathoms at the edge of the Continental shelf, in Lat. 33° 15′ 0″ S., Long. 126° 22′ 15″ E., a point approximately 75 miles south of Eyre and 150 miles E.N.E. by E. from Israelite Bay. The trawl was put down on February 23, in the late afternoon and the area covered by it was a stretch 100 feet wide and calculated to be 3½ miles long, the period of towing being 1 hour 55 minutes.

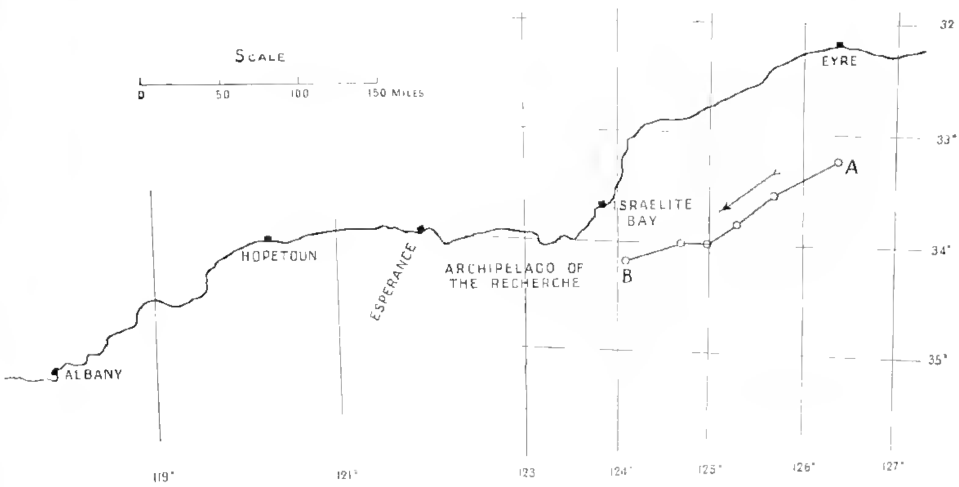
II. PHYSICAL OBSERVATIONS.

1. TEMPERATURES AND OCEAN CURRENTS.

The temperature of the surface water was comparatively uniform over the whole region, as the accompanying table shows, the range being only 1° C. (= 1·8° F.). The point is of interest in regard to the distribution of ocean currents. Halligan has shown (*1921*, pp. 189–190) that a warm easterly current sweeps around Cape Leeuwin, and flows some distance from the coast, its waters being 5° F. warmer than those of the cold easterly drift on which it is superimposed and which upwells around the immediate coastline. The uniformity of the temperatures of the present cruise suggests the influence of only one current, the cold one, and that the warm stream does not extend its influence so far north into the Bight as the course taken by the *Bonthorpe*.

Station.	Date.	Time.	Temperature.		Barometer.	Wind.
			Air.	Sea.		
Albany, Town Jetty	Feb. 19	p.m. 5·0	21·0	19·7°	30·12	
Lat. 33° 45′ S. ... Long. 124° 40′ E.	Feb. 22	...	18·9°	20·0	30·22	S.
Lat. 33° 14′ S. ... Long. 126° 16′ E.	Feb. 23	a.m. 10·30	19·2	19·9°	30·26	E.
Lat. 33° 23′ ... Long. 125° 44′ ...	Feb. 24	p.m. 2·0	19·7	19·9	30·23	E.
Lat. 34° 0′ ... Long. 124° 56′ ...	Feb. 26	3·30	22·0°	20·4°	30·01	E. Fairly strong.
Lat. 33° 50′ ... Long. 124° 40′ ...	Feb. 27	3·45	20·9	20·6	29·99	E.
13 mi. S.W. of previous position ...	Feb. 28	4·45	22·0°	20·7	29·74	E.N.E. Slight.
Lat. 34° 11′ ... Long. 124° 5′ ...	Mar. 1	2·15	22·5°	20·6	...	E.N.E. Strong.

A second point concerning the currents of the Bight was revealed through the predicament in which the *Bonthorpe* was placed owing to the failure of the engines at the fishing grounds when the vessel was forced to drift at the mercy of the currents for almost seven days. Daily observations for latitude and longitude throughout this period by Captain Claxton showed that there was a continual drift to the south-west at a rate varying from 12 to 25 miles per day. The *Bonthorpe* commenced her drift on the early morning of February 24 when she was approximately in Lat. 33° 15′ S. and Long. 126° 22′ E. In the late afternoon of February 27 two islands of the eastern group of the Archipelago of the Recherche were sighted. On the morning of March 2, on which day the engines were in commission again, the ship was west of, and in close proximity to, Salisbury Island. The full period of drift was 6 days 19 hours. The position of the ship during the drift at 4·30 p.m. each day is shown on the accompanying map.



TEXT FIG. I.

Locality map showing the drift of the *Bonthorpe* (from A to B). The point A marks the position of the fishing ground referred to in this paper.

The direction of drift—to the south-west—is contrary to what would be expected in a region where the easterly drift current dominates the water movements. However, in the following excerpt from "The Australia Pilot," volume 1, page 9, is explained how prevailing winds may materially alter the near-shore circulation of water.

"Near Cape Leeuwin, and off the south coast of Australia the current at all times of the year appears to be principally influenced by the prevailing winds, some vessels having experienced constant northerly and north-easterly currents, running from 1 to 1½ knots, while others have been set to the eastward, and but little to the northward, as they approached the south-western coast of Australia.

"From Cape Leeuwin to the Recherche Archipelago the current usually sets eastward, in a direction parallel with the coast, being strongest between D'Entrecasteaux Point and the King George Sound, where its rate is sometimes 1½ knots. From the Archipelago, round the Australian Bight to Cape Northumberland, it has less strength than farther to the southward; as Bass Strait is approached it is experienced, running eastward and south-eastward at a rate of 1 to 2½ knots.

"From November to April the easterly current abates in strength, and after a fresh easterly wind it not infrequently changes its direction to the north-westward.

"In the offing between Cape Leeuwin and Cape Otway the currents appear to be mainly influenced by the strong westerly winds, which prevail during nine months of the year.

"Near the Australian coast with easterly winds a current has been found setting to the westward, but this current is probably confined to the vicinity of the coast."

It is no doubt the current referred to in this last paragraph which was concerned in the drift of the *Bonthorpe*. It is most likely induced by the prevailing easterly winds of the summer months, which, as they blow fairly continuously, probably cause an important local swirl in the large expanse of water in the Great Australian Bight which, owing to the configuration of the coast line does not receive the full influence of the main Southern Ocean current. As the air pressure systems move northward in the winter and the prevailing winds over the Bight become westerly it might be presumed that the direction of flow of the current would become reversed. A year's observation in this area, which will become possible when trawling becomes firmly established should provide data of value in this connection.

Confirmatory evidence of this drift to the south-west has been accumulated by Captain Claxton during the brief period of his trawling operations in the summer. He found that there was a constant tendency for the *Bonthorpe*, and buoys that were put out at the fishing ground, to drift to the southward, often at variance with the direction of the wind blowing at the same time.

In Australia the tendency has been to overlook the importance of these local coastal currents and to refer to the main oceanic currents exclusively in zoo-geographical theorising. As physiographical agents, however, it is recognised that the local shore currents play the principal part in moulding the relief of a coastline and in effecting other shoreline processes, and that the effect of oceanic currents is almost negligible. Due regard should no doubt be paid to such local currents also by zoo-geographers in any investigation on the distribution of marine organisms around the Australian littoral, particularly where it can be shown that the currents are of regular seasonal incidence.

2. PHYSIOGRAPHY.

From the soundings made by the *Bonthorpe* and from the data on the Admiralty charts, the dip of the continental slope, from the comparatively level shelf into the abyss, commences about the 70 fathoms contour line. Beyond this depth the contour lines are crowded together on the map and the *Bonthorpe*'s soundings indicated marked declivity, as illustrated by the following depths recorded on February 23 whilst the vessel was hove-to and merely drifting with the current.

10·30 a.m.—Bottom not touched at 130 fathoms.
10·40 a.m.—Sounding of 89 fathoms.
11·50 a.m.—Sounding of 75 fathoms.
12·30 p.m.—Sounding of 100 fathoms.

In the early afternoon of the same day, whilst the vessel was slowly cruising around, sounding for a suitable depth to begin trawling, the following depths were recorded within 15 minutes :—

62 fathoms, 70 fathoms and 93 fathoms.

At each sounding a sample of the bottom deposit was collected from the sounding lead and preserved in neutral formalin. In all instances a firm, sandy bottom was indicated, of fine foraminiferal sand and evenly comminuted shell fragments.** The trawl brought up some fragments of limestone, but serious obstructions have never been encountered by the *Bonthorpe* during her operations in the area.

Geologically the adjacent land mass is a tableland of almost level-bedded limestones of Miocene age. The Bight is due to down-faulting, the scarp existing as the present line of limestone cliffs which border the Bight from Israelite Bay to the Head of the Bight, except between Twilight Cove and Eucla, where the scarp recedes inland as the Hampton Range. The Archipelago of the Recherche and the mainland to the north and west is of granite, a part of the Pre-Cambrian " shield " of Western Australia.

