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The Authors of Papers are alone responsible for the statements
and
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THE ROYAL SOCIETY OF WESTERN AUSTRALIA, INC.

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VOLUME XXVII.

The Royal Society of Western Australia (Inc.).

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDING 30TH JUNE, 1941.

Ladies and Gentlemen,

Your Council begs to submit the following report for the year ended 30th June, 1941.

Council.—The Council of the Royal Society met on five occasions and the Executive Committee on six occasions. As in previous years an Executive Committee was appointed to deal with the routine business.

Finance.—The General Fund shows a balance of £135 16s. 3d. The Endowment Fund now amounts to £245. It may be noted that the cost of the steel library shelving purchased by the Society for installation in the Gledden Building was met by the Endowment Fund. The surplus of assets over liabilities now amounts to £507. Volume XXVI. has not yet been completely paid for, so that there are certain commitments to the Government Printer against the General Fund.

The very satisfactory condition of the Society's finances are due to the very able management of the Honorary Treasurer, Dr. E. M. Watson. Dr. Watson retires from the office of Hon. Treasurer to become a Vice-President of the Society and the Council wishes to express their thanks for his services as Treasurer during the past four years.

Membership.—There has been a slight increase in membership of the Society during the year. Four ordinary members and one associate have resigned and two associates have transferred their membership—one to ordinary and the other to corresponding membership. The names of four associates have been removed from the register in accordance with Rule 6.

Members elected during the year include ten ordinary members and three associates.

There are at present 154 members of the Society, made up as follows:—

Honorary Members	7
Corresponding Members	8
Life Member	1
Ordinary Members	98
Associate Members	35
Student Members	5

Journal.—Volume XXVI. has been completed and is at present being distributed to members and scientific institutions with which the Society is in exchange.

During the year twenty papers were presented to the Society for publication in the Journal. Fourteen of these are already in the hands of the Government Printer.

Mr. Southern remains in the office of Hon. Editor and the Society is indebted to him for continuing to place his experience in this work at its disposal. The Council also desires to thank the Government Printer and his staff for their co-operation with the Hon. Editor in connection with the publication of the Journal.

Library.—The Library is now housed in the Professional Societies' Rooms at the Gledden Building, where it forms a distinct section of the combined Library of the various Professional Societies. During the year new steel shelving to conform with that in the Gledden Building Library was purchased by the Society from the Endowment Fund.

The Society has now entered into exchange of publications with a total of 184 scientific institutions, of which 54 are in Australia, 16 in the United Kingdom, 23 in other parts of the British Empire, 46 in North and South America, 42 in Europe, and three in Asia.

The Council wishes to express its thanks to Mr. A. Gibb Maitland for a number of donations to the Society's Library made during the past year.

Housing of the Society.—Early in the present year arrangements were finalised with the Institution of Engineers, and the Royal Society has since been housed, along with the other Professional Societies, in the Gledden Building. In addition to the improved meeting room, members will benefit by this change, as they will now be able to refer to volumes in the libraries of the various other Professional Societies.

Award of the Medal of the Royal Society of W.A.—The award for 1940–41 was made to Professor E. de C. Clarke, M.A., for his work in connection with the geology of Western Australia. The medal will be presented to him later this evening by His Excellency the Lieutenant-Governor, Sir James Mitchell.

Programmes for General Meetings.—The Council has endeavoured, during the past year, to present at the monthly meetings programmes which contain some variety of interest for the different sciences. In addition to the record number of original research papers, communicated talks of general interest to members have been arranged for nearly every meeting.

A. D. ROSS,
President.

REX T. PRIDER.
C. H. F. JENKINS,
Joint Hon. Secretaries.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA, INCORPORATED—*Statement of Receipts and Payments for the Year ended 30th June, 1941.*

Receipts.	£ s. d.	£ s. d.	*Payments.*	£ s. d.	£ s. d.
General Fund—			Petty Expenses, including Postage, etc.		8 16 6
Balance at 1st July, 1940		105 4 5	Clerical Assistance		2 12 0
Interest, 1939-40		2 3 6	Rent—Institution of Engineers		30 0 0
Subscriptions		113 7 3	Meetings—Catering		10 5 0
Transfer from Life Membership Fund		1 0 0	Library—Bookbinding		2 15 0
Interest from Life Membership Fund		0 10 0	Government Printer—Vol. XXVI., Printing	117 15 0	
Government Grant		100 0 0	,, Blocks	28 2 6	
Authors' Reprints and Half Cost of Blocks		51 6 10	Miscellaneous Printing	5 1 3	
Sale of Shelving		10 0 0			150 18 9
Other Receipts		13 18 9	Editor's Honorarium		15 15 0
			Transfer to Endowment Fund		39 9 11
			Other Payments		1 2 4
			Balance at 30th June, 1941		135 16 3
		£397 10 9			£397 10 9
Medal Fund—					
Balance at 1st July, 1940		20 3 8			
Interest, 1939-40		8 0	Balance at 30th June, 1941		20 11 8
		£20 11 8			£20 11 8
Endowment Fund—			Library Shelving		90 19 11
Balance at 1st July, 1940		290 15 0	Balance at 30th June, 1941—		
Interest—Fixed Deposit	15 0		War Saving Certificates	205 0 0	
War Saving Certificates	5 0 0		1956 War Loan	40 0 0	
		5 15 0			245 0 0
Transfer from General Fund		39 9 11			
		£335 19 11			£335 19 11
Life Membership Fund—			Transfer to General Fund		1 0 0
Balance at 1st July, 1940		20 0 0	Balance at 30th June, 1941		19 0 0
		£20 0 0			£20 0 0

Note.—£19 placed on fixed deposit at Commonwealth Bank, Perth, on 30th April, 1941, for 12 months, bearing interest at 2¼% per annum.

Balance Sheet as at 30th June, 1941.

Liabilities.	£ s. d.	*Assets.*	£ s. d.	£ s. d.
Subscriptions, etc., paid in advance	7 15 6	Cash at Bank—General Fund	135 16 3	
Amounts owing	2 9 6	Medal Fund	20 11 8	
Investment—Life Membership Fund	19 0 0			156 7 11
Surplus of Assets over Liabilities	507 0 3½	Petty cash in hand		1 12 3½
		Subscriptions, etc., in arrears		23 5 2
		Investments—War Saving Certificates	205 0 0	
		1956 War Loan	40 0 0	
		Fixed Deposit, Commonwealth Bank	19 0 0	
				264 0 0
		Library Shelving		90 19 11
	£536 5 3½			£536 5 3½

Audited and found in agreement with books, receipts, and vouchers produced.

E. M. WATSON, Hon. Treasurer.

1st July, 1941.

We consider this to be a true statement of the Royal Society's Accounts.

J. SHEARER,
W. F. COLE,

ABSTRACT OF PROCEEDINGS, 1940–1941.

9th July, 1940—

Annual General Meeting in Gledden Hall. Presidential Address: "The Ceramic Resources of South-Western Australia" by Mr. H. Bowley.

13th August, 1940—

Papers—"Further Permian Corals from Western Australia." Dr. Dorothy Hill, communicated by Dr. C. Teichert.

"The Results of a Microscopical Examination of Some Soil Colloids." Mr. W. F. Cole.

"The Granite-Cardup Series Contact at Armadale." Dr. R. T. Prider.

10th September, 1940—

Paper—"Some Kyanite-bearing Rocks from the Eastern Goldfields, Western Australia." Mr. K. R. Miles.

Talks—"His life work in Ornithology." Mr. Gregory Mathews.

"Criticism of Motor Head-lights Regulations illustrated with Models and Demonstrations." Professor A. D. Ross.

8th October, 1940—

Papers—"Permian Productinae and Strophalosiinae of Western Australia." Dr. K. Prendergast, communicated by Professor E. de C. Clarke.

"New Forms of Western Australian Birds." Mr. Gregory Mathews, communicated by Mr. Glauert.

Talks—"Chemistry of Strategic Materials." Professor N. S. Bayliss.

"The Habits of the Mallee Fowl." Mr. F. Lewis.

12th November, 1940—

Papers—"A Note on Fossil Corals from Langley Park Bore, Perth." Dr. J. W. Wells, communicated by Dr. Dorothy Carroll.

"Some Basalts from the North Kimberley." Dr. A. B. Edwards, communicated by Professor E. de C. Clarke.

Talk—"Some Phases of the Work of the Commonwealth X-ray and Radium Laboratory." Dr. C. E. Eddy.

10th December, 1940—

Paper—"Foraminifera and a Tubicolous Worm from the Permian of the North-Western Division of Western Australia." Mr. W. J. Parr, communicated by Dr. R. T. Prider.

Talks—"Night Photography." Mr. B. L. Southern.

"The Work of the Perth Observatory." Mr. H. S. Spigl.

11th March, 1941—

Papers—"Notes on the Vegetation of the North-Eastern Goldfields." Miss N. Burbidge.

"Contributiones Florae Australiae Occidentalis, No. XI." Mr. C. A. Gardner.

"Seeds of *Strychnos lucida* and their Alkaloid Content." Dr. E. M. Watson.

Talk—"The History and Development of King's Park." Mr. J. E. Watson.

8th April, 1941—

Papers—"Beraunite from Dandaragan." Mr. C. R. Le Mesurier.

"Marine Copepods from Western Australia, Part I." Dr. A. G. Nicholls.

"New Leaf-Hoppers (Homoptera Jassoidea) from Western Australia." Dr. J. W. Evans, communicated by Mr. C. F. H. Jenkins.

Talk—"Development of Western Australian Fisheries." Dr. A. G. Nicholls.

Exhibits—Mr. L. Glauert exhibited three rare specimens of Cirripedes or Barnacles, *Lepas fascicularis* Ellis and Solander, from Albany together with *Poecilasma fissa* Darwin and *Alepas tubulosa* (Quoy and Gaimard) found on crayfish *Panulirus longipes* A.M. Ed. caught at Houtman's Abrolhos. All are additions to the Western Australian list.

13TH MAY, 1941—

Paper—"Mineralogy of the Donnybrook Sandstone." Dr. Dorothy Carroll.

Talk—"Artificial Radio-activity and some Applications." Mr. J. L. Farrant.

10TH JUNE, 1941—

Papers—"The Geology and Physiography of the Gosnells Area." Mr. C. E. S. Davis.

"The Geology and Physiography of the Wongong-Cardup Area." Mr. B. P. Thompson, communicated by Dr. R. T. Prider.

"X-ray Analysis (by the powder method) and Microscopic Examination of the Weathering Products of the Gingin Upper Greensand." Mr. W. F. Cole.

"Ocean Birds of Perth Beaches." Mr. L. Glauert.

Exhibits—Mr. Glauert exhibited fragments of *Inoceramus* shell from a depth of 550 feet below the surface Woomerangie No. 1 Bore Tomala Station, Shark Bay, suggesting the presence of Gingin chalk. Dr. Prider exhibited specimens of *Sericite Schist* closely resembling Cardup Slate, collected at Black Boy Hill by Mr. J. E. Wells.

JOURNAL OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

VOLUME XXVII.

1.—RESULTS OF A MICROSCOPIC STUDY OF SOME SOIL COLLOIDS.

BY W. F. COLE.

Read 13th August, 1940; Published 14th November, 1941.

INTRODUCTION.

In two previous publications (1) and (2) J. Shearer and the author have described the X-ray analysis of some soil colloids from Western Australia and Tasmania. In this paper an account is given of a microscopic examination of these soil colloids.

In the first publication cited, the crystalline content of colloid separations (effective diameter 2μ and less) from two soil samples from the Salmon Gums district in Western Australia was determined. These two samples, designated as A 1346 and A 1351, represent the subsoil and deep subsoil respectively.

In the second publication cited, the crystalline content of colloid separations (effective diameter $1 \cdot 4\mu$ and less) from four soil samples from Tasmania was determined. The details regarding the source of these four samples are:

551 and 560	Colloid separations from soils from Illawarra in northern Tasmania;
499	Colloid separation from a basaltic soil of north-west Tasmania;
222	Colloid separation from a soil from the Huon valley in southern Tasmania.

The final X-ray conclusions regarding the composition of these soil colloid fractions are contained in Table 1. The terms "kaolinite," "montmorillonite," and "mica" have been used in this table and in the remainder of this paper, for brevity, to designate a mineral belonging to the kaolinite group, the montmorillonite group and the mica group respectively. This is necessary because at present it is not possible to identify minerals within a group in the diffraction pattern of a soil colloid.

TABLE I.

COMPOSITION OF THE SOIL COLLOIDS.

(Results of X-ray analysis.)

Mineral.	Tasmanian.				West Australian.
	222.	551.	560.	449.	A 1351 and A 1346.
Quartz ...	Much <——	Much <——	Much	Very Little	Possible trace
Kaolinite. ...	Little	Much	Much	Much	Little
Mica	—	—	—	—	Much
Montmorillonite	Little	Possible trace	Possible trace	—	—
Haematite ...	—	Very Little	Very Little	Little	—

Note : An arrow (—>) indicates increasing amounts of quartz. A similar assessment with regard to kaolinite in 551, 560 and 499 could not be made.

The soil colloid fractions from Western Australia were separated according to the International Method which gives particles of an effective diameter of 2μ and less. The soil colloid fractions from Tasmania were separated according to the former British system which gives particles of an effective diameter of $1 \cdot 4\mu$ and less. From the point of view of this study the main differences in these two methods of preparation are (1) the Tasmanian soil colloid fractions are of a finer grade than the soil colloid fractions from Western Australia, and (2) the former were oven-dried whereas the latter were air-dried. As supplied for examination the local material was still attached to the filter paper and had to be removed by scraping with a glass slide. The Tasmanian material was supplied in a loose powdered form.

For further information regarding modifications introduced into the two methods of separation used, reference may be made to the original articles.

SOIL COLLOID FRACTIONS FROM THE SALMON GUMS DISTRICT IN WESTERN AUSTRALIA.

Both soil colloid fractions A 1351 and A 1346 when viewed under the microscope were seen to be in the form of particles up to 50μ and greater in diameter. Since (it was claimed that) the clay separations were composed of particles of 2μ and less in effective diameter, it was assumed that the particles viewed beneath the microscope were aggregates of the soil colloid particles. In that they exhibited definite optical properties, all these aggregates, in both samples, closely resembled fragments of a single mineral. The optical properties of these aggregates, it is considered, are due to the individual components exhibiting uniformity of crystallographic orientation. This orientation of soil colloid and clay particles into aggregates after drying was originally observed by Hendricks and Fry (3) and has been further investigated by Bray, Grim, and Kerr (4). The aggregates appearing in the soil colloid fractions of A 1351 and A 1346 are larger than those noted by Bray, Grim, and Kerr.

In samples A 1351 and A 1346 the perfection of the uniformity of orientation of the individual components into aggregates is amazing. It was not possible to identify more than one type of aggregate. This indicated that such aggregates were characteristic of the sample as a whole.

The refractive indices were determined on aggregates by immersion in mixtures of clove oil and α-monochloronaphthalene.

The main differences between the two colloid separations A 1346 and A 1351 is one of colour. Under the microscope A 1346 is light brown; A 1351 is chocolate brown. All the material of both samples is doubly refracting; A 1351 being the more birefringent. The extinction of the aggregates is in all cases sharp. The indices in different directions were easily determinable. The optical interference figure of aggregates of both samples is biaxial negative and the axial angle is small. These figures are similar in character to those mentioned in the original work of Hendricks and Fry (3). The optical properties of aggregates of the soil colloid fractions A 1351 and A 1346 are summarised in Table 2.

TABLE 2.

OPTICAL DATA RELATING TO THE SOIL COLLOID FRACTIONS FROM WESTERN AUSTRALIA.