** The Foraminifera and Ostracoda of the soundings are reported on by F. Chapman and W. J. Parr, *Journ. Roy. Soc. W. Austr.*, vol. XXI, 1935, pp. 1–7.

III. THE FAUNA.

1. GENERAL.

The most comprehensive account of the fauna of the Western portion of the Bight is contained in the five volumes dealing with the biological results of the various cruises of the *Endeavour*, issued between 1911 and 1926. Other papers by independent workers are referred to in the sectional reports *infra* and the bibliography at the end of the paper.

The material from the present cruise, being from a single haul only, represents the concentrated gathering of the larger fauna of a strip of sea-bottom $3\frac{1}{2}$ miles in length and 100 feet wide, the trawl used being the German improved pattern of the Vigneron-Dahl net.

The animals in greatest proportion were the fishes, the nannygai or red snapper (*Trachichthodes gerrardi* Günth.) predominating and presenting a conspicuous spectacle by reason of its glittering pink scales. The smaller invertebrates of course passed through the meshes of the net, but large masses of a yellow sponge provided a store of material. This yielded a small collection of amphipods and sphaeromid isopods, and polychaetes. A few polyzoans were abundant and there were some "fronds" of the elegant pink Gorgonid *Mopsea*. Sertularians were quite common. Specimens of a large cowrie, *Zoila* (= *Cypraea, auctt.*) *thersites* Gsk. were the only living gastropods taken, but several shells, principally volutes, were present, each one tenanted by a hermit crab. Small crabs, belonging to two species of *Pilumnus*, began crawling in numbers all over the deck as soon as the sorting of the fish commenced.

No specimens whatever of Algae were obtained.

The only specimens new to science were a foraminiferan already described by Messrs. F. Chapman and W. J. Parr and a fish belonging to the Genus *Parapercis*.

2. FISHES.

(a) List of Species.

There were 19 species included in the haul, and in addition specimens belonging to five other species collected by Captain Claxton from a cruise in December, 1929, in 75 fathoms, were also examined. Much of the material was studied on board, and specimens of as many species as could be conveniently preserved with the limited facilities available were taken back to Perth. All of the fishes collected but one were referable to known species. Two additional forms, however, are new to the fish fauna of Western Australia, namely, *Pristiophorus nudipinnis* and *Gariehthys mirus*. The latter species is of special interest in that it was previously known only in waters west of Bass Strait. In the late A. R. McCulloch's "A Checklist of the Fishes Recorded from Australia" (1929–30), Western Australia as a locality record is not mentioned for the following species taken in the haul, though specimens of them had previously been taken in local waters:—

Parascyllium ferrugineum,
Squalus fernandinus.
Centriscops humerosus,
Trachichthodes gerrardi,
Cyttus australis.
Caesioperca lepidoptera.
Zanclistius elevatus.
Helicolenus papillosus.
Anoplocapros gibbosus.

Sub-Class ELASMOBRANCHII.

Order SELACHII.

Family HEMISCYLLIIDAE.

Parascyllium variolatum (Dum.)—Cat Shark.

Two male specimens were preserved by Captain Claxton from his previous haul. The species is said to be commonly taken in the trawl, but no examples came under notice on the present occasion.

Parascyllium ferrugineum McCull.—Rusty Cat Shark.

Parascyllium ferrugineum McCulloch, Zool. Res. *Endeavour* I, 1911, p. 7.

One specimen was brought up in the haul.

Family SQUALIDAE.

Squalus fernandinus Molina—Spiny Dogfish.

Several of these dogfishes were brought up, they being the most numerous of the Elasmobranchs in the catch.

Family PRISTIOPHORIDAE.

Pristiophorus nudipinnis Günth.—Naked-finned Saw Shark.

Pristiophorus nudipinnis Günther, Cat. Fish Brit. Mus., VIII., 1870, p. 432. McCulloch, Zool. Res. Endeav. I., 1911, p. 10.

Three adult specimens were taken in the trawl, the pallid bodies and the quivering saw-like snout and the tentacles making them arresting objects when the catch was emptied on deck. They were frequently taken by the *Bonthorpe* and Captain Claxton had preserved embryos on board. The *Simplon* collected examples in Long. 135°, but until the present occasion the species had never been actually taken in Western Australian waters. Owing to a printer's error the name of the *Pristiophorus* taken by the *Penguin* was omitted from Mr. Glauert's report (*1921*, p. 44), but I am informed by him that it was *P. cirratus*.

Family SQUATINIDAE.

Squatina tergocellata McCull.—Large-spotted Angel Shark.

Squatina tergocellata McCulloch, *Biol. Res. Endeavour*, II, 1914, p. 84.

One specimen was captured in the trawl and Captain Claxton had preserved an embryo taken from a female collected on a previous voyage. He stated that it was not uncommon in the catches, though hitherto in Southern Australia it has been known only from the single specimen on which McCulloch founded the species, collected by the *Endeavour* in this region of the Bight.

Sub-Class TELEOSTOMI.

Order TELEOSTEI.

Sub-Order ISOSPONDYLI.

Family GONORHYNCHIDAE.

Gonorhynchus greyi (Rich.) Rat Fish.

Captain Claxton had on board a specimen taken in a previous haul, November, 1929, in 75 fathoms.

Sub-Order INIOMI.

Family AULOPIDAE.

Aulopus purpurissatus Rich. Sergeant Baker.

One specimen was represented in the catch. Captain Claxton recalled its occurrence in the haul on only one previous occasion.

Sub-Order AULOSTOMI.

Family MACRORAMPHOSIDAE.

Centriseops humerosus (Rich.) Bellows Fish.

Several specimens.

Sub-Order ANACANTHINI.

Family MACROURIDAE.

Garichthys mirus (McCull.) Whip Tail.

Coelorhynchus mirus, McCulloch, *Zool. Res. Endeav.*, V., 1926, p. 178.

Garichthys mirus, Whitley, in McCulloch's "*Fishes of New South Wales*," 3rd. edn., 1934, Supp., p. 5.

A specimen of a whip-tail, which Captain Claxton preserved out of a haul made in 75 fathoms in December, 1929, was handed over to me. It agrees very well with McCulloch's description of a Sydney specimen of the above species which has hitherto remained unrecorded further west than the eastern edge of Bass Strait. The specimen represents an interesting new addition to the fauna of the State.

Sub-Order BERYCOIDEI.

Family BERYCIDAE.

Trachichthodes lineatus (Cuv. & Val.) Swallow Tail.

Beryx lineatus Cuvier et Valenciennes, Hist. Nat. Poiss., III., 1829, p. 226.

Trachichthodes lineatus, Waite & McCulloch, Trans. Roy. Soc. S.A., XXXIX., 1915, p. 461.

A considerable quantity of these edible fishes was taken, but they were not as numerous as the following species, although some catches of the *Simplon* were made up almost exclusively of Swallow-tails. They are of a smaller size and readily recognisable by the deeply forked tail.

Trachichthodes gerrardi (Günth.)—Red Snapper (Nannygai).

Beryx gerrardi Günther, Ann. Mag. Nat. Hist., (5) XX., 1887, p. 238.

Austroberyx gerrardi, McCulloch, *Zool. Res. Endeav.*, I., 1911, p. 41.

This species made up the bulk of the haul and it was stated that it was the most abundant of the fishes taken by the *Bonthorpe* during its previous operations. The fish was known on board as the nannygai, a name which is usually applied to the closely related *T. affinis* (Günther). Several specimens were examined on board and all were referrable to *T. gerrardi*. In a report on Australian fisheries published in connection with the Great All Australian Exhibition of 1913, H. C. Dannevig gave a plate of *T. gerrardi* with nannygai as the vernacular name.

Sub-Order ZEOIDEI.

Family **ZEIDAE**.

Zeus faber Linn.—John Dory.

Specimens were taken in the trawl.

Cyttus australis (Rich.)—Silver Dory.

Several specimens were taken. Their colour differed from that given by Waite (*1923*, p. 100) in that the back and snout were of a bright pink instead of brown. The pink colour, however, rapidly vanishes in preserved specimens.

Sub-Order PERCOMORPHI.

Family **HYPOPLECTRODIDAE**.

Caesioperca lepidoptera (Bloch & Schn.)—Butterfly Perch.

One specimen was preserved out of the haul. The general colour was a rich purplish blue, with bright yellow along the base of the dorsal fin, sides of the head, base of the pectoral and base of the ventral fins.

Family **CHAETODONTIDAE**.

Chelmonops truncatus (Kner)—Coral Fish.

A common species.

Family **HISTIOPTERIDAE**.

Zanclistius elevatus (Rams. & Ogil.)—Short Boar Fish.

Several specimens were taken.

Sub-Order JUGULARES.

Family **PARAPERCIDAE**.

Parapercis (Neopercis) naevosa sp. nov.

PLATE II.

Description :—D. iv. 23 ; A. 19 ; V. i, 5 ; P. 19 ; C. 17 ; Ll. 58 ; Lt. 6, 16.

Length of head 4·0, height of body 5·1, and lengths of caudal, pectoral and ventral fins all 5·1 in the total length (exclusive of the caudal fin). Diameter of eye 2·6, inter-orbital space 11·2, length of snout 3·6, and height of caudal peduncle 2·6 in the length of the head. The height of the body is slightly less than the width of the head and is equal to the length of the caudal fin.

Cleft of mouth slightly oblique, jaws equal with prominent lips. Maxilla reaches to the level of the middle of the eye. Eyes placed latero-dorsally.

Opercle with a flat spine above the root of the pectoral, its angle prominent with a few fine serrations. Pre-opercular border smooth.

The *teeth* consist of an outer row of prominent, spaced cardiform teeth in both jaws, behind which is a band of very small villiform teeth. The palatines and vomers are toothed.

In the *dorsal fin* the spines increase progressively in length from the front backwards, the last being double the length of the first, and 3·7 in the length of the head; the rays are 1·7 in the length of the head. The *anal fin* rises below the fifth dorsal ray and ends evenly with the dorsal fin, the rays are appreciably lower than the dorsals, and the posterior rays of both fins when folded back reach to the base of the caudal but not beyond. The *pectoral fins* are pointed, extending back to the beginning of the anal fin. The *ventral (pelvic) fin* is only very slightly shorter than the pectoral and reaches back as far as the vent. The *caudal fin* is rounded.

The top of the head and snout and a narrow zone around the eyes are scaleless. The naked area is covered with numerous rounded pores behind the eyes and sparingly so on the snout. A single row of pores extends along the pre-opercular border. The lateral line does not follow the contour of the back but curves down fairly boldly in the posterior part of the body.

Colour (after preservation), greyish white. Along the upper part of the body is a row of 15 regularly placed, brown spots on each side. The first three are very faint and are situated, respectively, behind the eye, on the opercle and above the base of the pectoral fin. The remaining 12 are well marked, and the last is set on the base of the caudal peduncle. The five anterior spots are below the lateral line, the sixth is crossed by it and the posterior nine are above. The six anterior spots are joined dorsally by faint brown bands which suggest that in the living condition the pattern may have been composed of transverse bands and not of separate spots. The above description was obtained three months after collection.

Total length, 115·5 mm.

Holotype collected by Captain L. W. Claxton from a haul made in 75 fathoms, December, 1929; preserved in the Western Australian Museum.

Affinities.—The presence of palatal teeth and the high posterior dorsal spines place the species in the sub-genus *Neopercis*, and the strong degree of curvature of the lateral line brings it into relation with *P. ramsayi* Steindachner, 1884, and *P. binivirgata* (Waite, 1904), both of which it resembles in general appearance, particularly the former in the contour of the anterior region, for the back between the eye and the base of the first dorsal spine is flat and not arched as in *P. binivirgata*. The large size of the eye is a prominent feature, and it is much larger than the eye of *P. ramsayi*, where it is only a quarter of the length of the head according to Ogilby (1885) (3/8 in *P. naerosa*). The ventral fin reaches only as far as the vent, which it fails to do in *P. ramsayi*, and over-reaches the vent to the second anal ray in *P. binivirgata*. The pectoral fin resembles that of *P. ramsayi* in shape and length, being much more pointed than in *P. binivirgata*, and shorter in that it does not extend as far back as the second anal ray. The opercle closely resembles *P. binivirgata*. It differs from the other Australian species of *Neopercis*, *P. allporti* (Günther, 1876) in the curvature of the lateral line, in the relative sizes of the dorsal spines, the contour of the head region, in that the ventral fin does not reach to the anal, in colour pattern, and fin formulae.

The following key to the Australian species of the subgenus *Neopercis*, expanded from McCulloch, summarises some of these differences and resemblances :—

A. Lateral line not following curve of back ; dorsal spines 4 or 5, increasing in size posteriorly.

B. Dark blotches all above lateral line ; 5 dorsal spines ; ventral fin reaching beyond vent to the anal fin ; pectoral rounded and reaching to the second anal ray ; back between head and dorsal fin arched——*binivirgata*.

BB. Some or all of the dark blotches extend to below lateral line ; 4 dorsal spines ; ventral and pectoral fins do not reach to second anal ray ; back between head and dorsal fin flattened.

C. Blotches few (7) all below lateral line ; ventral fin not reaching vent ; eye small ——*ramsayi*.

CC. Blotches many (15), anterior series below, posterior series above lateral line ; ventral fin reaching vent ; eye large ——*naevosa* sp. nov.

AA. Lateral line following curve of the back ; back with cross bars ; 5 dorsal spines, sub-equal ; ventral fin reaching to anal ——*allporti*.

Sub-Order CATAPHRACTI.

Family **SCORPAENIDAE**.

Helicolenus papillosus (Bloch & Schn.)—Red Gurnard-Perch.

A specimen was preserved by Captain Claxton from the December haul.

Family **TRIGLIDAE.**

Pterygotrigla polyommata (Rich.)—Flying Gurnard.

Many specimens of this handsome fish were gathered by the trawl, but though it was highly prized as a food fish on board, the full quantity caught was not preserved as there is comparatively small demand for the species on the Western Australian market.

Chelidonichthys kumu (Less. & Garn.)—Red Gurnard.

Some specimens of this Gurnard were also obtained. It is likewise accounted as a good food fish whose quality is not properly appreciated locally.

Family **PLATYCEPHALIDAE**.

Platycephalus conatus Waite & McCull.—Deep-water Flathead.

Platycephalus (*Neoplatycephalus*) *conatus* Waite & McCulloch, Trans. Roy. Soc. S.A., XXXIX, 1915, p. 466.

This species ranked second to the red snapper in abundance.

Sub-Order PLECTOGNATHI.

Family **ALUTERIDAE**.

Nelus ayraudi (Q. & G.) –Chinaman Leather Jacket.

Several leather jackets were taken and with other species made up one basket of miscellaneous food fishes. The crew of the trawler spoke of the peculiar young produced by this fish, which, however, was ascertained from descriptions to be a Cymothoid isopod. None of the parasites, however, were seen on the present occasion, though the fishermen kept a special lookout for them. One specimen collected by a student of the University from the deck of the *Bonthorpe* at Albany on another occasion has been examined by the writer and found to be *Ourozeuktes owenii* Milne-Edwards, a common parasite on local leather jackets.

Family **OSTRACIONTIDAE**.

Anoplocapros gibbosus Waite & McCull. Humpty-Dumpty.

Anoplocapros gibbosus Waite & McCulloch, Trans. Roy. Soc. S.A., XXXIX, 1915, p. 480.

Several of these box fishes were trawled up. They were known as "foot-ballers" to the crew.

Capropygia unistriata Kaup. Striped Box Fish.

Capropygia unistriata Kaup, Arch. f. Naturg., XXI, 1855, p. 220. Waite & McCulloch, l.c., p. 478.

One specimen preserved out of the catch has the flat spines on the lateral ridges, not sharp-pointed as figured by Waite and McCulloch, but markedly truncated, the spines being flatly trapezoidal in shape.

(b) Trawling Operations.

The commercial potentialities of the fish fauna of the western portion of the Great Australian Bight were known principally from the results of three previous trawling expeditions. The thorough prospecting of the F.I.S. *Endeavour* laid the foundations of the work, and this was supplemented by the cruises of the South Australian Government Trawler *Simplon* in 1914 and the Western Australian Government trawler *Penguin* in 1920. The activities of the latter were cut short by its wreck near Esperance. The *Simplon* trawled over an area whose western limit was 2° 23′ east of the locality fished over by the *Bonthorpe*. It is interesting to note that its results were not altogether favourable, thus contrasting sharply both with the experiences of the *Endeavour* and those of the *Bonthorpe*. However, the *Simplon* put down only ten hauls and operated under adverse weather conditions.

Captain Claxton has found the edge of the continental shelf, in particular about a depth of 75 fathoms, to be the most favourable zone for fishing, and during his operations, between November, 1929, and February, 1930, he trawled between 70 to 75 fathoms, the haul at 93 fathoms of the last cruise, on which this paper is based, being exceptional in its greater depth.

The main food fishes taken in the hauls are nannygai, leather jackets and deep-water flathead, and detailed records of the quantity of each of these taken on two of the earlier cruises, namely, January 12 18, and February 4-10, 1930, are filed with the Department of Fisheries and Game. They reveal some very interesting information, and are utilised here through the courtesy of the Chief Inspector (Mr. F. Aldrich).

Captain Claxton, when he started his operations in this area, soon found that the night hauls were much richer than those made during the day. The records he kept of the number of baskets of fish taken in each haul contain details of the duration of the haul, time, depth, etc., and the graph on (Plate III.) which has been constructed from his figures by the writer, clearly shows the regular alternation of poor and good catches each day and night. The graph shows the catch of nannygai and flathead between January 12 to 18. The figures, very low during the day, rise rapidly each evening after 7 o'clock, and reach a maximum by midnight, falling again to low values by 9 o'clock in the morning. The figures for leather-jackets show a similar tendency, but the catches of these fish were comparatively small in the cruises concerned.