Optical Properties.	A 1346 (Water Dispersed).	A 1351 (Water Dispersed).
α	1·562	1·555
γ	1·572	1·570
$\gamma - \alpha$	0·010	0·015
2V	Small	Small
Optical character	(–)	(–)

It may be seen from Table 3 that these optical properties are not those of any common clay mineral. X-ray evidence indicates that both the soil colloid samples are composed of a mixture of two clay minerals, one belonging to the mica group and the other to the kaolinite group. If the aggregates under examination are to be considered representative of the sample as a whole, then these optical properties could result from an aggregation of the above two clay minerals. That two clay minerals *belonging to different groups* may be closely intergrown into aggregates which possess uniformity of crystallographic orientation has already been noted by Bray, Grim, and Kerr (4). Hence the optical properties of aggregates of the soil colloid fractions A 1351 and A 1346 are consistent with the X-ray conclusions.

TABLE 3.

OPTICAL PROPERTIES OF CLAY MINERALS.

KAOLINITE GROUP.

Mineral.	γ	α	$\gamma - \alpha$	2V.	Sign.
Kaolinite ...	1·570—1·560	1·563—1·553	0·006	24°—50°	(—)
Nacrite	1·566—1·563	1·560—1·557	0·006	40°—90°	(+) or (—)
Dickite	1·556	1·560	0·006	52°—80°	(+)
Halloysite ...	Mean Index	1·561—1·549	Very slight		
Hydrous Halloysite	Mean Index	1·542—1·526	Very slight		

MONTMORILLONITE GROUP.

Mineral.	γ	α	$\gamma - \alpha$	2V.	Sign.
Montmorillonite ...	1·530—1·500	1·505—1·470	0·035—0·025	7°—25°	(—)
Beidellite ...	1·560—1·530	1·530—1·500	0·035—0·025	Small	(—)
Nontronite ...	1·610—1·560	1·575—1·530	0·035—0·030	Small	(—)
Saponite	Indices of refraction similar to Montmorillonite				

MICA GROUP.

Mineral.	γ	α	$\gamma - \alpha$	2V.	Sign.
Illite	1·605—1·565	1·570—1·535	0·035—0·030	Small	(—)

Note: This Table is based on that published by Grim (5).

SOIL COLLOID FRACTIONS FROM TASMANIA.

In general the remarks made in the previous section as regards aggregation of soil colloid material after drying apply also to the Tasmanian soil colloid fractions. When viewed under the microscope all four samples were seen to be in the form of particles up to 50μ and greater in diameter. In view of what has been previously stated, these particles are considered to be aggregates of the soil colloid particles which have an effective diameter (in this case) of 1·4μ and less. Sample 222 is, however, the only fraction which shows any deducible uniformity of crystallographic orientation of individual components. The three samples, 551, 560, 499, and the greater part of 222, are dark between crossed nicols. In such samples a mean index of refraction only was determined. Variations from the mean value are small.

The soil colloid samples 551, 560, and 499 are very similar. Aggregates formed from each of these three samples are characterised by their colour, high indices of refraction, and apparently isotropic character. The colour of 499 under the microscope is chocolate brown, that of 551 and 560 dark brown. The high indices of refraction are probably due to the high iron content of the soil colloid samples. This iron content does not enter the structure of the clay minerals present in the soil colloids (a conclusion arrived at from the X-ray analysis) but probably coats the colloid particles in the form of iron oxides or hydroxides. Such a possibility has already been noted by Nagelschmidt (6). These indices of refraction, therefore, clearly do not represent the refractive index of the clay mineral shown to be present by X-ray examination. Hendricks and Fry (3) have noted that a high iron content in a soil colloid fraction tends to mask the doubly refracting material present. In view of the X-ray conclusion that the clay mineral present in these three colloid fractions is predominantly kaolinite, it is believed that, in the absence of a high iron content, aggregates formed from each of these three colloid fractions would still possess only a very weak birefringence. Hence, generally speaking, the optical data relating to aggregates of the soil colloid fractions 551, 560, and 499 (which are summarised in Table 3) are consistent with the X-ray conclusions.

Sample 222 is different from the other Tasmanian samples in that the colour beneath the microscope is greyish-yellow, the indices of refraction are lower, and the aggregates are more birefringent. Many aggregates are dark between crossed nicols but some show fairly uniform crystallographic orientation of individual components and for these $\gamma - \alpha = 0 \cdot 005$. Such aggregates failed to show interference figures sufficiently satisfactory for the determination of the optical character. X-ray evidence indicates that kaolinite and montmorillonite are the clay minerals present in this soil colloid fraction. In view of the fact that the three colloid fractions 551, 560, and 499, containing kaolinite as the only clay mineral are non-birefringent, the slightly birefringent character of 222 (Table 4) is consistent with the above X-ray conclusion. That is, if the aggregates under examination are to be considered representative of the sample as a whole, then these two minerals (kaolinite and montmorillonite) are occasionally closely intergrown into aggregates which possess uniformity of crystallographic orientation.

TABLE 4.

OPTICAL DATA RELATING TO THE SOIL COLLOID FRACTIONS FROM TASMANIA.

Sample.	α	Mean Refractive Index.	γ	$\gamma - \alpha$
222	1·567	...	1·572	0·005
551	...	1·605	...	...
560	...	1·618	...	...
499	...	1·655	...	...

RE-DISPERSION AND RE-AGGREGATION OF THE SOIL COLLOIDS.

In view of criticism of the observations made in this study that firstly the particles examined were aggregates (of a size up to 50μ and greater in diameter) of soil colloid particles rather than original single crystals which had not been broken down in the preparation, and that secondly two clay minerals belonging to different groups may be closely intergrown into aggregates which possess uniformity of crystallographic orientation, it was of interest to restore the particles to their original suspended state where they had an effective diameter of 2μ and to reproduce the aggregates by removing the particles from suspension. This applied particularly to the soil colloid fractions from Western Australia which exhibit a well marked crystallinity.

Re-dispersion. The re-dispersion of one of these samples (A 1351) was undertaken by Mr. Burvill, of the State Department of Agriculture, who was responsible for the original separation of the West Australian soil colloids. By repeating precisely the procedure adopted in the preparation, Mr. Burvill was able to re-disperse the greater part of the soil colloid sample A 1351. The individual particles of this suspended material were not visible under high power magnification. That some material was not re-dispersed is of little consequence when it is realised that, as a result of the grinding a sample receives in a mechanical analysis, the amount of clay recorded is rather arbitrary.

Re-aggregation.—By removing the clay particles from suspension in the same manner as originally carried out by Mr. Burvill, the author was able to reproduce the state of large-sized crystal aggregates in which the sample originally existed. These aggregates again exhibited a well marked uniformity of crystallographic orientation.

Undoubtedly then the large-sized particles used in the optical examination were not original unbroken particles, but on the contrary, were aggregates of soil colloid particles (the particles being of 2μ and less in effective diameter) which had formed after the dispersion of the material.

OBSERVATIONS ON THE PROCESS OF AGGREGATION OF SOIL COLLOIDS.

A series of observations were made with a view to determining the particular stage at which the soil colloid suspension tended to aggregate. In this study (which was carried out on the re-dispersed material of A 1351) colloid particles in suspension were allowed to settle on a flat surface (under various conditions) and the collected material was kept constantly under examination, as the water content was slowly removed by evaporation. It was noted, firstly, that the particles settled in such a manner that all the material collected remained dark between crossed nicols no matter whether evaporation was slow or fast, whether flocculated or unflocculated material was used. Secondly, the definition of the interference figure improved as the material lost water. The interference figure became only definitely recognizable when the sample first showed the production of contraction cracks. This is in conformity with the observations of other workers (previously noted) that individual particles existing in a soil colloid suspension tend to orient themselves after drying into aggregates which possess uniform optical properties. That the whole surface was set in an optically uniform manner was seen from the fact that the interference figure produced was the same for all the material collected. This is completely in accord with Grim's observations (7) on the production of ordered aggregates after the drying out of clay particles which had been allowed to settle on a slide immersed in a clay suspension.

The interference figure (which was particularly good for that material which had lost the largest amount of water) had the same characteristics as are summarised in Table 2 for both original samples of A 1346 and A 1351. These properties indicate that the aggregates are superimposed basal plates (with β γ), normal to which is the acute bisectrix (α). In view of the X-ray conclusions that the soil colloid under examination (A 1351) contained two clay minerals, mica and kaolinite, these observations provide additional evidence that two clay minerals belonging to different groups may be closely intergrown into aggregates which possess uniformity of crystallographic orientation.

SUMMARY.

An account is given of the results of a microscopic examination of soil colloid materials from Western Australia and Tasmania. These results are consistent with the mineralogical composition as deduced from X-ray analysis. The methods employed and the observations made are in conformity with those of other workers in this field.

ACKNOWLEDGMENTS.

These investigations were carried out in the Physics Department of the University of Western Australia during the tenure of a Hackett Research Studentship and a Commonwealth research grant. The author wishes to express his thanks to the University of Western Australia for the former and to the Council for Scientific and Industrial Research for the latter.

The author's thanks are also due to Dr. R. T. Prider, of the Department of Geology, and to Mr. J. Shearer, of the Department of Physics, for helpful criticism, and to Mr. Burvill, of the State Department of Agriculture, for the redispersion of sample A 1351.

BIBLIOGRAPHY.

(1) Shearer, J., and Cole, W. F.—" Analysis of Soil Colloids by X-ray Diffraction Methods." *Jour. Roy. Soc. W. Aust.*, 1940, XXVI., p. 121.

(2) Shearer, J., and Cole, W. F.—" X-ray Analysis of some Tasmanian Soil Colloids." *Jour. Roy. Soc. W. Aust.*, 1940, XXVI., p. 133.

(3) Hendricks, S. B., and Fry, W. H.—" The Results of X-ray and Microscopic Examination of Soil Colloids." *Soil Sci.*, 1930, XXIX., pp. 457–479.

(4) Bray, R. H., Grim, R. E., and Kerr, P. F.—" Application of Clay Mineral Technique to Illinois Clay and Shale." *Bull. Geol. Soc. Amer.*, 1935, XLVI., pp. 1909–1926.

(5) Grim, R. E.—" Properties of Clay." Recent Marine Sediments, A Symposium, London.

(6) Nagelschmidt, G.—" The Identification of Minerals in Soil Colloids." *Jour. Agr. Sci.*, 1939, XXIX. [4], pp. 477–501.

(7) Grim, R. E.—" The Petrographic Study of Clay Minerals. A Laboratory Note." *Jour. Sed. Petr.*, 1934, IV. [1], pp. 45–46.

NOTE ADDED IN PROOF-READING.

Since this paper was first prepared the author has been successful in obtaining characteristic reflections from oriented aggregates of soil colloid samples. A film of an oriented aggregate of sample A 1351 shows strong basal reflections at 7 A and 10 A indicating the presence of both kaolinite and mica in the same aggregate and thus fully confirming the conclusions reached above on the aggregation of soil colloids.

2.—SOME KYANITE-BEARING ROCKS FROM THE EASTERN GOLDFIELDS, WESTERN AUSTRALIA.*

By Keith R. Miles, B.Sc. (Hons.).

Read 13th August, 1940; Published 12th November, 1941.

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INTRODUCTION.

While engaged in a programme of field work undertaken by the Geological Survey in the country north of Laverton, Mt. Margaret Goldfield, during the winter of 1939, the writer noted and mapped at a spot known as the Camel Humps, an interesting occurrence of a variety of rock hitherto unrecorded from this district. This is a kyanite-bearing quartz schist, a fairly high grade metamorphic type, and part of the Older Greenstone Series (Pre-Cambrian) which forms a narrow belt of auriferous country in this portion of the State.

Comparison of this rock with rather similar looking metamorphics from a number of other localities in the Eastern Goldfields has led to the discovery or confirmation by the writer, of the existence of kyanite in several of these latter rocks also, and the object of this paper is to give a brief description of the occurrence and petrology of these interesting rocks.

The presence of the mineral kyanite in crystalline schists is of peculiar interest, because of the light that it may shed upon the origin, constitution and metamorphic history of the rock in which it is developed. It is a silicate of aluminium, $Al_2O_3SiO_2$, and is generally recognised as one of the few typical "stress minerals" (1), and appears to form only at definite stages in progressive regional metamorphism. It is a mineral which is peculiarly sensitive to changes in temperature and pressure conditions, and requires

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for its development, appropriate conditions of moderately high temperature in conjunction with essential shearing stress. It appears to have only a temporary status or field of stability in regional metamorphism, and together with its polymorphs, andalusite and sillimanite, has been for a long time regarded as a "key" mineral, indicative of a certain distinct grade or zone of metamorphism. (4 p208 et seq.), (3), (2).

Kyanite has been recorded from comparatively few localities in Western Australia, these being mostly confined to the Chittering Valley, (5), (6), (7), and (11), and the Chittering-Jimperding-Clackline-York belt of metamorphic rocks generally (8). Specimens of kyanite have been obtained from other scattered localities i.e., from Richenda River, West Kimberley, (where it is associated with emery); Milly Milly Station, Murchison River (9); Smithfield and the Donnelly River, near Bridgetown in the South-West Division, where it occurs in patches of waterworn boulders (12), (10), and (13); Mt. Barren, South-West Division; but little if anything is known of the field relations of many of these occurrences. From the Goldfields, one occurrence of a mineral rather doubtfully referred to kyanite, has previously been recorded. (14). This is from the vicinity of Mt. Kenneth in the Yalgoo Goldfield, and this rock will be described in some detail below. It is proposed to discuss separately the occurrences and petrographical details of the several kyanite bearing rocks which have been noted.

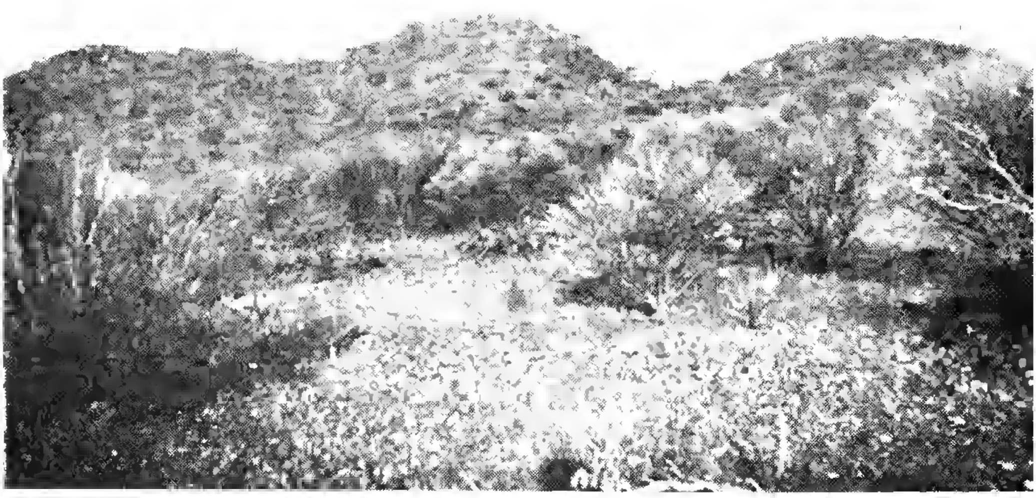

Photo. K. R. Miles, 1939.

Fig. 1. Hills of the northern Camel Humps, looking east. Soil and talus in the foreground.

THE CAMEL HUMPS, MT. MARGARET GOLDFIELD.

Field occurrence.