As has been mentioned only one haul was made on the cruise on which the writer was present, engine trouble curtailing the operations. This haul was made at 93 fathoms, a greater depth than any hitherto, and was made between 3·30 and 5·30 p.m. The surprising result is that though it was a daylight haul, the quantity of fish taken was a record one, and believed to be the greatest ever taken in a single haul on these grounds. There were 32 baskets of nannygai (about 15 fish to each basket, of a total weight of about 45 lbs.) and 27 baskets of flathead (av raging 28 fish per basket).

The most obvious factor which has a bearing on the richness of this unprecedented daylight haul is the depth. The previous daylight hauls, notable for their barrenness, were usually made between 70 to 75 fathoms, and one was made at 50 fathoms when no fish at all were taken. The fish definitely seem to move up and down during the twenty-four hours, rising into shallow water in the night and moving back into deeper water in the day. As in other parts of the worl l, this is no doubt a phenomenon intimately connected with the food supply. Some essential link in the food chain is directly dependent on copepods, whose diurnal rise and fall impose a similar rhythm on all the associated predators. Professor W. J. Dakin (*1931*, p. 31) has suggested a similar cause for the diurnal movements of the tiger flathead in the trawling grounds in New South Wales. There is a difference, however, between the conditions there and in the Bight. In New South Wales the night catches are poor and those in daylight good, for the nightly rise of the fish takes them up from the sea bottom out of reach of the trawl. In the Bight the *Bonthorpe* trawling groun l was at the very edge of the continental shelf, which, as has been shown earlier, is decidedly steep. The most feasible explanation on present evidence of the local conditions is that the fish move up and down the slope, and therefore they are within range of the trawl both night and day. Night fishing would take them at relatively shallow depths, while day fishing would have to be carried on further down the slope. At night the fish rise within the 70 fathoms line, and in the daytime retreat deeper. The one successful daylight haul captured them at the 93 fathoms level, and as this was in the late afternoon the fish were rising, therefore the centre of the concentration of the shoals at noon must be considerably deeper.

3. MOLLUSCA.

Very few molluscs were contained in the haul, being represented for the most part by empty shells of large gastropods inhabited by hermit-crabs (*Dardanus arrosor*). The only live specimens were two species of *Zoila* (= *Cypraea Auct.*). In 1912 Sir Joseph Verco accompanied the *Endeavour* on a cruise to the western portion of the Bight and specialised in the collecting of shells, supplementing the meagre catch from the ship's trawl with a bucket dredge.

Of the nine species represented in the *Bonthorpe* collection, all but two, *Cuspidaria erma* and *Zoila friendii*, were recorded by Verco. A feature of the collection is the pallor of the shells. While this is partly due in some of the examples to their being "dead" shells, the *Cypraea* series and others strongly suggest that it is an effect of the darkness.

Class PELECYPODA.

Order SEPTIBRANCHIA.

Family **CUSPIDARIIDAE**.

Cuspidaria erma Cotton.

Cuspidaria erma Cotton, Rec. S.A. Museum, vol. IV, No. 3, 1931, p. 347.

A single right valve was recorded from the haul. The shell is thin and ovate in outline. Umbo slightly opisthogyrous. Antero-dorsal border concave. Anterior end ovate; the convex ventral border passing concavely into the rostrum which has an upward tilt. Resilifer directed obliquely forward. A sharp lamina-like tooth extends from the resilifer half-way along the postero-dorsal border. The antero-dorsal border has just the suggestion of a groove on the inner surface near the umbo. The exterior sculpture consists of numerous, more than 30, sharp concentric ridges, which are pronounced also on the interior surface. They pass obliquely on to the rostrum where, however, they become less defined and are evident only as a set of fine indefinite anastomosing ribbings. The main concentric ridges are marked by secondary lines, and the intervals between them by fine growth lines. Colour, dull white. Antero-posterior length, 38 mm.; umbo-ventral length, 23 mm.

This specimen was forwarded to the Adelaide Museum where Mr. B. C. Cotton identified it with a species he has described from off Eucla. The present specimen is considerably larger than his type which, moreover, has only 24 concentric ridges.

Class GASTROPODA.

Order PECTINIBRANCHIA.

Family **CYPRAEIDAE**.

Zoila friendii (Gray).

Zoila friendii has been taken by local collectors between Cottesloe and Cape Naturaliste; but is known from Esperance and, extra-limitally, from Java. The securing of a specimen so far to the east is of interest. It was not taken in the haul under review, but Captain Claxton preserved a shell from a previous haul in 75 fathoms. It was a small specimen 51 mm. long, with the brown markings mainly developed in a restricted zone on the dorsal surface, most of the shell being a creamy white, a character, no doubt, due to its deeper water habitat. The three species, *Z. decipiens* from the North-West, *Z. friendii* from the South-West coast, and *Z. thersites* from South Australia and the Bight, are very much alike, and hitherto it was considered that their ranges were distinct.

Zoila thersites (Gsk.)

Cypraea thersites Gaskoin, Proc. Zool. Soc., 1848, p. 90.
Verco, Trans. Roy. Soc. S.A., vol. xxxvi, 1912, p. 209

Zoila thersites contraria Iredale, Austr. Zool., 1935, vol. 8, p. 107.

One specimen was trawled alive but there was a collection of five more specimens on board, all obtained alive on previous cruises. The entire series was pallid in the extreme, the shells being almost devoid of any colouration. Four of the examples were solid, fairly old mature shells, three of them having the spire almost wholly enclosed. The two remaining ones were light young shells with a distinct orange-coloured spire. The smaller, 60 mm. long, was of a delicate blue-grey tint with two medial transverse darker bands of pale orange-buff. One of the more mature shells also possessed these pale buff bands on a whitish ground, with orange spots around the borders and the extremities of the shell. In the others the spots were of a brown colour and were dotted generally over the shell, forming an ill-defined zone in the region which the dark bands occupied in the young shells. These more massive shells were from 69 to 82 mm. in length. Plate IV. shows one of the shells contrasted with a normally pigmented specimen, richly marbled with deep brown and chestnut, from St. Vincent Gulf, South Australia. The pigmented shell was quite opaque to light, the deep-water ones being translucent. Until Sir Joseph Verco collected his specimens at depth in the western Bight the species was unknown beyond St. Vincent and Spencer Gulfs. Iredale recently described these forms as a new sub-species, *Z. t. contraria*, characterised by their "sub-adult appearance and whitish colouration."

Family **TONNIDAE**.

Tonna variegata (Lam.).

The shell is pale and rather sparingly ornamented with chestnut spots. It contained a hermit crab.

Family **FUSIDAE**.

Verconella oligostira (Tate).

The single specimen, tenanted by a hermit crab, agrees well with Verco's description of the examples he collected (*1912*, p. 221), being markedly angulated with comparatively sharply pointed coronating tubercles. The spiral cords are well indicated but the longitudinal striae are not so apparent as in other specimens examined by the writer from the South-West coast. The interior is a polished flesh colour.

Family **VOLUTIDAE**.

Ericusa fulgetrum (Sowerby).

The example collected did not possess any axial zig-zag markings. Verco remarked that the shells he obtained from this area were all dead specimens and tenanted by hermit crabs, as was the case with the present specimen.

Livonia roadnightae (McCoy).

This single specimen, which was occupied by a hermit crab, is without colour. Two live shells, collected by the late H. C. Dannevig, in 100 fathoms, and referred to by Verco, are almost albino varieties.

Cymbiola nodiplicata (Cox).

Voluta nodiplicata Cox, Proc. Malac. Soc., ix, 1910, p. 146.

Scaphella dannevigi Verco, l.c., p. 224.

Cymbiola nodiplicata, Hedley, Journ. Roy. Soc. W.A., vol. i, 1916, p. 201.

Sir Joseph Verco collected nine examples 90 miles west of Eucla and described them as a new species, *Scaphella dannevigi*, which Hedley has relegated to the synonymy of Cox's species, described from Rottnest Is. The *Bonthorpe* specimen agrees with Verco's description and plate, and like his type it has lost the protoconch. It was tenanted by a hermit crab.

Cymbium flammeum (Bolten).

The specimen measures 19·2 cm. in length and has only three columellar plaits, agreeing both in size and the number of plaits with the third of Verco's *Endeavour* examples, his others being smaller shells with four plaits. A large hermit crab occupied the shell.

4. CRUSTACEA DECAPODA.

Seven species of Decapod Crustacea were contained in the *Bonthorpe* collection, one being an addition to the Bight fauna and others representing species which have not been taken other than by the *Endeavour*.

Order DECAPODA.

Sub-Order NATANTIA.

Tribe CARIDEA.

Family **RHYNCHOCINETIDAE**.

Rhynchocinetes rugulosus Stimpson.

Rhynchocinetes rugulosus Stimpson, Proc. Acad. Sci. Philadelphia, vol. xii, 1860, p. 36.

Kemp, Rec. Ind. Mus., vol. xxvii, 1925, p. 263.
Gordon, Proc. Zool. Soc. Lond., 1936, pt. i, p. 75.

A single specimen was found, the first record for south-western Australian seas. It measured 34·5 mm. There were two teeth on the carapace behind the rostral articulation, with four teeth on the upper border of the rostrum near the tip and ten on the lower border. There was a prominent supra-orbital spine and the cuticle was conspicuously striated. Later, in February, 1932, a second Western Australian specimen was collected in shallow water at Triggs Is., 10 miles north of Fremantle and sent to the W.A. Museum by the finder. It measured 61 mm. and had eleven teeth on the ventral border of the rostrum. Neither of the specimens was dissected.

Sub-Order REPTANTIA.

Section ANOMURA.

Family **PAGURIDAE.**

Dardanus arrosor Herbst.

Hermit crabs were abundant in the haul, all of the empty gastropod shells trawled up being tenanted by a specimen. Only the one species occurred, represented by six examples collected. The fact that no uninhabited shells were secured suggests that the gastropod fauna may be a limiting factor in the number of Pagurids.

Section BRACHYURA.

Family **INACHIDAE.**

Leptomithrax globifer Rathbun.

Leptomithrax globifer Rathbun, Biol. Res. *Endeavour*, vol. v, 1918, p. 25.

Captain Claxton preserved a specimen trawled in 75 fathoms in December, 1929. It was from approximately the same area that the type specimens described by Dr. Rathbun were taken by the *Endeavour*. The species has not otherwise been collected.

Family **PORTUNIDAE.**

Nectocarcinus tuberculosus (A. Milne-Edwards).

One ovigerous female; carapace 28 mm. long by 36 mm. broad from spine to spine.

Thalamita sima M. Edw.

One specimen of this widely distributed species was obtained. The diameter of the egg is ·43 mm. The dimensions of the specimen are 35 mm. wide by 28 mm. long.

Family **XANTHIDAE.**

Pilumnus rufopunctatus Stimpson

Pilumnus rufopunctatus Stimpson, Proc. Acad. Sci. Phil., x, 1858, p. 36.

Rathbun, Biol. Res. *Endeavour*, vol. v, 1923, p. 115.

This and the following species were very abundant in the haul. The largest specimen measured 21 mm. in length and 23 mm. in width. The ova of this species are ·55–·64 mm. in diameter.

Pilumnus acer Rathbun.

Pilumnus acer Rathbun, Biol. Res. *Endeavour*, vol. v, 1923, p. 124.

Several specimens of this species were taken, the dimensions of the carapace of the largest being 21 mm. long by 28 mm. wide (with spines). The specimens compare satisfactorily with Miss Rathbun's description. The ova are much larger than those of the preceding species and fewer in number, being 1·52 1·65 mm. in diameter.

5. ECHINODERMATA.

By E. W. Bennett, M.Sc.

The Echinoderms in the collection include seven species. There are four specimens of an Ophiuroid, and one each of two species of Holothurians. They are not dealt with here, but have been forwarded intact to Dr. H. L. Clark, of Harvard, who is engaged in a study of Echinoderms recently collected in this State, and who, moreover, is already familiar with the deep-water Echinoderms secured by the *Endeavour* in the Great Australian Bight and elsewhere. There are nine Asteroids in the collection, representing four species; specimens have also been forwarded to Dr. Clark for confirmation.

The Asteroids include nothing new, unless the specimen of *Pseudophidiaster* merits separation. The species were otherwise all secured by the *Endeavour* but two were not collected before or since that expedition.

Class ASTEROIDEA.

Family GONIASTERIDAE.

Nectria ocellata Perrier.

Nectria ocellata Perrier, Archiv. de Zool. exp. et gén., V., 1876, p. 4.
Clark, Biol. Res. *Endeavour*, vol. IV, 1916, p. 34.
Rec. S.A. Mus., vol. III, 1928, p. 378.

Four specimens of average size. Clark compares the largest and smallest of his series of 22 specimens and states that the number of paxilliform ossicles does not increase, but that in the large specimen are so widely separated that the abactinal skeleton and papular areas are fully exposed. The present specimens form a well-graded series, which indicates scarcely any increase in the number of ossicles, but, nevertheless, a distal expansion of the ossicles, which more than keeps pace with the general growth. The paxillae are fully exposed in the smaller specimen, but hidden in the larger. The base of the pedicel does not grow proportionately and the papular areas are considerable in the large specimen. There is also disagreement with the figures quoted in the artificial key (Clark, 1928, p. 379) where R : r is said to be 2·5 - 3. In the largest specimen, R 49, r 3·5; in the smallest, R = 80, r 21, R : r = 3·8.

Family OREASTERIDAE.

Asterodiscus truncatus Coleman.

Asterodiscus truncatus Coleman, Mem. Aust. Mus., vol. IV, 1911, p. 699.
Clark, Biol. Res. *Endeavour*, vol. IV, 1916, p. 50.

Two specimens, agreeing well with Coleman's description and figures. R = 83, r = 34, R · r = 2·44 (regular); R 67 - 63, r 24 - 25, R : r = 2·8 — 2·5 (irregular).

Family LINCKIDAE.

Pseudophidiaster rhysus Clark.

Pseudophidiaster rhysus Clark, p. 54.

One specimen. R = 114 — 122, r = 17, R : r = 6·7 — 7·2. The granules become suddenly coarser between the ambulacral grooves and the first (actinal) row of papular areas, and still larger towards the jaws, but there are always at least 10 per sq. mm. Those of the dorsal surface almost uniformly small, about 60 per sq. mm., except around the periproct, which in the dried specimen is deeply sunken. Four upper series of papular areas very irregular on distal half of arm. Ambulacrals almost invariably with three equal spines. Sub-terminal ambulacral spines represented only by flat granules, but 27 conspicuous and projecting spines of varying length around the mouth, 4 — 8 in each angle. Pedicellariae apparently confined to ventral surface of disc, in a straight but broken series, 0 — 6 along each row of ambulacral plates, total about 30.

Colour: alive, dark purple; dried, pale dingy fawn.

There are slight but distinct differences from the specimens from 80—120 fathoms in the Bight, for which Clark founded the species and genus, and the verification of the specific identity of the species may be awaited with interest.

Family ECHINASTERIDAE.

Plectaster decanus (Muller & Troschel).

Echinaster decanus Muller & Troschel, Archiv. f. Naturg., IX, 1843, p. 114.

Plectaster decanus Clark, Biol. Res. *Endeavour*, vol. IV, 1916, p. 66; Rec. S.A. Mus., vol. III, 1928, p. 397.

Two specimens. R = 105, r = 31, R : r = 3·4; R = 52 — 63, r = 17 — 19, R : r = 3·1 — 3·3 (variable). In Clark's specimens R : r = 4·3, so that in the present series, which were preserved in neutral formalin and after about a week were dried out of corrosive formalin, the disc appears less shrunken.

Colour, alive, red and purple, in patches.

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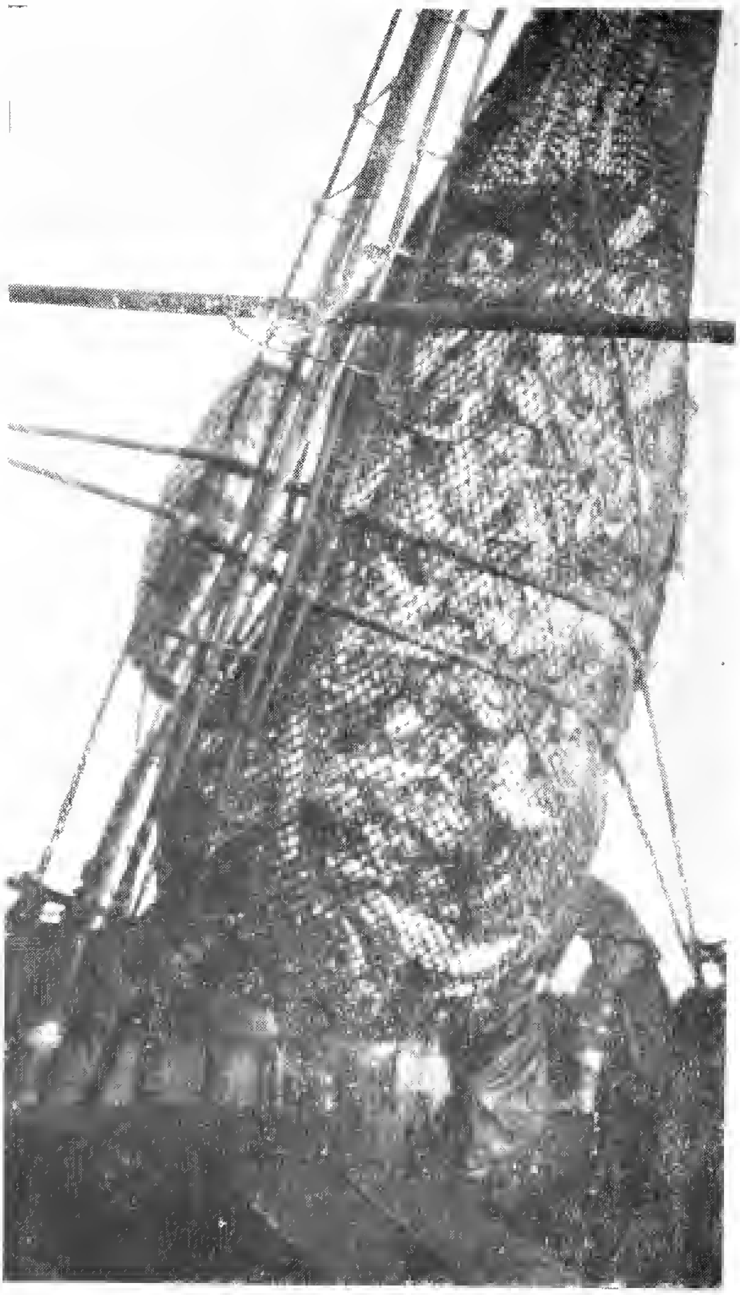

PLATE I.