The Camel Humps is the name given to two prominent ridges standing up in marked relief above rather low, flat or gently undulating country lying some $2\frac{1}{2}$ miles west of the main Laverton-Cox's Find road, at a point about 33 miles north of Laverton. These two ridges lie a little over half a mile apart on a north-northwesterly line, their highest points being marked by small cairns. The northern Camel Hump is the more prominent and consists of a long ridge extending over a length of more than 20 chains, broken by

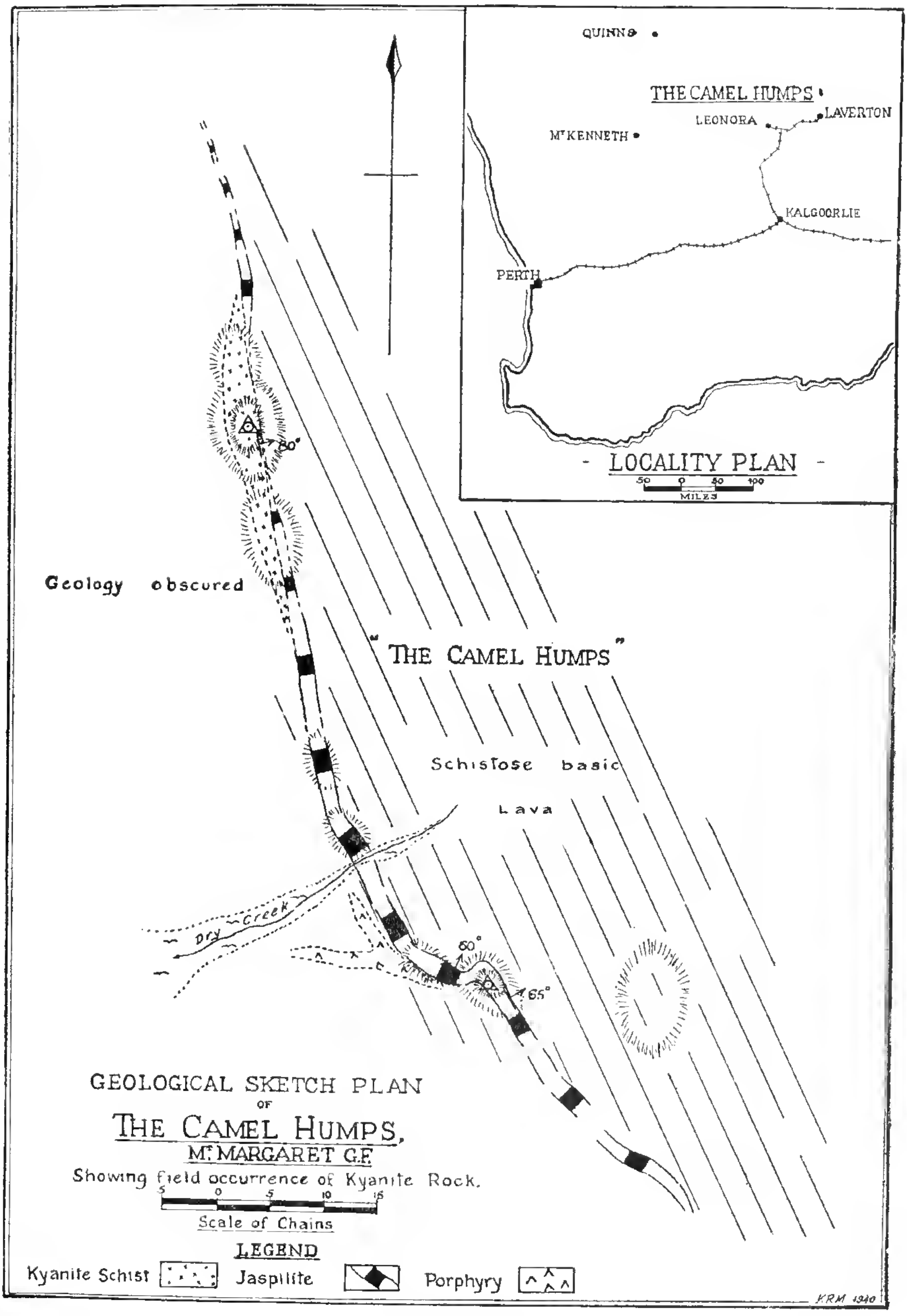

Fig. 2.

erosion gaps into three hills, the central and highest carrying a cairn. (Fig. 1.) These hills are made up of outcrops of a hard yellowish-white coloured, rudely jointed and bedded quartzose rock which dips from vertical to 80 degrees to the east. The jointing has resulted in the production of large slabs of rock which often stand up like enormous blunt spear heads. Both the western and eastern slopes of the ridge are steep to precipitous, and strewn with these flat slabs and with smaller rock talus, and sprinkled with sparse mulga scrub.

On the western side of the hills this talus, together with red gravelly soil and milk white quartz rubble, completely obscures the geology. To the east, though outcrops are scarce, the country appears to consist principally of decomposed greenstone schists, probably schistose basic lava. On traversing the ridge southwards one sees that the yellowish quartzose schist lenses out along the strike, and without any visible unconformity its place becomes taken by a banded ferruginous quartzite bed. This relationship is shown in the geological sketch plan. (Fig 2.). Outcrops of this banded ferruginous quartzite or jaspilite extend southwards in a series of low hills forming a curved line linking up with the hills of the southern Camel Hump. (See Fig. 2.). To the immediate north of the northern Camel Hump hills the country flattens out into a rubble-covered plain but traces of a banded ferruginous quartzite bed can be found extending for nearly a quarter of a mile to the northwards.

Petrography.

A close inspection of hand specimens (L397.)* of this yellowish-white rock taken from near the cairn at the northern Camel Hump discloses the presence of a knotted schistose structure. The knots consist of kyanite in either rounded rather stumpy crystals averaging about 2 mms. in diameter and 2.5 mms. long, or longer flat bladed crystals up to 6.5 mms. in length. Most of these crystals are roughly oriented so that their shorter axes lie approximately normal to the plane of schistosity. They are colourless and have a lustre ranging from dull vitreous to distinctly pearly upon cleavage faces. These knots of kyanite are set in a "flowing" or foliated aphanitic matrix of whitish, very finely granulated quartz, usually flecked with tiny flakes of sericite giving a silky sheen to surfaces of the rock which have been broken parallel to the schistosity. This quartzose matrix is here and there stained yellowish or pink by a little introduced limonite.

It has a porphyroblastic gneissic structure—the porphyroblasts of kyanite being arranged in rudely oriented bands of very irregular shaped crystals whose boundaries are frequently crenulated and embayed, whilst the terminations are generally resolved into a granular diablastic aggregate of kyanite and quartz.

Individual crystals of kyanite are occasionally curved and bent due to rotation during growth. In thin slice they are colourless and non-pleochroic and have characteristic high relief. Many elongated sections show a well defined cleavage (100) while sections cut parallel to this disclose an imperfect (010) cleavage. The cross parting (001) at approximately 85° to the length of the crystals, i.e., the c-axis, is seldom well developed (See Fig. 3A.). End sections (cut approximately normal to the c-axis) disclose the perfect (100) cleavage whilst the (010) is represented by a strong cross parting at from 80°-85° to (100) (See Fig. 3B.) In such sections extinction is parallel to (100) cleavage.

* All numbers in parentheses represent either field or registered numbers of specimens in the Geological Survey Rock Collection—except those preceded by the letter U. which belong to the General Collection of the Dept. of Geology, University of W.A.

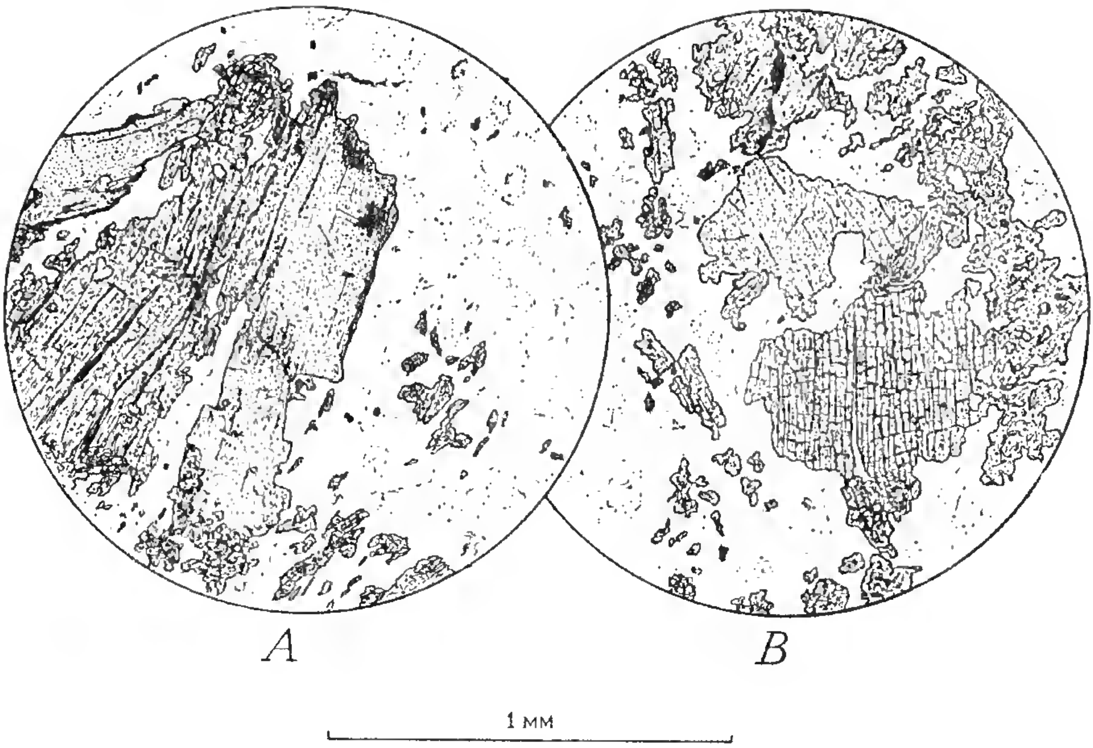

Fig. 3.

A. Kyanite-quartz schist (specimen L397) from the Camel Humps. Showing characteristic bladed form of kyanite cut parallel to (100) (clear crystal). Rutile inclusions in clustered aggregate (black).

B. The same, with kyanite crystal showing perfect (100) cleavage and imperfect (010) cross-parting in section cut approximately parallel to (001). Note diablastic intergrowth of granular kyanite with quartz matrix.

The following optical properties have been determined:—

The optical elongation is positive. $Z \wedge c$ is 29°-30° on sections cut parallel to (100).

The mineral is biaxial with negative optical character.

Optical axial plane is approximately normal to (100) and inclined at 29°-30° to c-axis.

2V is large ($>$ 80°).

The refractive indices are:—

$$\left.\begin{aligned} \alpha &= 1\cdot711 \\ \beta &= 1\cdot718 \\ \gamma &= 1\cdot726 \end{aligned}\right\} \pm \cdot002$$

$$\gamma - \alpha = \cdot015 \qquad \pm \cdot002$$

Twinning, often a characteristic feature of this mineral, was only occasionally noticed on (100) as twin plane. Micrometric observations indicate the presence of 15% to 25% of kyanite in this rock. Inclusions in these kyanite porphyroblasts consist of quartz grains, clusters of yellow rutile prisms and occasonal detrital zircons.

The quartz matrix enclosing the kyanite consists of a fine grained, even-granular mosaic of crystals averaging about .04-.08 mms. in diameter, included in and surrounding the broken grains of kyanite.

Quartz and kyanite constitute the essential minerals in this rock.

Accessory minerals present are:—

Rutile in very abundant scattered clusters and separate individuals of tiny golden yellow prismatic crystals frequently occurring in geniculated twins, often as poikiloblastic inclusions in kyanite, but also scattered irregularly throughout the quartzite matrix.

Sericite or muscovite occurs in some tiny parallel oriented rods "flowing" throughout the quartzite matrix and also as a few larger flakes and stringers occasionally moulded upon or enclosed by kyanite.

Zircon exists in a few rounded, colourless, zoned detrital grains often enclosed in kyanite.

Hematite is present in a few small scattered grains, usually showing some alteration to limonite, while limonite occurs as a thin secondary stain in a few places, marking the presence of small fractures upon the surface of the rock.

Thus this rock is a kyanite-quartz schist.

The simple mineralogical composition of this rock indicates a comparatively simple chemical composition. From its mineral content it would appear to consist chiefly of silica, SiO_2, and alumina, Al_2O_3, with minor quantities of titanium oxide, TiO_2. A remarkable feature of this rock is the almost complete absence of Fe in any form, particularly as from the field occurrence it appears to grade into normal banded ferruginous quartzite along the strike.

No chemical analysis of this rock has yet been made but as will be seen in the following section its remarkably close similarity to the Mt. Leonora rock indicates an essentially similar chemical composition, and an analysis of the Camel Humps rock would probably be found to compare very closely with those of the Mt. Leonora type quoted below.

MT. LEONORA, MT. MARGARET GOLDFIELD.

Field occurrence.

Mt. Leonora lies about 3 miles to the south-southeast of the townsite of Leonora and forms the highest and most conspicuous summit of a long line of intermittent ridges and low hills which run northwards for many miles. These also extend southwards from the Trig. Station for about three miles in a line of rock outcrops which form ridges of gradually decreasing stature and which finally disappear beneath the alluvial flats of Lake Raeside. The rocks of which Mt. Leonora is composed are creamy yellow to light grey in colour and are usually dense, hard quartzose schists of variable grain size, frequently having a knotted character.

These rocks are distinctly bedded and dip fairly constantly at 55° to the west (See Fig. 4.). They were first described in 1904 by C. F. V. Jackson (15) who considered Mt. Leonora to be an area of "crushed granite," despite the evidence of a chemical analysis of this rock (5084) published along with his description.

In 1909 A. G. Maitland, as a result of a brief re-investigation of the field occurrence of the Mt. Leonora rock, pointed out its obviously bedded nature and from the field evidence concluded it to be of sedimentary origin and not a metamorphosed granite (16). He also remarked that the quartz schists of the Mt. Leonora type extended northwards for over six miles without interruption to Mt. George.

In the geological map accompanying his report on the geology of Leonora, Jackson (op. cit.) shows a broken line of ridges running southward from Mt. Leonora, apparently forming the southern continuation of the strike of the Mt. Leonora rock, for over two miles. Similar ridges are also shown running northwards from the eastern outskirts of Leonora township to beyond Mt. George. The centre of all this line of ridges is mapped as composed of a more or less continuous bed of "banded hematite-bearing quartz."

G.S.W.A. Neg. No. 196. *Photo. C. F. V. Jackson.*

Fig. 4.—Outcrops of andalusite quartz schist, or quartzite, Mt. Leonora, showing bedding planes dipping at about 55° to the west.

Outcrops of this rock on the eastern edge of the townsite are certainly those of quite typical bedded ferruginous quartzite or jaspilite, and consequently it would appear that in its broad geological association with these jaspilite beds the Mt. Leonora rock shows a striking similarity to the Camel Humps occurrence, described above.

In his bulletin dealing with the field geology of the Leonora-Duketon District, E. de C. Clarke (17), in an account of the Mt. Leonora rock quoted Farquharson's determination of it as a "finely foliated, much granulated andalusite-quartz schist which he considers to be a metamorphosed sediment." Chemical analyses of specimens collected by Jackson (5084) and by Clarke (1/2002) were compared with two analyses of metamorphic rocks from Quinn's, (Murchison Goldfield), and their general similarity noted. These analyses are quoted below.

Petrography.

A recent re-examination by the writer, of a number of the old thin slices together with several new ones cut from different specimens of the Mt. Leonora rock has disclosed the interesting fact that, in addition to andalusite, some hand specimens also contained the higher grade metamorphic minerals, kyanite and sillimanite. In fact different specimens of this rock provide excellent examples of arrested mineral development with the inception of a higher grade facies due to change in stability conditions during progressive metamorphism.

Hand specimens of this rock collected from various points in the vicinity of the Trig. Station and from the western slopes, are creamy white to grey in colour and of varying density and grain size. Coarser grained specimens are much more foliated or schistose and have a strong knotted structure and a characteristic silky lustre on cleavage planes. The knots, presumably representing andalusite crystals, are usually rounded and flattened and show up as slightly lighter colour than the foliated matrix. They may be up to 7.5 mms. long and nearly 5 mms. wide. The finer grained specimens are much more compact and though not markedly schistose, have a tendency to cleave along parallel planes. The andalusite knots are only revealed on polished surfaces and then appear as innumerable small roundish, light coloured patches, averaging less than 1 mm. in diameter. The material surrounding these knots appears dense, fine grained and siliceous.

In one hand specimen (5084), a medium-coarse grained schistose type, one can distinguish, in addition to the andalusite knots, a few small flat, pearly lustred laths of kyanite up to 2 mms. long.

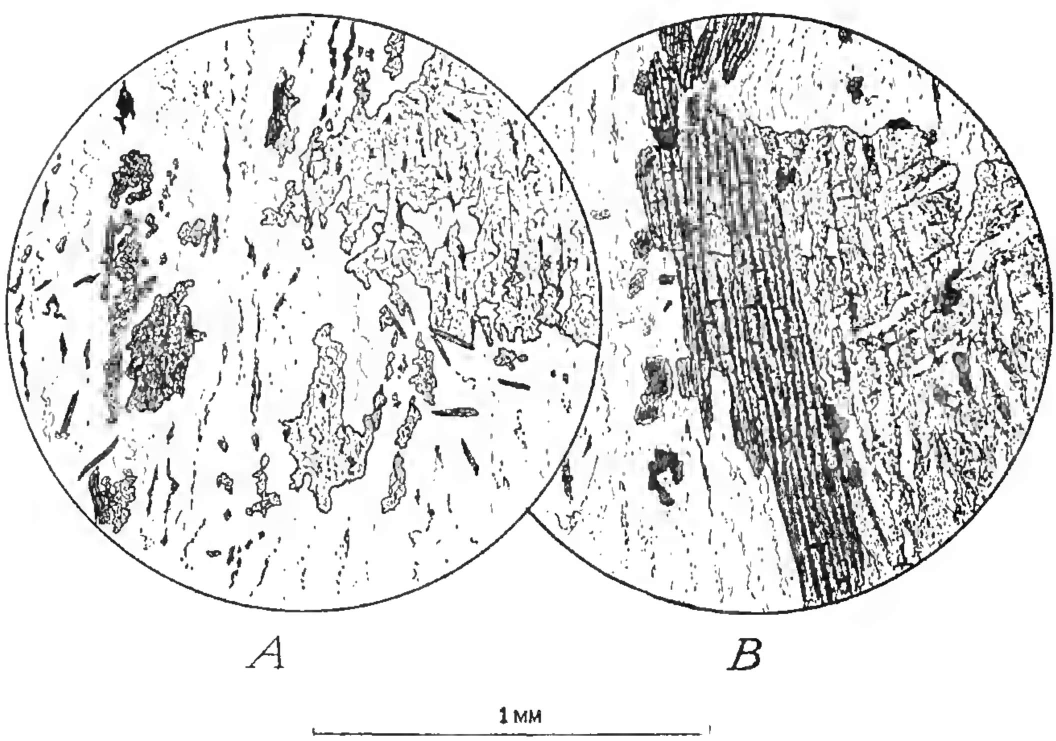

Fig. 5.

A. Kyanite-bearing andalusite-quartz schist (Spec. 5082) from near Trig. Station, Mt. Leonora. Showing part of a large granular porphyroblast and some granulated kyanite (darker). The quartzite matrix contains flakes of muscovite and oriented stringers of dark carbonaceous material.

B. Sillimanite-bearing andalusite-quartz schist (Spec. U3165) from near west slope of Mt. Leonora. Showing sillimanite in flowing needles developing upon the margin of granular poikiloblastic andalusite. Black opaque grains are hematite altering to limonite, and some graphite.

Thin slices show a uniform porphyroblastic gneissic texture. The "knots" or porphyroblasts consist chiefly of colourless andalusite. This mineral has reached only a very early stage of crystalloblastic development, the "knots" being more or less equidimensional but otherwise without form. Indeed so weak has been the force of crystallisation of the andalusite that crystals have in most cases entirely failed to clear themselves of inclusions, which consist of flowing aggregates of quartz granules, finely divided dusty graphitic material, shreds of mica, and scattered yellow rutile needles, identical and continuous with the material of the matrix which surrounds these porphyroblasts. Only seldom has the andalusite developed clear crystals showing any semblance of form, but where seen these usually show characteristic prismatic (110) cleavage and have moderately low relief, weak birefringence, straight extinction in elongated sections, negative elongation and negative optical character. A few sections occasionally show a faint pleochroism from Z = pale pink, to X and Y = colourless.

Kyanite is present as porphyroblasts in a few specimens (e.g. 5084, 5082, U17265) and usually forms rather irregular shaped elongated crystals or occurs in granular aggregates indicating an early stage of growth. The kyanite is sometimes partially enclosed in granular aggregates of andalusite from which it is developing, or it may occur as isolated porphyroblasts in the quartzite matrix. (See Fig. 5A.) It is easily distinguished from the andalusite by its high relief and consequent darker appearance, and by its typical bladed form, cleavage, extinction angle, stronger birefringence and positive elongation. Twinning on (100) was noticed in several crystals. Though characteristically showing a much stronger force of crystallisation than the andalusite, crystals are never entirely free of inclusions of quartz granules, carbonaceous material and some rutile needles, while the terminations of the crystal blades are usually broken into granular aggregates and occasionally resolved into needle-crystals of sillimanite.

Sillimanite is present in several specimens (U3165, 10833) usually associated with and developing directly from granular andalusite (See Fig. 5B). It occurs in slender elongated and cross-fractured prismatic crystals or in felted masses of acicular fibres, generally lying in parallel optical orientation with the andalusite. These are distinguished from the andalusite by their form, higher relief, stronger birefringence and positive elongation, and where associated with granular kyanite, from this mineral by their straight extinction.

The matrix enclosing the porphyroblasts consists mainly of a fine granular lepidoblastic aggregate of quartz, charged with some finely divided carbonaceous material, together with scattered oriented shreds and flakes of sericite, and frequently abundant tiny yellow granules and prisms of rutile.

Accessory minerals include small quantities of iron-ore—both hematite and limonite, and also occasional limonite pseudomorphs after pyrite, fragments of brown mica, and a few zircons, all distributed sporadically throughout both the matrix and the porphyroblasts.

Thus the Mt. Leonora rock may be said to vary in mineralogical composition from andalusite-quartz schist or quartzite, to kyanite, and sillimanite-bearing andalusite-quartz schist. Their similarity of chemical composition is clearly demonstrated, however, in the analyses quoted below. (A) and (B). Their essential similarity to the Camel Humps rock is also very noticeable, the chief mineralogical differences arising from differences in temperature and pressure conditions during metamorphism, as will be discussed in a later section.

MT. KENNETH, YALGOO GOLDFIELD.

Field occurrence.

Another interesting metamorphic which bears a general resemblance to the Camel Humps and Mt. Leonora rocks, comes from several low rocky rises at about seven miles east-southeast of Mt. Kenneth, near the eastern boundary of the Yalgoo Goldfield. This occurrence was described by H. W. B. Talbot in 1919 (14) and a chemical analysis, and brief petrographical description by R. A. Farquharson, were also published. The field relations of this rock are rather obscure, but it is apparently enclosed and presumably intruded by granite.

Petrography.

The rock is pale greenish in colour, is medium grained and has a typical even, granulated schistose appearance, but has not the marked knotted, or porphyroblastic structure of the two rocks described above, and hand specimens appear to consist chiefly of quartz and chlorite.

The microscope, however, reveals the presence of numerous ragged prisms and irregular, rather fragmentary crystals of typical kyanite showing usual high relief, good (100) cleavage, moderate birefringence and positive elongation, with characteristic maximum extinction and negative acute bisectrix figure obtained from broad sections cut parallel to (100). These crystals are occasionally enclosed by and apparently developing from chlorite and sericite flakes, or are scattered in groups in random orientation through an irregular cataclastic granular matrix of quartz, and irregular ragged plates of chlorite and muscovite.

The most common accessory mineral in this rock occurs in small irregular, rather pointed prisms and rounded granules, scattered liberally throughout. These are pleochroic in dark yellow-brown to red-brown colours, maximum absorption being parallel to the longest axis. Relief is very high, surfaces of these crystals having a stippled appearance. Birefringence appears weak, and interference colours are mostly masked by absorption. Extinction is straight. A few grains show apparent development of penetration twins. Grains were too small to give an interference figure. They have the colour, general form and extremely high refringence of perovskite, ($CaTiO_3$) whilst the pleochroism and extinction suggest either brookite, (TiO_2), or the metamorphic mineral staurolite (hydrated silicate of Fe and Al.). The entire absence of CaO in the chemical analysis of this rock (C) rather disposes of the possibility of perovskite. The general distribution is that of a detrital mineral and brookite is suggested.

Other accessories include clear yellow-brown rutile in euhedral prisms, pale yellow zircons often producing pleochroic haloes in chlorite, broken apatite needles, and a few grains of cloudy felspar.

In 1920 E. de C. Clarke visited the Mt. Kenneth district and collected a suite of specimens of the metamorphic rocks. Several of these hand specimens (1/2694, 1/2695) resemble very closely Talbot's specimen described above. Examination of thin sections failed to reveal the presence of any kyanite however, the indications being that these rocks have apparently failed to pass the chlorite stage of metamorphic development (4, p 209). They consist essentially of quartz, muscovite stained with limonite, and some pale green chlorite. Of the accessories, rutile in bright yellow recrystallised prisms and dark detrital grains is most abundant. Others include detrital zircon and apatite.

Chemical analyses of Talbot's rock and of one of these (1/2695), given below, clearly indicate their common composition, however, and strongly suggest their common origin.

QUINN'S, MURCHISON GOLDFIELD.

Field occurrence.

From a little over half a mile to the south-west of Quinn's townsite in the Murchison Goldfield, comes another set of metamorphic schists, comparable with those described above. These rocks were first described in 1904 by C. G. Gibson (18) who believed them to be granite schists. In 1921 they were further described and figured by F. R. Feldtmann (19) and a brief account was given of their field occurrence. Petrographic descriptions of a number of these rocks were provided by R. A. Farquharson (19, p16) who considered several of them (1/791-2) (1/794) (5332-3) to be metamorphic chloritic quartz schists containing a granular mineral which he doubtfully referred to andalusite. Feldtmann concluded that they were contact metamorphosed sediments. Analyses of two of the rocks (1/791 and 1/792) which are quoted below, were also published.

Petrography.

Hand specimens of one of these metamorphics (1/791) are pale greenish grey coloured, rather uneven, medium to fine grained, granulated with an unusual streaky appearance, consisting mainly of pink and colourless quartz, and abundant pale green chlorite scales.

This rock has a granulated porphyroclastic texture, with scattered "eyes" of slightly broken, clear quartz in a fine granulated matrix of rounded quartz grains and chlorite shreds. The granular mineral referred to andalusite by Farquharson occurs in several roughly rectangular patches, enclosing abundant grains of quartz and chlorite and some rutile needles. The determinable optical characters of this mineral are those of andalusite present in a very early stage of skeleton growth.

In addition to the andalusite, the specimen also contains kyanite in a few small ragged elongated prisms, usually enclosed by and apparently developing at the expense of chlorite, but also occasionally associated with the andalusite. These crystals have moderately high relief, moderate birefringence, positive elongation, maximum extinction angle on (100) of about 30° ($Z \wedge c$), negative optical character and large axial angle, and undoubtedly represent an incipient growth of kyanite.

Other minerals include scales of muscovite associated with abundant altered chlorite, a few cloudy grains of kaolinised felspar, rutile in pale yellow prisms, a few clusters of dark yellow irregular shaped granules with extremely high relief (probably brookite), zircon, apatite and a little granular carbonate.

A second rock (1/792) from the same area has a similar texture in hand specimens but is of a mottled pink colour. Small clear white crystals of andalusite can be seen scattered through a fine granular matrix of pink quartz and pale green to colourless mica flakes.

The thin slice reveals a typical porphyroblastic granular texture of andalusite in quite well crystallised products crowded with fluid inclusions, grains of quartz and a few rutile needles, and usually surrounded by and apparently altering to aggregates of scaly colourless chlorite, with some muscovite, set in a ground mass of clear broken and irregular to rounded quartz grains, and interstitial fibrous chlorite, and sericite.

Kyanite occurs in one or two scattered crystals distinguished from the andalusite by their characteristic bladed form and higher relief. Other accessories include rutile, in tiny rods and geniculate twins ranging from almost colourless to dark yellow and occurring often in clusters or in strings of crystals, and fragments of bleached, obviously detrital biotite, and a few grains of zircon.

ORIGIN AND METAMORPHISM.

Following are the chemical analyses of the Mt. Leonora, Mt. Kenneth and the Quinn's rocks:—

	A.	B.	C.	D.	E.	F.
SiO_2	76·71	82·74	72·57	75·35	78·28	84·11
Al_2O_3	20·08	14·84	10·15	11·35	9·48	8·05
Fe_2O_3	1·70	·43	·49	·79	·40	*Nil*
FeO	...	...	2·70	1·76	2·65	·62
MnO	*Nil*	*Nil*	·05	·12	·03	*Nil*
MgO	·06	*Nil*	9·38	4·69	5·60	4·21
CaO	·56	·09	*Nil*	Trace	·11	·18
Na_2O	·07	·40	·34	·30	·23	·25
K_2O	·11	·26	·28	2·06	·19	·18
H_2O —	·21	·03	·02	·10	·06	·06
H_2O +	·24	·17	3·19	3·10	3·19	2·15
TiO_2	·66	1·33	·57	·51	·04	·05
P_2O_5	...	Trace	·20	·07	·05	·01
ZrO_2	...	...	...	Present	Trace	Trace
CO_2	...	...	...	·03	·02	*Nil*
FeS_2	...	...	...	·17	*Nil*	·02
	100·40	100·29	99·94	100·40	100·33	99·89
Sp. Gr.	2·81	?	?	2·72	2·70	2·67
Analyst:	C. C. Williams.	H. Bowley.	H. Bowley.	D. G. Murray.	H. Bowley.	H. Bowley.

A. Spec. 5084 Kyanite-bearing andalusite-quartz schist. Vicinity of Trig. Station, Mt. Leonora, Mt. Margaret Goldfield (15, p19).

B. Spec. 1/2002 Andalusite-quartz schist. West slope of Mt. Leonora, Mt. Margaret Goldfield (17, p25).

C. Spec. 1/1679 Kyanite-bearing quartz-chlorite schist. 7 miles east-south-east of Mt. Kenneth, Yalgoo Goldfield (14).

D. Spec. 1/2695 Quartz-muscovite schist. Near Camel Paddock (162M. on No. 1 Rabbit Proof Fence) vicinity of Mt. Kenneth, Yalgoo Goldfield.

E. Spec. 1/791 Andalusite bearing quartz-chlorite schist with incipient kyanite. Dump of No. 2 Stock Well, near Water Res. 13435, Quinn's, Murchison Goldfield (19, p18).

F. Spec. 1/792 Andalusite-quartz-chlorite schist with incipient kyanite. Princess Dagmar Water Shaft, GML 843N, Quinn's, Murchison Goldfield (19, p18).

An examination of the above analyses clearly indicates the essential similarity of the rocks, and the variations closely reflect the mineralogical differences. In general they all show a very high percentage of SiO_2, and a notable excess of Al_2O_3 over the 1 : 1 ratio necessary to satisfy the CaO and the alkalies present. From the alumina content the percentage of andalusite, kyanite, etc., present in the Leonora rock is 30.8% for A and 20.80%

for B, and in the Quinn's rocks 5.36% for E and approximately 5.00% for F. In the Mt. Kenneth rocks this figure lies between 10% and 11% for C, while for rock D the amount of alumina available after satisfying the soda and potash is too small to permit of the production of any andalusite. The percentage of alkalies in most of the rocks is very low—in all but one specimen (D) being less than 0.7% and of these the Na_2O content is generally slightly in excess of the K_2O. The Mt. Kenneth and Quinn's rocks all show an overwhelming dominance of MgO over CaO— and the total lime content in all the rocks except A is extremely low.