The cod-end of the net containing the haul forming the subject of the present report. The stooping figure of the man on the right furnishes a standard for the estimation of size.

Photo: D. L. Serventy.

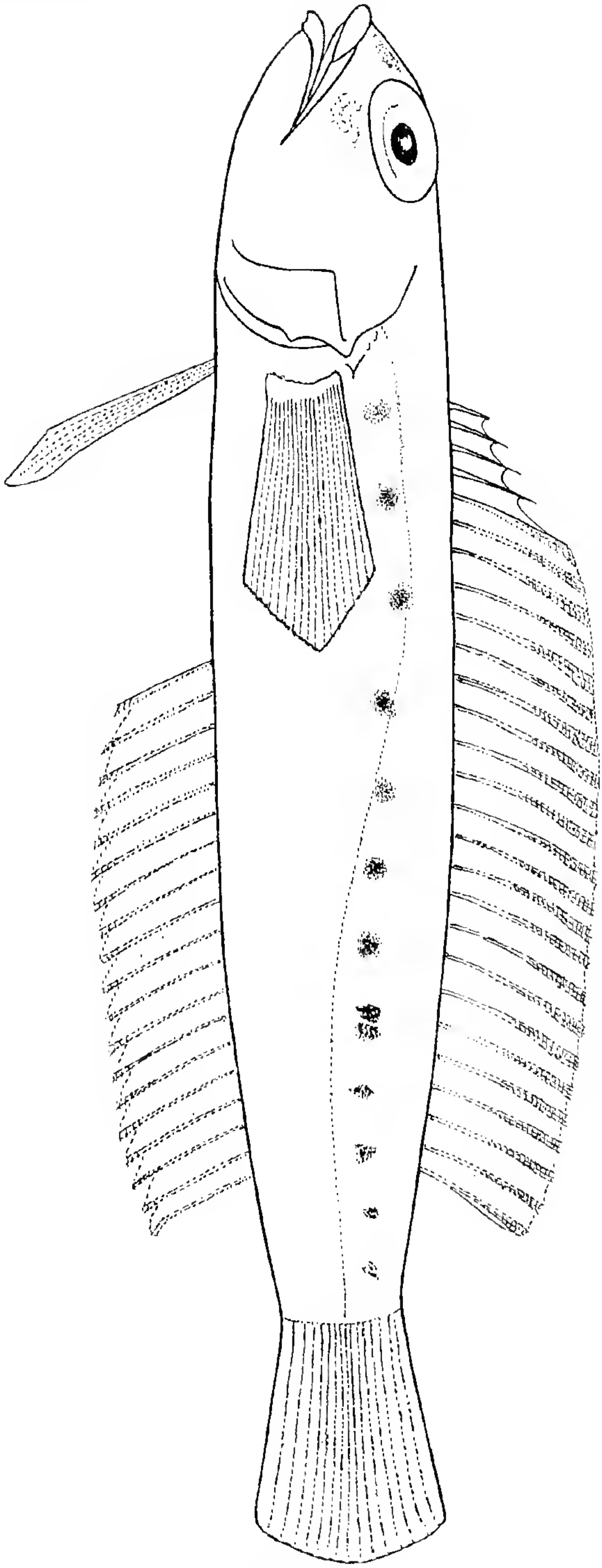

PLATE II.

Parapercis nacrosa, sp. nov., × 1.65

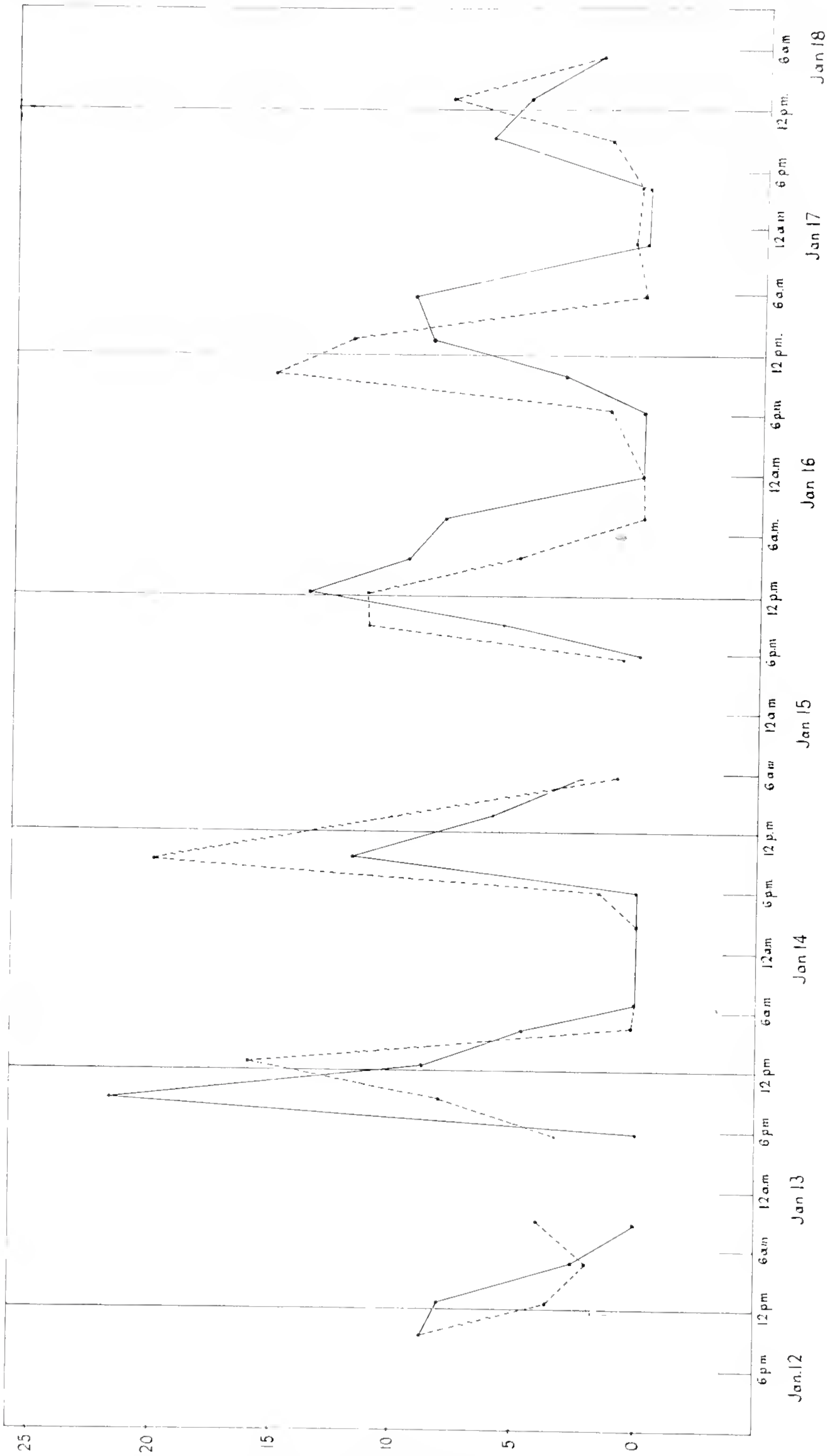

PLATE III.

Catches of Nannygai (full line) and Flathead (broken line) by the trawler *Boulthorpe*, January 12–18, 1930, between 70 and 75 fathoms. The vertical scale shows the number of baskets of fish obtained during two hours of trawling, the values being plotted along the horizontal scale at the mid-points of the trawling periods.

PLATE IV.

Pallid and pigmented specimens of *Zoila thersites*. The shell on the left is from the *Bonthorpe* collection, and that on the right from St. Vincent Gulf.

Photo: H. J. Smith.

7.—THE SUSPENSOR AND EMBRYO OF ACTINO-STROBUS

BY ALISON M. BAIRD, B.Sc.

Read 8th June, 1937; Published 1st November, 1937.

The life history of *Actinostrobus pyramidalis* was described by Saxton (1913), his work being based on paraffin sections of material sent from Western Australia, but it seemed that many details of suspensor and embryo development could be more satisfactorily determined by dissection of fresh material. For this account both species of *Actinostrobus* were examined in this way.

As material of both species has been collected from plants growing in their natural habitats a few notes on the development of cones in the field are given. *A. pyramidalis* was obtained from swamps (which are dry in summer), in the neighbourhood of Perth and *A. acuminatus* from sandplains between Watheroo and Geraldton.

The period of development is long with marked resting stages associated with the summer drought. It was found that actually fourteen to fifteen months elapse between pollination and fertilisation, not three as stated by Saxton, a mistake which could be very easily made if one had not seen the plants in the field. In *A. pyramidalis* young female cones are distinguishable in December, remain very small through the summer and are found open for pollination the following July. Male cones are also visible early in December with the pollen shedding in July and August. The pollinated cones close and enlarge during the spring (September-November). There is little further development before the next winter rains. In June the sporophylls are scarcely projecting above the scales at the base of the cone and the embryosac is still minute. July to September the cones enlarge and the embryosac, still in free nuclear condition, extends to the base of the nucellus. Wall formation takes place in September, about a month before fertilisation which occurs in most plants about the second or third week in October. Embryos with long suspensors are found through November, and the embryo reaches its full size early in December by which time the cones are full size and the testa hard and brown. Cones may remain on the tree for several years before opening. In *A. acuminatus* pollen is shed about the middle of May—2 months earlier than in *A. pyramidalis.* Fertilization occurs about the end of October of the following year, so that the interval between pollination and fertilization is 17 months.

Pollination drops are formed in both species.

For this investigation fresh ovules were dissected in water under a binocular dissecting microscope. The stage of development of the embryos can be judged as soon as the prothallus is removed from the nucellus. Very young embryos show as a darker spot in the clear uniform prothallus, while after the suspensors have elongated a distinct cavity is visible, showing their position. Later stages are indicated by the collapse of the upper part of the prothallus and tho presence of starch in the lower part which is also much broador than in early stages; the whole ovule enlarging to fully twice its size at the time of fertilization.

Camera lucida drawings were made immediately while the embryos were still turgid and unplasmolysed. This method was found much more satisfactory than fixing and mounting the very delicate thin walled suspensors. Methylene blue was used occasionally to show up the nuclei in the embryo. All drawings show surface views of the embryos.

The development of suspensor and embryo was found to be essentially the same for the two species, so that except where specific differences are mentioned the following account applies to the genus.

The archegonia are lateral and deep seated in the narrow prothallus in one or two groups according to the number of pollen tubes. Two adjacent archegonia are fertilised from each tube. The proembryo as described by Saxton fills the Archegonium, the arrangement of the cells being variable and not in definite tiers.

At the earliest stage at which embryos are recognisable a group of minute cells with dense contents can be seen at the lower end of the archegonial complex. Each of these embryonic units consists of a suspensor cell and a much smaller embryonic cell. Four of these are formed from each zygote and the remaining few cells in the upper part of the proembryo disappear very early. There is no elongation of any region of the proembryo as a whole. Fig. 1 shows a proembryo as dissected from the prothallus. A certain amount of disturbance of the embryo initials is unavoidable in dissection but it has been confirmed by sections that there is no definite arrangement of the embryo initials. The small embryonic cells point in various directions. A certain amount of breakdown occurs even before any appreciable elongation of the suspensors. The embryos at the stage shown in Fig. 2 float out freely when the prothallus is dissected under water. Figs. 3 and 4 show typical embryo systems after the suspensors have begun to elongate. The large suspensor nucleus lies embedded in cytoplasm near the lower end while the upper part of the suspensor contains little or no cytoplasm. Starch is occasionally present round the nucleus but it is not a regular condition as in *Callitris*.

The suspensors are long and slender, of uniform diameter except for a slight enlargement at the upper end. The wall is thin in comparison with that in *Callitris*. The central tissue of the upper part of the prothallus has, by this time, broken down to form a cavity in which lie the coiled and folded upper portions of the suspensors. The embryonic cells are embedded in the firmer tissue below the cavity. Fig. 3 shows the lower part of the embryo as it is in the ovule. There are usually 2–5 suspensors with straight ends deeply buried in the prothallus and several shorter ones ending in the region of the suspensor coils. Occasionally a suspensor is found growing through the megaspore membrane. Suspensors with balloon-like enlargements of the ends occur in some ovules. These are usually among the shorter suspensors and always bear somewhat crushed and deformed embryos. It seems reasonably certain they never contribute the final embryo. The usual number of embryos per ovule is 8–16 according to the number of pollen tubes.

Some of the suspensors may collapse even before the first division of the embryonic cell. In the group shown in Fig. 5 all except three have collapsed. Disappearance of some of the suspensors may take place at almost any stage of development. As would be expected it is the shorter suspensors (and upper embryos) which collapse first, and it is invariably one of the embryos with long straight ends to the suspensors, usually the terminal one, which ultimately persists.

The first division of the embryonic cell probably takes place when the suspensors are about half their final length, but as the length of the suspensors differs very greatly in different cones this is difficult to determine. There is no thick inner wall round the embryonic cell as in *Biota* (1921). The first two walls are vertical, giving a tier of four cells. The next are more or less horizontal, and later ones very irregular. The walls are frequently oblique (cf. Figs. 7 and 8). Some embryos at early multicelluar stages are shown in Figs. 6–9. It can be seen that at no time is there growth from a single recognisable apical cell. Divisions take place in all of the primary quadrants.

When a considerable group of cells has been formed—the number varying within wide limits—the upper cells elongate to form embryonal tubes. Figs. 10–13 show embryos at this stage and also at slightly later stages. Figs. 11 and 12 indicate the variation in size of embryos when embryonal tubes begin to form. Both of these are terminal embryos of the same species (*A. acuminatus*) at the same scale, from different ovules. In general, upper embryos form embryonal tubes when there are far fewer cells in the embryo, but these rarely develop further. There is great variation in the number and size of cells, position of walls and relative size of suspensor and embryo. The variation within the species is too great to provide any significant difference between the species.

Following the initiation of the secondary suspensors by embryonal tubes, growth of the embryo is very rapid; repeated cell divisions giving a massive multicellular structure. An embryo system of *A. pyramidalis* with secondary suspensors in shown in Fig. 14. This also shows the enlargement of the lower end of the suspensor which is common at this stage.

In *A. acuminatus* the suspensor becomes considerably longer than it does in *A. pyramidalis*. A typical secondary suspensor of *A. acuminatus* is shown in Fig. 15, and one of *A. pyramidalis* about the same age in Fig. 16. Another difference between the species is shown at this stage in relative degrees of development of the several embryos of a group. In *A. pyramidalis* several may develop secondary suspensors (Fig. 14); in *A. acuminatus* no case has been seen where more than one embryo passed the early embryonal stage and the upper embryos often remain in the 1 to 4-celled condition.

The number of cells in the embryo continues to increase and the apex becomes smoothly rounded. Cotyledons show first as slight protuberances at the sides of the mass of small cells. Figs. 17, 18, and 19 show the developing cotyledons. It is obvious that the stem apex is conspicuous from the start and is only buried as the cotyledons approach maturity. The number of cotyledons is two, but one embryo has been found in which there were three, equally developed. In *Widdringtonia* this condition is apparently more frequent.

CONCLUSION AND DISCUSSION.

The embryology of *Actinostrobus* agrees in all essentials with that of *Callitris* (an account of which is appearing in another paper). From Saxton's work and from dissections which I have made of fairly late stages from material of *Widdringtonia cuppressoides* (kindly sent by Mr. Saxton), there is apparently a close agreement with *Widdringtonia* also.

These three genera differ, therefore, from all others so far described, in the complete absence of a prosuspensor, lending further support to the view that the Callitroideae are a natural group distinct from the rest of the Cuppressaceae. The present investigations, however, indicate that the affinities of the Callitroideae are with the Cuppressineae rather than the Taxodineae. The embryo initials forming the bulk of the proembryo in *Actinostrobus* and *Callitris* appear to be the direct equivalent of the group of cells on the end of the prosuspensor in *Biota*, *Chaemycyparis*, etc., and the later development of the primary and secondary suspensors is very similar to that figured by Buchholz for *Chaemycyparis* (1932). The type of embryology that occurs in *Actinostrobus* could be derived from that of *Chaemycyparis* by complete suppression of the prosuspensor and earlier division of the embryo initials. That this is not an unreasonable supposition is indicated by the case of *Sciadopitys* (1931), where, although the normal prosuspensor becomes very long, in rare instances it may completely fail to elongate. The suppression of the prosuspensor and the elimination of practically all the proembryo, except the embryonic and primary suspensor cells, is probably related to the small size of the archegonia, the absence of a nutritive jacket layer and the position of the proembryo deeply sunken in the small prothallus. In *Taxodium*, *Cryptomeria* (1932a), and *Arthrotaxis* it is the primary suspensors which are absent, the embryos developing directly on the ends of the prosuspensor strands.

SUMMARY.

The suspensor and embryo are described for both species of Actinostrobus.