The high silica percentage, the predominance of alumina over lime and the alkalies, the dominance of magnesia over lime and the low alkali content are criteria favouring the sedimentary origin of a metamorphic rock. (20). The presence of large quantities of andalusite or the allied kyanite or sillimanite in quartzose crystalline schists reflects the existence of an abundant alumina content and is usually a reliable indication of contact or thermal metamorphism of original sedimentary material in the case of andalusite, and of a higher grade more regional type of metamorphism where kyanite or sillimanite predominates.

The Camel Humps and Mt. Leonora Rocks.

As has already been shown by the microscopic descriptions, the Camel Humps and Mt. Leonora rocks are similar in composition, the essential minerals of the former being quartz and kyanite with minor quantities of rutile, and of the latter quartz, andalusite (and kyanite or sillimanite) and rutile. The accessories in each case are confined to a little mica, iron ore and detrital zircon, with possibly a slightly increased quantity of graphitic material in the Leonora rock. The percentage of aluminium silicate minerals in both is approximately the same, ranging from about 20% to 30%.

The microscopic texture and the mineralogical and chemical compositions of both the Camel Humps and the Leonora rocks, then, are essentially typical of metamorphosed sedimentary rather than igneous rocks. They were probably both originally fairly pure, fine grained argillaceous sandstones (slightly carbonaceous in the case of the latter) derived from the mechanical denudation of an original granitic or acid sedimentary terrain. Without considerably more detailed field observations little can be said regarding the conditions of sedimentation but the material originally deposited evidently consisted of an admixture of fine sand and clay, which suggests a comparatively rapid deposition with little mechanical sorting under such conditions as may be expected to exist, say, in deep water near the mouth of a stream channel. The apparently localised occurrences of the clay-bearing sands within what appear to be extensive ferruginous sandy beds may also suggest original delta deposits.

The pronounced titanium content indicated by the abundance of rutile in both the Camel Humps and the Leonora rocks, and reflected in the analyses of the latter, was probably derived in part from detrital rutile but also from the break-down of the original leucoxene and biotite in the sediments before and during deposition. Under increasing temperature conditions fresh rutile has crystallised out contemporaneously with the development of the aluminium silicate minerals.

The metamorphism in both the Camel Humps and the Leonora areas appears to be essentially of the regional type due probably to depression of these portions of the earth's crust into a zone of higher temperature and pressure. It is conceivable that in the Camel Humps area these conditions were produced as a large scale granite contact-intrusion effect but it appears improbable that during such an intrusion shearing stress would remain sufficiently constant for the formation of kyanite as the sole representative of the aluminium silicate minerals. There is no evidence of the existence of andalusite at any stage in the development of the Camel Humps rock. In the field the nearest undoubted outcrops of intrusive granite are about a mile to the west of the outcrops of kyanite quartz schist. The actual contact is marked by a thick layer of overburden which covers the intervening country. The only other intrusive rock in the vicinity is a very small dyke of acid porphyry occurring near the southern Camel Hump. Contact thermal effects of this intrusion can be assumed negligible.

No large body of undoubted intrusive granite or other igneous rock is known to exist in the immediate vicinity of Mt. Leonora. The general north-south schistosity of the country in the neighbourhood of both the Camel Humps and Leonora was probably the result of regional shearing pressures mostly contemporaneous with the formation of the metamorphic minerals.

It is evident that the Mt. Leonora rock commenced recrystallisation largely under deficient shearing stress as shown by the predominant early development of the andalusite. At a slightly later stage, however, whilst the rock was still at a fairly high temperature, it became subjected to increasing shearing stresses—probably associated with folding movements responsible for the schistosity of adjacent greenstone. This pressure finally reached such a stage that further growth of the so called "anti-stress" mineral andalusite was completely inhibited and it commenced recrystallisation into the more stable kyanite and sillimanite.

According to Harker (4, p. 232-3) this association of andalusite with kyanite is decidedly rare. He quotes an occurrence in the Flüela district, near Davos (Switzerland), but here it is believed that the formation of the andalusite belonged to a later phase of metamorphism after a rapid falling off of shearing stress while temperatures still remained high. Examples of the growth of kyanite in pseudomorphs after chiastolite as a result of regional metamorphism superimposed on normal thermal metamorphism of an area of original pelitic sediments are recorded by C. E. Tilley from Ross-shire, Scotland (1).

The presence of such a high grade metamorphic mineral as kyanite in rocks believed to form part of the Older Greenstone Series is of particular interest in so far as it shows that in some portions of the Mt. Margaret Goldfield this Series has suffered a higher grade of metamorphism than had previously been recognised there. In these localities the rocks have evidently been subjected to regional pressures and temperatures comparable with those which must have existed in some of the more advanced metamorphic areas of the State, e.g., the Chittering Valley and the Clackline-York districts. Igneous greenstones, believed to have been chiefly lavas contemporaneous with the sediments, probably form the bulk of the Older Greenstone Series in most parts of the Mt. Margaret Goldfield. In some places well preserved structural features indicate that these igneous greenstones have suffered very little metamorphism of any kind but in the localities described above the presence of kyanite in associated meta-sedimentary beds show that here at least they have been subjected to high stresses and temperatures. However, their composition is such that they show no striking evidence of these high grade metamorphic conditions which have produced in them some internal recrystallisation often with development of schistosity, but without any marked mineralogical reconstitution.

Finally the significant association of both the Camel Humps and the Mt. Leonora rocks with horizons of banded ferruginous quartzite should be once more noted. They may represent merely more argillaceous and non-ferruginous zones in such banded quartzites, or possibly portions of beds in which the iron content was largely leached away before metamorphism.

It is interesting to note that such minerals as andalusite and sillimanite have been recorded as contact alteration products of banded ironstones near Bulawayo and Salisbury in Southern Rhodesia. (21).

Mt. Kenneth and Quinn's Rocks.

The Mt. Kenneth and Quinn's metamorphics bear a striking similarity to each other in their chemical composition. The principal mineral differences are in the aluminium silicates, the Quinn's rocks containing predominant andalusite, whilst of the Mt. Kenneth types, one specimen (C) carried abundant kyanite while the other (D) has suffered but weak dynamic metamorphism with recrystallisation of white mica under inappreciable temperatures, and no alumino-silicate has been formed. These rocks differ from the Mt. Leonora and Camel Humps types mainly in their lower alumina content and greater proportions of ferrous iron, magnesia, and combined water. These differences are reflected in the much lower percentage of the aluminium silicate minerals and the relative abundance of such minerals as chlorite, muscovite, and to a lesser extent, biotite. A noticeable feature of all these rocks is their remarkably low lime content.

The Mt. Kenneth and Quinn's rocks both have the general appearance, texture and mineral composition, of original medium-fine grained, impure argillaceous grits, which since compaction have suffered some crushing under shearing pressures, and with increasing temperatures have reached an early stage of recrystallisation. In the case of one of the Mt. Kenneth rocks kyanite has been produced as a result of a continuation of shearing stress at the increased temperature. This stress must have been largely absent during the growth of andalusite in the Quinn's rocks but some retrogressive alteration of this mineral to chlorite and muscovite in specimen F suggests a later increased pressure during cooling.

SUMMARY.

During the 1939 field season of the Geological Survey, an occurrence of kyanite-bearing quartz schist, a type hitherto unrecorded from the district, was noted amongst the hills of the Camel Humps, north of Laverton, Mt. Margaret Goldfield. This rock is a fairly high-grade regionally metamorphosed sediment which forms portion of an horizon of banded ferruginous quartzite. In both its field occurrence and its petrography, it is closely comparable with an occurrence of metamorphosed sediments at Mt. Leonora, Mt. Margaret Goldfield.

Mt. Leonora rock is predominantly an andalusite-bearing quartzite or quartz schist in which the andalusite has reached only an early stage of crystalloblastic development. Although some specimens contain minor quantities of the higher grade stress minerals kyanite and sillimanite, mineral composion

indicates that, unlike the Camel Hump's type, shearing stress was largely ineffective during recrystallisation and when at all appreciable occurred only in the closing stages. The mineralogical compositions point to closely similar chemical compositions for the Camel Humps and Mt. Leonora rocks.

Two other interesting varieties of meta-sediments from Mt. Kenneth in the Yalgoo Goldfield, and from Quinn's in the Murchison Goldfield are kyanite-bearing quartz-chlorite schists and andalusite-bearing quartz-chlorite schists respectively, the latter containing incipient kyanite. Comparisons of the chemical analyses of these with the Mt. Leonora rock indicate that the two former consisted originally of very similar sedimentary material—argillaceous sands or fine grits—and that while this may have differed in minor details from the original Mt. Leonora (and Camel Humps) sediments, all these rocks were of essentially similar chemical composition. The existing mineralogical differences have been produced partly by slight chemical variations in the original sediments, and partly as the result of differences in the type and degree of metamorphism which they have suffered.

The discovery of a kyanite rock associated with the Older Greenstone Series in the Mt. Margaret Goldfield is of considerable interest in that it provides evidence of the existence in this district of an hitherto unsuspected high grade of regional metamorphism comparable with that found in such places as the Chittering Valley and the Yilgarn Goldfield.

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Geological Survey of Western Australia.
Perth.

REFERENCES.

(1) Tilley, C. E.: "The Role of Kyanite in the Hornfels Zone of the Carn Chuinneag Granite, Ross-shire." *Min. Mag.* 1935, **24**, p. 92.

(2) "Metamorphic Zones in the Southern Highlands of Scotland." *Quart. Journ. Geol. Soc.* 1925, **81**, pp. 100-10.

(3) Barrow, G.: "The Geology of Lower Deeside and the Southern Highland Border." *Proc. Geol. Assoc. London.* 1912, **23**, pp. 274-90.

(4) Harker, A.: "Metamorphism." London. 1932.

(5) Simpson, E. S.: "Contributions to the Mineralogy of W.A. Ser. 1 (4)." *Jour. Roy. Soc. W. Aust.* 1925-6, **12**, pp. 62-6.

(6) "The Occurrence of Andalusite, Kyanite, Sillimanite and Staurolite in the Chittering Valley." *Jour. Roy. Soc. W. Aust.* 1931-2, **18**, p. 75.

(7) "New Mineral Records—Kyanite, Middle Chittering Valley." *Ann. Rept. Chem. Branch Dept. Mines W.A. Perth.* 1934, p. 78.

(8) "Contributions to the Mineralogy of W.A. Ser. 9." *Journ. Roy. Soc. W. Aust.* 1935-6, **22**, pp. 10-13.

(9) "New Mineral Records—Kyanite, Milly Milly Station, Murchison River." *Ann. Prog. Rept. Geol. Surv. W.A.* 1915, p. 137.

(10) "Kyanite Deposit at Smithfield." *Ann. Prog. Rept. Geol. Surv. W.A. for* 1939, p. 10.

(11) Miles, K. R.: "The Geology and Physiography of the Lower Chittering Area." *Jour. Roy. Soc. W. Aust.* 1937-8, 24, pp. 13-42.

(12) Ellis, H. A.: "A Kyanite Deposit 10 miles S.W. of Bridgetown." *Ann. Prog. Rept. Geol. Surv. W.A. for* 1939, pp. 9-10.

(13) Carroll, D.: "Report on Laterite Specimens from Kyanite Locality, S.W. of Bridgetown." *Ann. Prog. Rept. Geol. Surv. W.A. for* 1939, p. 11.

(14) Talbot, H. W. B.: "A Geological Reconnaissance in the Southern Portion of the Yalgoo Goldfield." *Ann. Prog. Rept. Geol. Surv. W.A. for* 1919, pp. 9-10.

(15) Jackson, C. F. V.: "Geology and Auriferous Deposits of Leonora, Mt. Margaret Goldfield." *Geol. Surv. W.A. Bull.* 13, 1904, pp. 18-20.

(16) Maitland, A. G.: "Notes on the Geology of Leonora." *Ann. Prog. Rept. Geol. Surv. W.A. for* 1909, p. 14.

(17) Clarke, E. de C.: "The Field Geology and Broader Mining Features of the Leonora-Duketon District." *Geol. Surv. W.A. Bull.* 84, 1925, pp. 23-4.

(18) Gibson, C. G.: "The Geology and Mineral Resources of a part of the Murchison Goldfield." *Geol. Surv. W.A. Bull.* 14, 1904, p. 40.

(19) Feldtmann, F. R.: "The Mining Centres of Quinn's and Jasper Hill, Murchison Goldfield." *Geol. Surv. W.A. Bull.* 80, 1921, pp. 13-19.

(20) Bastin, E. S.: "Chemical Composition as a Criterion for Identifying Metamorphosed Sediments." *Journ. Geol.* 1909, **17**, p. 445.

(21) Mennell, F. P.: "The Geological Structure of Southern Rhodesia." *Quart. Journ. Geol. Soc.* 1910, **66**, p. 357.

3.—THE CONTACT BETWEEN THE GRANITIC ROCKS AND THE CARDUP SERIES AT ARMADALE.

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CONTENTS.

I.—INTRODUCTION.

The Darling Scarp (Jutson, 1934, p. 84) is a prominent physiographic feature of the country near Perth. It forms the western edge of the Western Australian Pre-Cambrian plateau, which stands about 1,000 feet above sea level, and which is made up mainly of granitic rocks with later doleritic intrusions. West from this scarp and extending to the coast is a comparatively flat coastal plain underlain by Cainozoic and Recent sediments and bordered along the coast by Recent sand dunes (Clarke, 1926).

On the western face of the scarp a series of steeply dipping slaty sediments which form a narrow band between the granitic rocks and the younger horizontal sediments of the coastal plain is developed in a number of places extending from Gosnells and Kelmscott in the north to at least as far south as Mundijong (Honman, 1912 and Esson, 1927). These slaty sediments have been referred to as the Cardup Series (Clarke, 1930, table, p. 187) and they are considered by both Clarke (loc. cit.) and Forman (1937, p. xxiv.-xxv.) to be contemporaneous with the Jimperding Series of Yilgarn (early Pre-Cambrian) age and therefore older than the granites and granitic gneisses of the Darling Range. Forman (1937, p. xxiv.) says that the structures in the Cardup Series between Kelmscott and Mundijong conform to the local structures in the adjoining gneisses and suggests that the gneisses are, in part, of the same age as the 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 Darling Range.

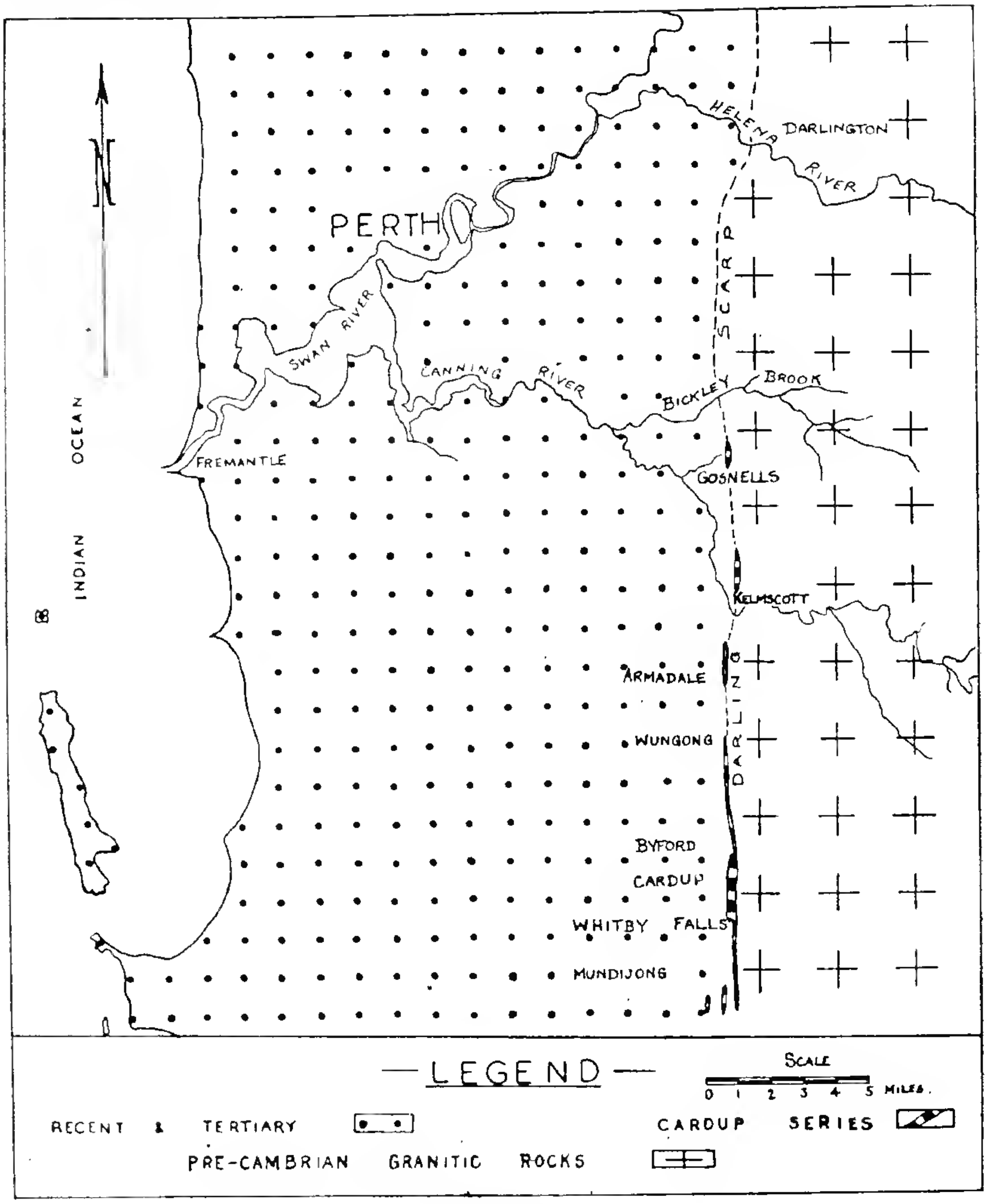

Figure 1.

Geological sketch map of the country between Upper Swan and Mundijong and extending to the coast, showing localities mentioned in the text.

The present investigation was undertaken to determine if possible, whether this "granitisation" of the Cardup Series has actually taken place and to determine the relative age of the granitic gneisses and the slaty sediments of the Cardup Series. I am indebted to Mr. H. A. Ellis, Assistant Government Geologist of Western Australia, for suggesting that the possibility of granitisation of the Cardup sediments should be investigated.

The area examined in detail is situated on the Darling Scarp just south of the Narrogin Inn at Armadale, some 19 miles south-east from Perth (fig. 1). It measures only about ½ mile x ¾ mile, but outcrops are fairly abundant; fresh examples of both the sedimentary and granitic rocks are obtainable in the two quarries; and most of the rock types that have been noted elsewhere in the vicinity of the Darling Scarp are developed. This small area is therefore perhaps the most suitable place to commence a detailed study of the petrology and structure of the Scarp.

II. GEOLOGY.

(1) *The field distribution and age relations of the rocks.*

The eastern half of the area (Plate 1) is occupied by granitic gneisses in which there appear to be two distinct groups:

(i) The fine banded granitic gneisses forming the western edge of the granitic rocks. These form a band approximately 8 chains wide which trends 350° parallel to the contact of the granitic rocks and the Cardup sediments. The foliation in these gneisses strikes parallel to the gneiss-sediment contact and dips at 50° to 60° towards the east. These gneisses appear to be uniform and granitic in character throughout the whole band and nowhere were they found to carry xenolithic inclusions as do the hybrid gneisses farther to the east. Contortion of the gneissic banding is visible in places and in other places the banding may be almost invisible, the rocks there being indistinguishable from massive granites.

(ii) The hybrid gneisses which occupy all the area to the east of (i). These gneisses have a general strike of 25° and dip at angles of 40° to 60° to the east. They are best exposed in the Roads Board quarry in the north-eastern corner of the area.

The rocks in this quarry and their field relations will be described in some detail as it is clear here that there have been two distinct periods of granite intrusion, the evidence for which periods of granite intrusion in the Pre-Cambrian history of Western Australia has been accumulating during recent years (Miles, 1938, p. 36; Prider, 1938, p. 101, and 1939, p. 93; Ellis, 1939, p. 91).

The rocks developed and their field relations as seen in this quarry are:—

(a) Dark coloured biotite-epidote-hornblende hornfelses. These rocks are well developed on the southern wall of the quarry where they appear to form a flat lying band in a more granitic gneiss (b) which is crowded with xenoliths of this dark green hornfels. On the western wall of the quarry, just inside the entrance the biotite-epidote-hornblende hornfels occurs as numerous xenoliths up to 12 inches diameter accompanied by xenoliths of coarsely granular quartz (? quartzite) in a hybridised gneiss (b) (plate 2, fig. 1). This dark coloured hornfels (together with the quartz xenoliths) is clearly the oldest rock exposed in the quarry.

(b) Mesocratic hybrid augen gneisses. These form the base in which the xenoliths (described above) occur. They are well banded coarsely granular rocks, often exhibiting augen structures and are composed of quartz and felspar with thin lenticular dark coloured bands, which under the microscope are seen to be remnants of the biotite-epidote-hornblende hornfels and they appear to have resulted from the intrusion of granitic material into the biotite-epidote-hornblende rocks (see under petrology)—this rock thus represents the first period of granite intrusion (or granitisation). The best exposures of this rock are to be seen on both faces of the quarry just inside the entrance.

(c) Aplogranite. This rock, a leucocratic medium grained massive to very slightly gneissic granite with little or no ferro-magnesian constituents (with the exception of occasional biotite-epidote-hornblends clots picked up from the older rocks) is exposed over the greater part of the north-west and south-west walls of the quarry. It is clearly intrusive into the hybrid gneiss (b above) which, in places, occurs in the form of large irregularly oriented angular blocks suspended in the aplogranite which truncates the banding of the gneiss. The aplogranite is therefore definitely a later intrusion and represents the second period of granite intrusion.

(d) Dolerite. A post-aplogranite dolerite dyke is present near the north-eastern edge of the main quarry and is younger than all the above mentioned rocks which it cuts indiscriminately.

The exposures in this Roads Board quarry therefore give us considerable information regarding the age relations within the eastern group of gneisses of the Armadale area. The sequence is:—

Younger.	(4)	Dolerite dykes.
	(3)	Massive aplogranites.
	(2)	Hybrid augen gneisses.
Older.	(1)	Biotite-epidote-hornblende hornfelses and quartz xenoliths in the hybrid gneiss.

The field relations of the eastern group of gneisses to the western group are unknown. The eastern group shows the highest degree of hybridisation in the north-eastern part of the area but continue to be hybridised to some extent even at the south-eastern corner.

A number of well defined quartz veins which all have the same strike of approximately 305° and dips of 85° to 90° to the north-east are seen to cut through both the hybrid gneisses and the fine banded granitic gneisses. Two of these quartz veins (one of them some three or four feet wide) were traced right to the contact of the gneiss and the Cardup sediments but careful search shows that they do not extend beyond the contact and they appear to be of pre-Cardup age, probably representing an ultra-acid differentiate from the aplogranite magma. If this be the case the position of the Cardup Series in the Pre-Cambrian succession is fixed as younger than the granite but older than the quartz dolerite intrusions, which are considered by all observers to have taken place during late Pre-Cambrian times and which represent the youngest rocks in the Western Australian Pre-Cambrian shield. (Clarke, 1930; Forman, 1937.)

Quartz veins striking almost due north also occur but are not so well developed as those which strike north-west. The main member of the north striking group forms a prominent quartz blow on the north side of the Bedfordale Road near the southern boundary of the area (Plate 1). The "blow" is lenticular and appears to be surrounded by granitic gneiss. There are some small mineworkings on this blow in the form of a shallow incline shaft and an adit—observations made on the white quartz from the surface and the softer more micaceous rock below are described in the section on petrology. The surface quartz in places shows the presence of irregular strings of fine grained dark coloured rock, not unlike slate in appearance. Extending north from this quartz blow along the same strike there is a band where no outcrops are to be found but where occasional small boulders of the dark coloured fine grained slaty rock are noticeable. There is no doubt that this band of slaty rock extends north to at least as far as the centre of the mapped area (Plate 1). Further consideration of the origin of this rock is given in the petrology section of this paper.

The western strip of the area is occupied by the sedimentary rocks of the Cardup Series. These rocks strike parallel to the granite gneiss-sediment contact and dip (on the average) 60° to the west. Traversing this series in a westerly direction from the contact the succession is quartzite (with fine cherty bands), sandy slate, fine white slate, dark greyish to black carbonaceous slate, and fine white slate (these rocks are referred to as slates but they are little more than shales with a very poorly developed fracture cleavage). A few examples of graded bedding were noted in the section exposed along the Bedfordale Road at the south end of the area and readings taken here indicate that the older beds lie to the east, i.e., that the sequence is normal and not overturned. The actual contact with the granitic gneisses is only visible in one place (on the road at the south end of the area) but it can be fixed within several yards over the remainder of the area and the succession of beds is everywhere the same. The Cardup sediments are best exposed in the quarry at the south-western corner of the area (where the slates have been quarried for brickmaking) and are seen to be slightly drag-folded and traversed by numerous minor faults with displacements of several inches. The nature of this minor faulting and drag-folding will be more fully described in the following section dealing with the structure of the area.

The Cardup Series is cut by a number of doleritic dykes which may be traced from the granitic rocks into the neighbouring sediments. From the geological plan of the area (Plate 1) it will be seen that the dolerite dykes appear to have been intruded along a definite set of fractures which extend from the granitic rocks into the sediments. In one place (on the west wall of the slate quarry) greenstone has been intruded in the form of a sill in the sediments and has produced slight contact alteration of the slaty rocks. No such contact effects were noticed along the gneiss-sediment contact.

From the field occurrence the chronological order of the rocks exposed in the area mapped appears to be:—

Youngest. (8) Minute barite veinlets in the dolerite on the east face of the slate quarry.

(7) Dolerite dykes.

(6) Epidiorite sill in Cardup slates.

(5) Cardup sediments (quartzites, sandy slate, white slates, black carbonaceous slates, white slates).

(4) Quartz veins in gneisses.

(3) Aplogranite intrusions. } Fine banded granitic gneisses, exact relation to (2) and (3) unknown.

(2) Hybrid augen gneisses. }

Oldest. (1) Biotite-epidote-hornblende hornfels and quartz (? quartzite) xenoliths in the hybrid augen gneisses.

(2) *The Geological Structure.*

Mapping of all of the available minor structures of the exposed rocks has yielded a considerable amount of information regarding the structure of the area (and of the Darling Scarp generally). The hybridised gneisses of the eastern section show minor folding in a number of places but no constancy in the orientation of these structures could be found, as will be readily understood after an examination of the exposures in the Roads Board quarry, where the gneisses are seen to be in xenolithic blocks, irregularly oriented, in the intrusive aplogranite. No attempts have therefore been made to interpret the minor drag-folded structures seen in these rocks.

The drag-folds in the fine banded granitic gneisses are more constant in character and indicate that the easterly dipping rocks of this band form the eastern limb of a normal anticline with a pitch to the south varying from 0° to 30°. All outcrops in this band were carefully examined for these drag-folded structures and wherever visible they invariably indicated that this band formed the east limb of a normal anticline.

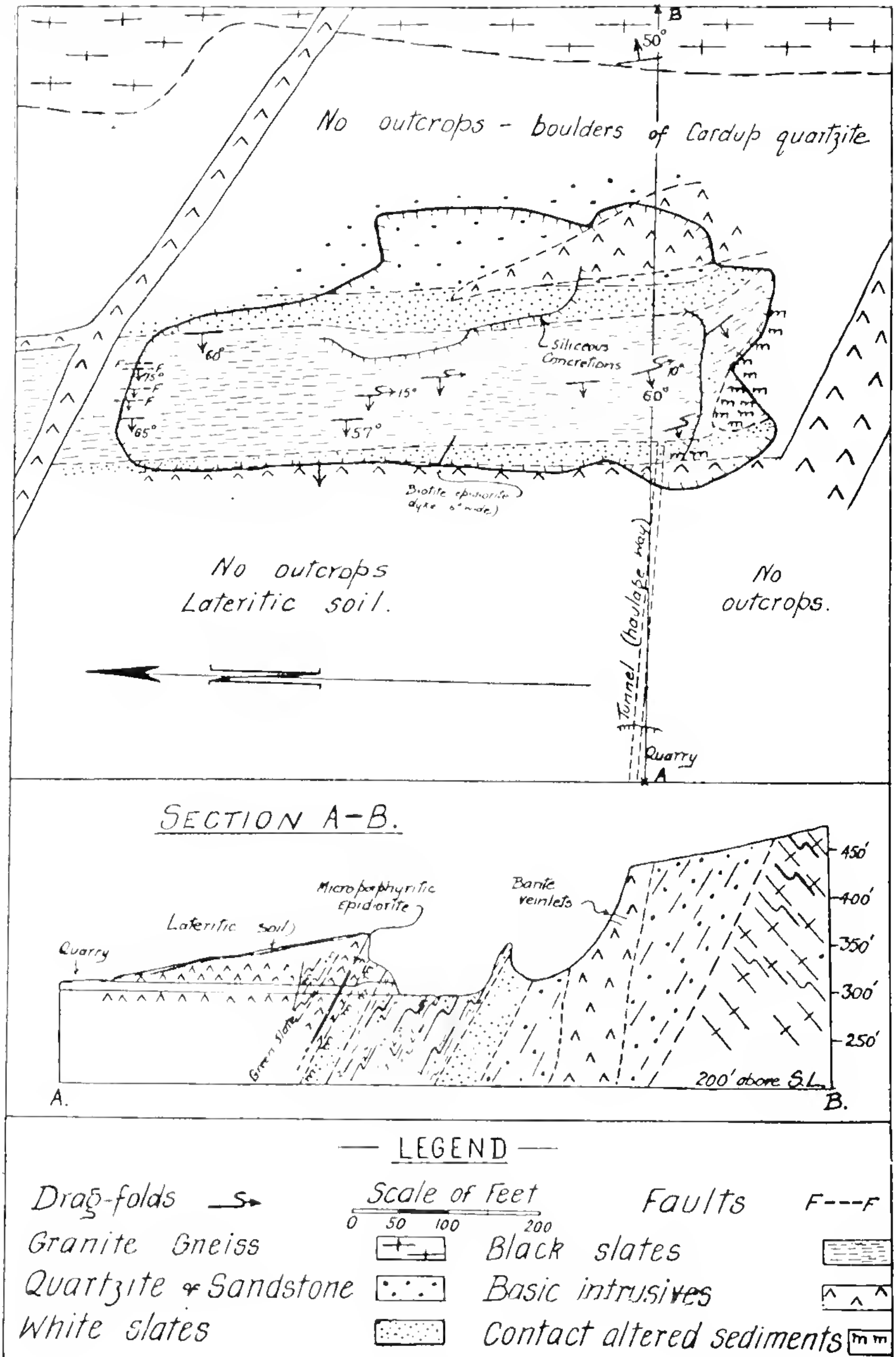

Figure 2.
Geological plan and section of the slate quarry, Armadale.

Minor structures (other than the graded bedding seen in several places on the Bedfordale Road) observed in the Cardup sediments were visible only in the slate quarry as other exposures are rather poorly developed. A detailed survey of the quarry was made for dragfolding, minor faulting and fracture cleavage and the results are shown in figure 2 (plan and section of the slate quarry). The drag-folds indicate that the beds to the west have moved *up* and over the beds to the east, i.e., that the slates in this quarry form the western limb of a normal anticline. A close examination across the black carbonaceous slate band at the south end shows that the dragfolds are directed in the same direction right throughout the band thus precluding the possibility of isoclinal folding in these rocks. All of the dragfolds observed pitch to the south at 10° to 15°. The bedding planes of the dragfolded slates show a distinct set of slickensides (Harnisch) which strike E. to W. normal to the axes of the dragfolds. Tests made of the roughness of the bedding surface in this direction indicate that the beds to the west have moved up and over the beds to the east.