Cleavage polyembryony is a constant feature, four embryos being formed from each zygote.

There is no structure comparable to the prosuspensor of other genera of the Cupressaceae.

Primary suspensors become free from each other early, elongate greatly, and lie coiled in a cavity formed by breakdown of tissue in the upper part of the prothallus.

The first two divisions of the embryonic cell are vertical, the next horizontal.

A massive secondary suspensor is formed which is multicellular from the start.

The mature embryo has two cotyledons. The stem apex is conspicuous between the developing cotyledons.

The embryology of Actinostrobus agrees with that of Callitris and Widdringtonia, but is different from that of any other Conifer so far described.

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EXPLANATION OF FIGURES.

Fig. 1.—Small embryos still adhering to upper part of proembryo. X 140.

Fig. 2.—Young embryo in optical section showing details of suspensor and embryonic cells. X 140.

Fig. 3.—An embryo system of A. acuminatus at the 1-celled stage. X 25.

Fig. 4.—A pyramidalis—same. X 25.

Fig. 5.—A. acuminatus. A system with embryos at 2-celled stage, some suspensors collapsed. X 25.

Fig. 6.—4-celled embryo. X 130.

Figs. 7 and 8.—16-celled embryos. X 130.

Fig. 9.—Terminal embryos of a gp., centre one 8-celled.

Fig. 10.—Embryonal tubes just forming. A pyramidalis.

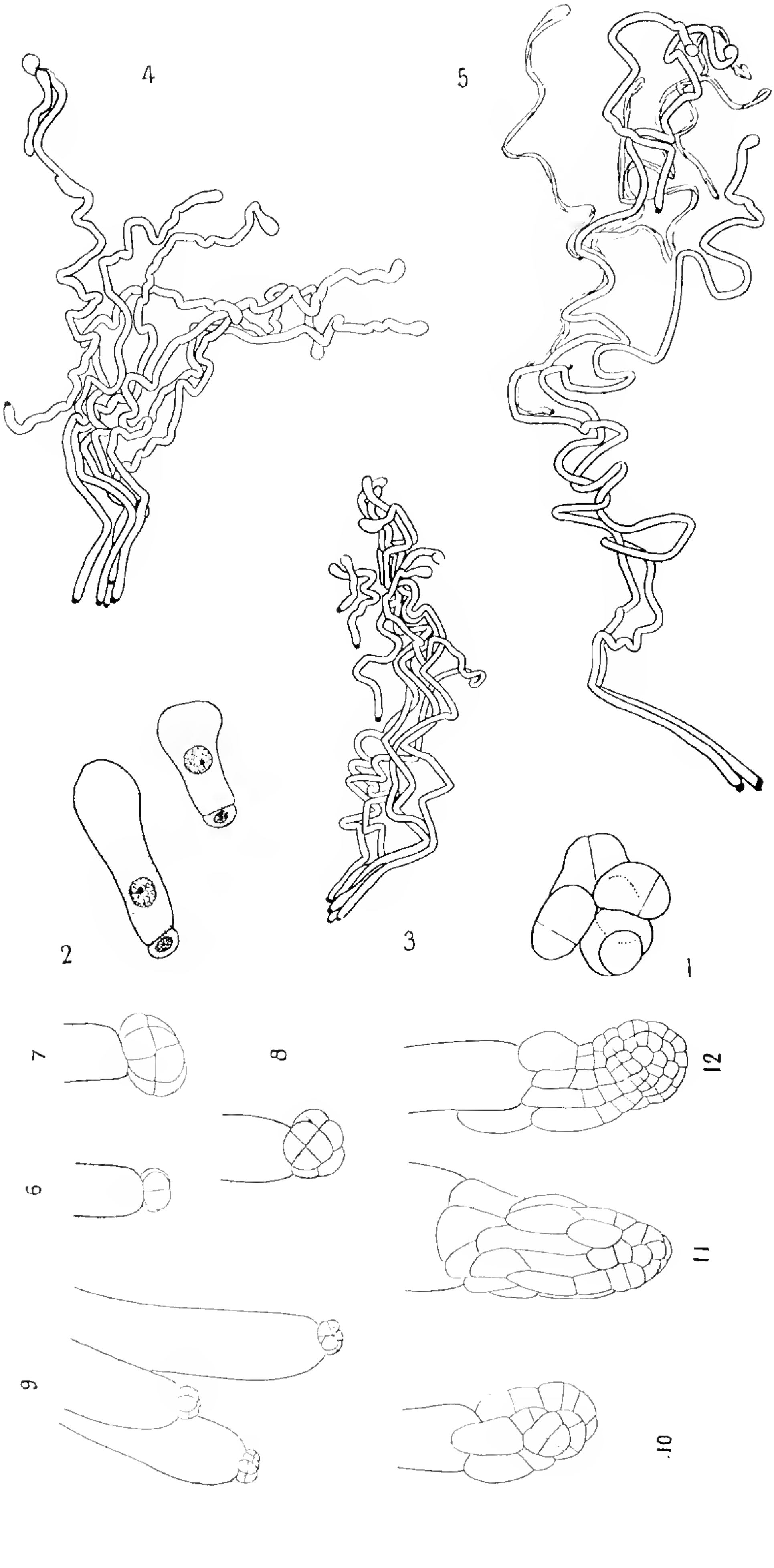
Figs. 11 and 12.—2 Embryos of A. acuminatus at a later stage. X 130.

Fig. 13.—Early secondary suspensor stage. A. acuminatus. X 65.

Fig. 14.—Group showing primary and secondary suspensors—A pryamidalis. X 30.

Figs. 15 and 16.—Fully developed secondary suspensors of A. acuminatus and A. pyramidalis.

Figs. 17–19.—Stages showing the development of the cotyledons A. acuminatus. Figs. 17 and 18 X 17. Fig. 19 X 8.5.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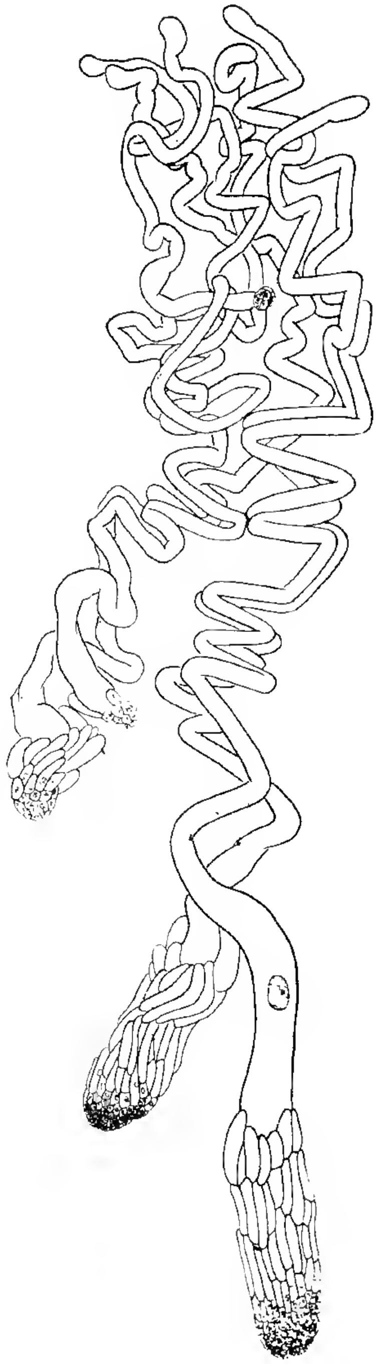

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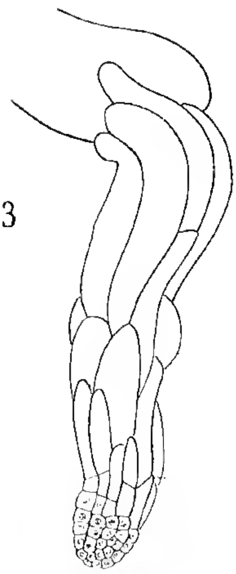

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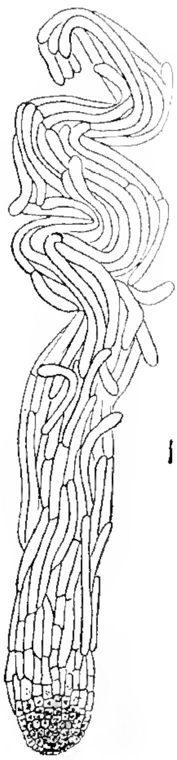

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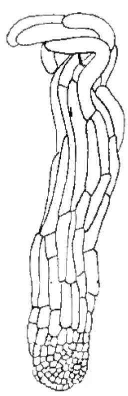

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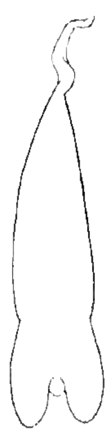

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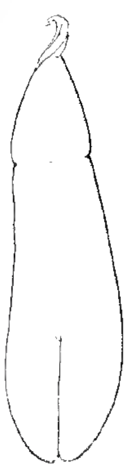

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GENERAL INDEX.

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