The fracture cleavage is rather poorly developed in these rocks but where present is constant in strike (parallel to the bedding) and dip (almost vertical) throughout the quarry. In the northern wall of the quarry there are a number of small faults developed which are generally parallel to the fracture cleavage and along which movements up to 6 inches have been observed. All of these small faults (which are either vertical or dip very steeply to the west) are of reversed character and indicate upthrusting from the west (as deduced from the curvature, due to dragging, of the bedding planes in the vicinity of the faults).

It will be seen that all of these minor structures are closely related and almost certainly developed by the same movement, viz., a movement causing the western beds to be moved up and over the beds to the east. There are therefore two possible interpretations possible for these minor structures:—

(i) That these beds form the western limb of an anticline which pitches flatly to the south

or

(ii) That there has been upthrusting from the west, the sediments having been upthrust over the granitic gneisses lying to the east.

Considering the structural features of the Cardup sediments in conjunction with the structures in the band of fine grained granitic gneisses adjoining them to the east we see that they appear to be to some extent complementary, the gneisses forming the east limb of an anticline, the sediments forming the west limb of the same anticline. Forman (1937, p. xxiv.) considers that the gneisses may represent portions of the Cardup sediments which have suffered granitisation and it has been suggested to me (in discussions with Mr. H. A. Ellis) that in the Armadale Area the gneisses and sediments form part of a single structural unit (an anticlinal fold) which at the time of folding consisted entirely of sedimentary rocks of the Cardup Series, but which has since suffered partial granitisation, all of the rocks lying to the east of the axial plane of this anticline having been granitised and those to the west remaining unaffected by the granitising solutions which came from the east. Detailed field mapping, especially in connection with the field relations of the quartz veins, appears to indicate that the gneisses antedate the sediments, whereas the granitisation theory suggested by Forman (loc. cit.) requires that the Cardup sediments should be older than the granitic gneisses. The petrological evidence regarding the relative age of the gneisses and sediments and the possibility of granitisation of the Cardup sediments is discussed in the next section of this paper.

III. PETROLOGY.

(A) *The older hybrid gneisses and the associated xenoliths.*

These rocks are best exposed in the Roads Board quarry and most of the material described below came from this locality. Since the material forming the xenoliths has largely controlled the character of the hybridised granitic gneiss it will be described first.

Amongst the xenoliths three distinct types of material can be seen, thus:—

(i) *Quartz xenoliths.*

These are fragments up to four or five inches in diameter, mostly smaller. The quartz is clear and coarsely crystalline and under the microscope is seen to be an allotriomorphic mosaic of irregular shaped grains with crenulate boundaries. No signs of original clastic structure are visible and the large grains show only very slight strain shadows. Minute gas-liquid inclusions are very abundant. This material may have originated either from a quartzite or from quartz veins. It has contributed a considerable amount of what would at first sight appear to be primary (magmatic) quartz of the gneiss, for the size of the xenolithic quartz bodies varies down to the order of 5 mm. diameter.

(ii) *Epidote-muscovite xenoliths.*

These xenoliths occur in fragments up to four inches diameter. The rock is massive, very fine grained and consists of a fine mesh of small muscovite flakes with idioblastic tablets of highly birefringent epidote uniformly and abundantly dispersed throughout. The epidote is present to the extent of about 30 per cent. of the rock. In places remnants of untwinned (?) plagioclase (with the refringence approximately the same as that of canada balsam) crowded with sericitic inclusions are present. This rock appears to have resulted from the alteration of a basic plagioclase rock which must have been closely associated with the rocks from which the next group of xenoliths were derived.

(iii) *Hornblende-epidote-biotite hornfels xenoliths.*

Xenoliths of this type, which are dark greenish to black in colour, are the most abundant type and have exerted considerable control on the character of the hybrid gneiss, having contributed most of the ferromagnesian content of that rock. Rocks of this type appear to be rather constant in character wherever noted and are best developed in the Roads Board quarry. They are fine even grained, with no trace of any directed structure, the structure being coarse hornfelsic. Under the microscope the rock is seen to consist of a decussate aggregate of biotite and hornblende associated with granular aggregates of epidote. Irregular grains of magnetite are scattered uniformly throughout the rock, and apatite, in stout euhedra to 0.5 mm. diameter, is abundant.

The biotite and hornblende are closely associated. The biotite is a brownish-green, practically uniaxial variety with $\beta = 1.637$ and in all of the slices examined is considerably in excess of the bluish-green amphibole which occurs in well shaped prisms with irregular terminations, towards which the biotite is idioblastic. The amphibole has pleochroism, X brownish-green, Y brownish green, Z green (slightly bluish) and absorption $X < Y > Z$. The extinction $Z \wedge c$ is 18° and the optical character -ive. In several specimens a blue-green amphibole with X light yellow-green, Y olive green, Z bluish-green, absorption $X < Y < Z$ and $Z \wedge c = 17°$, is idioblastic towards the biotite. It occurs in elongated prisms, often in clusters with the long axes of individual prisms subparallel.

The epidote occurs in patches with an aggregate structure, made up of a mesh of tiny euhedral prisms, with which is associated some brownish-green biotite (in much smaller flakes than in the biotite-hornblende areas). The epidote is practically colourless and brightly polarising pistachite, although some fine granular zoisite appears to be present in the granular aggregates. These epidotic areas appear to represent a replacement of original calcic plagioclase.

In one specimen (19209)* the original structure of the rock can be seen by an examination of the slice under very low magnification—it is that of a coarse grained rock with plates to 4 mm. diameter of blue-green amphibole (now partially replaced by biotite aggregates) and felspar (now completely replaced by epidote) and it has undoubtedly originated from a coarse grained basic igneous rock. This is supported by the presence of skeletal plates of magnetite (fig. 3c) which appear to have been derived from ilmenite plates.

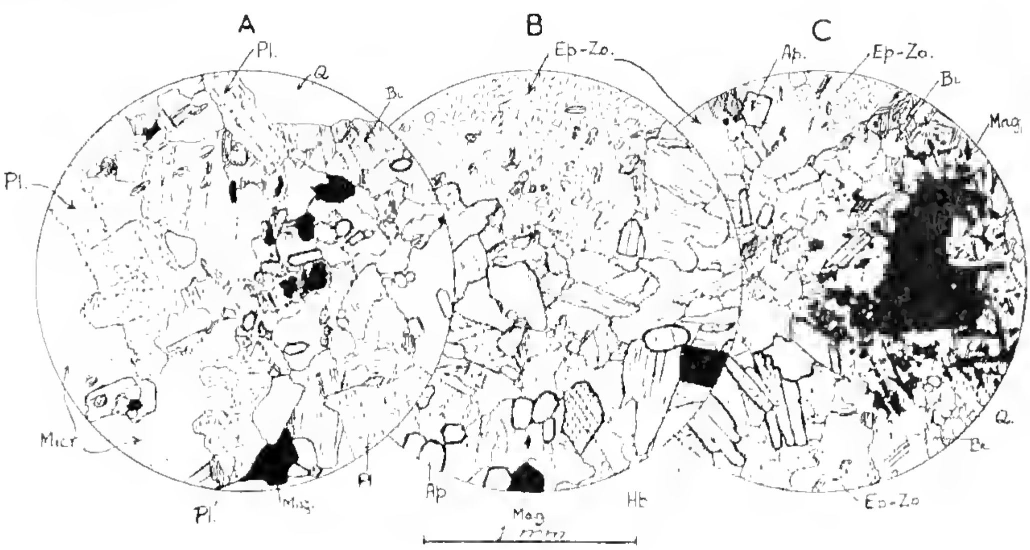

Figure 3.

A. Hybridised granite gneiss—showing basic clots consisting largely of greenish brown biotite, with magnetite and apatite. The granitic portion consists of an allotriomorphic granular aggregate of microcline (Micr), turbid plagioclase (Pl) and quartz (Q).

B. Basic xenolith—coarser variety of hornblende-biotite-epidote hornfels showing occurrence of epidotic aggregates (Ep-Zo) in distinct areas (originally plagioclase crystals). Shows also the deenssate structured aggregates of biotite and hornblende (Hb), with magnetite and apatite (Ap) euhedra.

C. Basic xenolith—finer grained variety of hornblende-biotite-epidote hornfels, showing segregation of epidotic minerals in patches and large skeletal plate of magnetite (after ilmenite).

* Catalogue number, Geology Dept., University of Western Australia.

Apatite is remarkably abundant and builds well shaped stout prisms which are idioblastic towards all the other constituents—it appears to have been introduced during the process of granitisation to which these basic rocks have been subjected. Magnetite and pyrite, scattered uniformly (the latter very sparsely) throughout the rock are the only other accessories.

An analysis made of this type yielded the result shown in Table I., column 1.

TABLE I.

	1.	2.
SiO	40·09	66·52
Al_2O_3	14·01	13·22
Fe_2O_3	6·05	4·99
FeO	14·42	3·29
MgO	4·34	0·58
CaO	9·89	2·84
Na_2O	0·46	3·45
K_2O	3·78	2·95
H_2O+	1·97	0·50
H_2O-	0·07	*Nil*
CO_2	0·08	0·03
TiO_2	2·76	0·66
P_2O_5	1·24	0·10
MnO	0·38	0·15
BaO	*Nil*	0·53
FeS_2	0·77	0·07
Fe_7S_8	0·02	*Nil*
Cr_2O_3	*Nil*	*Nil*
V_2O_3	0·03	0·04
SO_3	*Nil*	*Nil*
	100·36	99·92

Analyst: C. R. Le Mesurier.

1. Hornblende-epidote-biotite hornfels (19483), xenolithic in hybrid gneiss, Roads Board quarry, Armadale.
2. Hybrid gneiss (19482), rock enclosing the xenolith from which analysis 1 was made, Roads Board quarry, Armadale.

The composition of the basic xenoliths is peculiar, the most striking feature being the low silica and magnesia and the high figures for the iron oxides and potash. From the texture of the rock it appears to have been originally a medium grained basic igneous rock such as a gabbro although the FeO/MgO ratio is rather high. It must be borne in mind, however, that this rock has suffered considerable change, the original pyroxene having gone over to biotite, involving a loss of silica, magnesia, and lime and an addition of potash and alumina—the chemical evidence then supports the suggestion that these rocks were originally basic igneous types. There has been a marked concentration and fixing of P_2O_5 in these xenoliths. No rocks have been noted amongst the Cardup Series which could possibly be related in any way to the xenolithic masses in the hybrid gneisses.

The *hybridised gneiss* itself is a medium grained, well banded mesocratic rock. The dark bands which produce the gneissic appearance are composed largely of material similar to the basic xenoliths described above. Interbanded with this material are leucocratic bands of pale flesh coloured felspar closely associated with quartz and a pale greenish slightly epidotised felspar—in places the flesh coloured felspar is present as augen.

Under the microscope the most pronounced feature is the presence of dark clots, elongated parallel to the banding, which are made up of brownish green biotite, euhedral apatite, sphene, magnetite, and rare blue-green hornblende (fig. 3A). These clots are undoubtedly derived from the basic xenoliths which are so abundantly scattered through this gneiss (plate 2, fig. 1). The other constituents are considerably epidotised plagioclase (most abundant), clear microcline and quartz. The quartz is all slightly strained. Both quartz and microcline have enclosed the plagioclase.

An analysis of this rock is shown in Table I., column 2, and this indicates that there has been a considerable addition of both silica and soda to the original basic rock. As mentioned above some of the quartz of the hybrid gneiss may be xenolithic although the greater part, as seen from its relations with the introduced microcline, has undoubtedly been introduced during the granitisation process.

Read (1926, p. 165) has described the process of hybridisation of a granitic magma by ultrabasic material and his remarks apply equally well to the Armadale hybridised rocks. The basic xenoliths, in their high biotite content, are clearly hybrid types representing basic igneous material which has been permeated with potassic solutions from an intrusive granite. This granite, which represents the first period of granite intrusion in this area, was itself considerably hybridised by the incorporation of this basic hybrid and is now represented by the mesocratic hybridised gneiss described above.

(B) *The younger granite (Aplogranite).*

The aplogranites are leucocratic, medium to coarse grained (in places pegmatitic) rocks composed of quartz and felspar with practically no ferromagnesians. The texture is allotriomorphic granular and the constituents seen in thin slice are quartz, slightly perthitic microcline and oligoclase-albite with an occasional shred of greenish biotite. Both the microcline and finely twinned plagioclase are slightly dusted with inclusions and a noticeable feature is the frequent occurrence of myrmekitic structures in the plagioclase when it occurs in contact with microcline. Most of the quartz shows slight strain shadows.

This acid granite may have possibly been the intrusion which caused the earlier granitisation effects that have been noted above but in its field relations appears to belong to a distinctly later period of intrusion.

(C).—*The fine banded granitic gneisses* (forming the western edge of the granitic rocks).

In many respects these rocks are similar to the various gneisses and acid rocks of the Roads Board quarry, although no dark coloured xenolithic bodies have been found in them. Their structure varies from place to place, from finely banded granitic gneisses to almost massive granites in which no banded structures are visible. The massive structured rocks have a granitic texture and are made up of quartz, fresh microcline and slightly turbid oligoclase and so appear to be very similar to the aplogranites of the eastern half of the area. The finely banded gneisses contain quartz, microcline, oligoclase, clotted shreds of strongly pleochroic greenish-brown biotite and some muscovite, which appears to be developing from a turbid sericitised felspar. The microcline is perfectly fresh.

The exact relations of these rocks to the eastern gneisses are unknown. Petrologically they appear to be very similar although not so extensively hybridised and are only considered apart here because of their somewhat different strike. So far as could be seen there are no remnants of slate (see also under "quartz veins") in these granite-gneisses nor any development of minerals which would suggest the assimilation of argillaceous material by the intrusive granite. There is no chilled contact, the rocks being coarse grained right to the contact with the Cardup sedimentary series.

(D).—*The Cardup Series.*

(i) *The Sandstones:*

Near the contact with the granitic rocks the sandstones are medium grained grits and as the series is traversed in a westerly direction the average grain size diminishes. All types are very quartzose varying in colour from white to pale yellow green, where the rocks have been considerably epidotised. The white quartzites are composed almost entirely of slightly rounded to subangular equidimensional quartz grains to several mm. diameter in a finer grained quartzose groundmass containing occasional grains of epidote. Amongst the coarse grains there are occasional slightly rounded grains of clear microcline—these appear to be detrital and not introduced by later solutions and probably were derived from the erosion of the microcline bearing rocks to the east.

Close to the quartzite-granite gneiss contact on the Bedfordale road a peculiar light greenish epidotic quartzite is often developed. This rock is banded, made up of layers of epidotised quartzite (grit) and layers of darker greenish fine grained actinolite-epidote-quartzite with narrow irregular and lenticular bands of pale brownish cherty material. In some instances these cherty patches are small flattened ellipsoidal bodies, scattered throughout the comparatively coarse grit from which they are very sharply defined. The structure of these chert patches is fine grained hornfelsic and the constituents are mainly slightly turbid isotropic material with fine granular quartz, granular epidote and acicular (?) actinolite ($Z \wedge c = 16°$, pale greenish to colourless, not sensibly pleochroic, $\gamma = 1.644$). The origin of these peculiar cherty bands and lenticles is obscure but they appear to be original sedimentary structures which have later been contact altered. The most probable origin that suggests itself is that they represent small clay balls which have been flattened during the earth movements to which these rocks have been subjected. The presence of (?) actinolite suggests that these balls may have been to some extent calcareous.

The coarser gritty parts of these greenish quartzites are similar to the white quartzites with the addition of granular epidote which often occurs as angular grains moulded around the larger detrital quartz grains indicating that the epidote has been introduced after the formation of the original gritty sediment and was probably derived from the quartz dolerite intrusions which cut through the sediments in this locality.

(ii) *The slates.*

Two distinct types of slate are developed—their field relations have been discussed above.

(a) *The black slates*: these are finely bedded, dark grey to black in colour, different bands having varying content of graphitic material. The dominant constituent is fine fibrous sericite together with extremely fine granular weakly birefringent (?) quartz and black graphitic material. An interesting constituent is pale brownish green tourmaline, which occurs in minute idioblastic prisms to 0.05 mm. in length scattered sparsely, with random orientation, throughout the rock. It is strongly pleochroic, ω brownish green, ϵ colourless, and the refractive indices $\epsilon = 1.621$, $\omega = 1.649$, appear to indicate a member of the dravite-schorl group.

(b) *The white slates:* these rocks are made up almost entirely of fine fibrous sericite with a much smaller amount of pale brownish flaky biotite and minute clear grains of quartz. Minute idioblastic tourmaline prisms, similar to those in the black slates are distributed sparsely throughout the rocks (all of the slaty rocks examined contained this tourmaline none of which is detrital). Narrow darker coloured bands (up to 1 inch wide) occur in the white slates in places and these consist predominantly of pale brownish biotite with sericite in minor amount. The grain in these narrow bands is considerably coarser but this is largely an original feature and is not due in the main to recrystallisation as the quartz grains of such bands are markedly larger than in the white slate. The minute tourmaline prisms appear to be more abundant in these bands.

In some places near the western wall of the slate quarry, close to the albite-epidiorite, the white slate has a slightly knotted structure, the "knots" usually being small rectangular shaped plates (up to 4mm. x 4mm. x 1mm.) which consist of kaolin with small quartz grains distributed uniformly throughout. These porphyroblasts appear from their shape to be andalusites but careful search has not disclosed any relicts of this mineral. Their true character must therefore remain unknown but they appear to be the result of contact metamorphism of the slate by the nearby basic intrusion.

Joint planes in the white slates near the south-west corner of the slate quarry are coated with pale yellow earthy jarosite.

Other than the occasional thin dark bands and rare examples of the knotted slate, this group of white slates appears to be rather uniform in character. An analysis of a specimen from the west side of the slate quarry yielded the result shown in table II.

TABLE II.

	1.	2.	3.	4.	5.
SiO_2	65·22	61·63	58·38	50·10	50·00
Al_2O_3 ...	16·71	16·33	15·47	25·12	24·14
Fe_2O_3 ...	1·93	4·10	4·03	5·12	2·79
FeO	3·23	2·71	2·46	1·52	4·67
MgO ...	2·87	2·92	2·45	3·93	4·16
CaO	0·05	0·50	3·12	0·35	0·07
Na_2O ...	0·76	1·26	1·31	0·05	1·10
K_2O	5·98	5·54	3·25	6·93	8·63
H_2O+ ...	2·12	3·24	3·68	6·82*	3·06
H_2O- ...	0·16	0·31	1·34	...	0·24
TiO_2 ...	0·35	0·68	0·65	0·50	0·50
CO_2	0·05	0·41	2·64	...	0·07
P_2O_5 ...	0·08	0·16	0·17	...	0·11
MnO ...	0·03	0·09	Tr.	...	0·04
BaO	0·11	0·06	0·05	...	0·15
FeS_2 ...	*Nil*	0·04	...	...	...
Cr_2O_3 ...	0·01	...	...	...	0·01
V_2O_3... ...	0·03	...	...	...	0·04
SO_3	0·11	...	0·65	...	0·15
Graphite ...	0·05	*Nil*	0·81†	...	0·07
NaCl... ...	*Nil*	...	...	...	..
(Others) ...	...	0·06	...	...	..
	99·85	99·98	100·46	100·44	100·00

Analyst: C. R. Le Mesurier.

* Ignition loss on material dried at 110°C. † Organic material.

1. White slate (19203), west side of slate quarry, Armadale.
2. Cambrian slate, Vermont (*U.S. Geol. Surv. Bull.* 591, p. 250).
3. Composite analysis of 78 shales (F. W. Clarke, "Data of Geochemistry," *U.S. Geol. Surv. Bul'.* 770, 1924, p. 30).
4. Illite (fine colloid fraction), Ordovician shale, Gilead, Calhoun Co., Illinois (R. E. Grim, R. A. Bray and W. F. Bradley, "The micas in argillaceous sediments," *Amer. Min. Vol.* 22, 1937, p. 823).
5. Analysis of Armadale slate (of col. 1) with SiO_2 reduced to 50% and the other oxides recalculated to sum to 100, for comparison with analysis of illite (col. 4).

In this table the analysis of the Armadale slate is compared with that of a slate from Vermont, U.S.A. (col. 2) which it resembles very closely, and with the average of 78 analyses of shale (col. 3). The main features of the analysis are the high silica, alumina and potash, the two latter being a reflection of the high sericite content. Such features would be common in slates derived from illite rich clayey sediments (an analysis of illite is shown in table 2, col. 4 and is compared with that of the Armadale slate from which excess silica has been removed (col. 5), and although the potash content is high, it is quite normal and does not indicate that the rock has suffered any "granitisation."

(c) *More arenaceous types*: to the east the slates become more arenaceous and pass gradually into the normal sandstones. On the western side of the quarry, between the white slate and the albite epidiorite, there is a band of greenish more sandy slate. This band swings towards the east at the south end of the quarry. This rock is distinctly coarser textured and comparatively large rounded quartz grains are abundant—the only other constituent of note is a greenish brown biotite which appears to have developed during contact metamorphism of this band by the basic intrusive. Separation of the heavy minerals yielded only a few much worn and rounded zircons. At the south end of the quarry this greenish rock encloses several rounded boulders of granitic material which consist largely of a granophyric intergrowth of quartz and acid plagioclase. These "boulders" appear to be somewhat rounded and some doubt exists whether they are boulders or irregular granophyric intrusions, as they are traversed by narrow (¼-inch wide) veinlets of quartz which appear to pass through both the boulders and the enclosing green sandy sediment. I incline to the view that they are boulders and that the associated veinlets are similar to the quartz veins developed in the Cardup Series (which are described under "quartz veins" below).

(iii) *Contact metamorphism of the Cardup sediments.*

Considering first the arenaceous rocks close to the contact with the granitic rocks—the main contact metamorphic effects have been the introduction of epidote and the development in certain narrow bands of acicular (?) actinolite—the latter are in radiating aggregates and appear to result from the thermal metamorphism of a slightly calcareous rock but whether this alteration is due to intrusion by the granite or to intrusion by the quartz dolerite dykes is not clear—the introduction of the epidote was most likely effected during the intrusion of the doleritic rocks.

In the slates lying farther to the west there has been some new mineral development:—

(1) The development of the kaolinic knots which seems to be closely related to the greenstone intrusions.

(2) The presence of idioblastic tourmaline in all the slaty rocks of this area is interesting—this mineral may have been introduced from granitic intrusions, from the basic intrusives (Agrell, 1939, p. 333, has described the development of dravite in adinoles and considers that the boron was introduced from nearby albite dolerites) or may have developed from the boron contained in the original unmetamorphosed sediments. Goldschmidt and Peters (1932) have shown that the boron content of clay sediments is often sufficient to bring about crystallisation of tourmaline when these sediments suffer dynamic metamorphism and that it is not necessary to look to later acid intrusives for the origin of the boron. The absence of tourmaline from the rocks immediately adjacent to the granite and its occurrence in the slates some distance away seems to suggest that it was not derived from that source. It is possible then that the tourmaline was introduced from the basic igneous rocks but more probable that it resulted from the crystallisation of original constituents of the argillaceous sediments from which the slates were derived.

(3) The development of biotite and chloritoid. Biotite has undoubtedly been formed during the metamorphism of the slaty rocks as it is often well developed on the fracture cleavage surfaces. It is well developed in small pale brownish flakes in the slates from the slate quarry which are close to greenstone intrusions but is absent farther to the north (along the Bunbury Road) where the slates are some distance from the intrusive dykes. This points to the development of the biotite being due to contact alteration consequent upon the intrusion of the basic rocks. Specimens from the haulage tunnel leading out from the south-west corner of the slate quarry afford information regarding the contact alteration of the Cardup sediments—the rocks in this tunnel consist of slates and sandstones which have been intruded by a chlorite-albite epidorite sill and then later by a quartz-dolerite dyke, both of which have in some measure affected the sediments. The rocks (together with brief descriptions) encountered in this tunnel are (see fig. 4):—

From east end to 45 feet in*—*normal slates* showing development of small flakes of pale brownish biotite.

From 45′ to 49′ in—*chloritoid slate*—this is the normal slate (similar to that from 0′ to 45′) with a development of small chloritoid porphyroblasts, at first rare and then becoming more abundant towards the west. The chloritoid porphyroblasts are well formed but have been replaced by penninite with extremely weak birefringence (almost isotropic with very weak ultra blue interference colours), positive elongation and marked pleochroism X pale yellow green, Y = Z deep green. At first sight these small porphyroblasts appear to be chloritoid but the pleochroism and orientation are those of penninite. There is little doubt, however, that they were originally chloritoid. This is the only place where this mineral has been found in the area and it is of interest as it seems to fix the period of intrusion of the chlorite-albite epidiorite as more or less contemporaneous with the earth movements affecting the Cardup Series. Chloritoid is generally regarded as a stress mineral—in the present instance it is clearly related in some way to the epidiorite sill as it decreases in amount away from that body.

* All measurements are from the east end of the tunnel and have been measured along the north wall.

It appears most probable that it developed during the earth movements which affected the Cardup Series while these rocks were still at elevated temperatures following the intrusion of the greenstone sill.

From 49′ to 53′ in—*biotite-quartz hornfels*—these rocks are hornfelsed argillaceous sandstones. They are fine grained, dark green in colour and under the microscope are seen to be made up of rounded quartz grains with interstitial flaky pale brown biotite with some pale green chlorite and sericite.

From 53′ to 90′ in—*chlorite-albite epidiorite sill* (described in a later section) with a narrow intrusion of a microporphyritic epidiorite between 57′ and 58′.

From 90′ to 99′ in—contact altered *sandy slate* similar to that between 49′ and 53′ except that it is much finer grained and apparently less altered, the biotite being in much smaller flakes.

From 99′ to 109′ in—*quartz-biotite-actinolite hornfels* similar to the actinolite bearing hornfelses developed in the arenaceous sediments nearer the granite contact (described in the section dealing with the Cardup sandstones).

From 109′ to 311′ in—*uralitised quartz-dolerite*. At 311′ there are several small irregular bodies (? veins) of coarse grained quartz (which under the microscope shows considerable cataclasis).

From 311′ to the west end—greenstone, probably the chlorite-albite epidiorite but the rocks here become too weathered for exact determination.

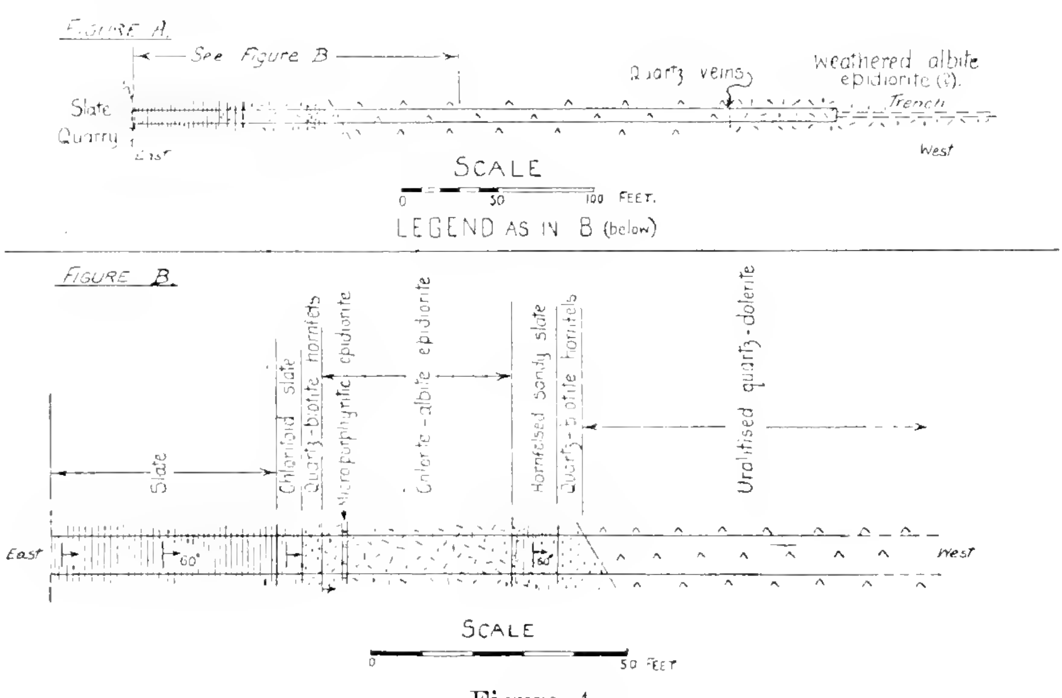

Figure 4.

A. Geological sketch plan of the tunnel leading out from the south-west corner of the slate quarry, Armadale.

B. Enlargement of geological plan of east end of the tunnel from the slate quarry, showing the relations of the Cardup sediments, the chlorite-albite epidiorite sill and the later quartz dolerite dyke (note the narrow intrusion of microporphyritic epidiorite into the chlorite-albite epidiorite sill).

The section exposed in this tunnel indicates that the Cardup sediments have been contact metamorphosed over limited distances by both the chlorite-albite epidiorite and the later quartz-dolerites. It also indicates that the development of the epidote-actinolite-quartzite noted near the granite contact is a contact effect due to the quartz-dolerites and not to the granitic rocks.

(E). *The basic intrusives of post-Cardup age.*

The following types have been recognised:—

(i) *Chlorite-albite epidiorites.*

This type has been noted in one place only, viz., in a sill like intrusion into the slates in the west wall of the slate quarry. This body is itself intruded by a narrow "sill" (12 inches wide) of a microporphyritic epidiorite, which is described below.

The chlorite-albite epidiorite is of interest because it can undoubtedly be correlated with the porphyritic albite epidiorite (referred to as albite porphyrite by Esson, 1927, p. 6) which occurs at various localities (Wungong, Cardup, Whitby Falls and Mundijong) extending some 15 miles to the south along the Darling Scarp. The rock at Armadale is not porphyritic but its texture and mineralogical composition (both of which differ considerably from the normal quartz-dolerites) are similar to those of the rocks from the areas to the south.

The Armadale rock is medium, even grained and almost indistinguishable in hand specimen from the uralitised quartz-dolerites. It consists of a plexus of clear albite prisms (figure 5B) with interstitial aggregates of chlorite, uralite and biotite together with some turbid epidotic material and a little leucoxene. The chlorite forms a fine grained mesh enclosing patches of green uralitic amphibole and occasional flakes of pale greenish-brown biotite. It is a pale greenish prochlorite, very slightly pleochroic and almost isotropic (with very weak anomalous colours)—the optic character is neutral and the refractive index $\beta = 1.633 \pm .002$. This mineral agrees with the chlorites of the low grade epidiorites described by Wiseman (1934, p. 360.) The albite is fresh (although slightly dusted with inclusions and penetrated by acicular amphibole) and thus differs considerably from the epidotised plagioclase of the other basic igneous rocks of the area.

The analysis of this rock is recorded below:—

TABLE III.

			Norm.	
SiO_2	...	47·08		
Al_2O_3	...	14·78		
Fe_2O_3	...	1·32	Or	6·12
FeO	...	13·80	Ab	26·20
MgO	...	7·45	An	18·35
CaO	...	4·24		
Na_2O	...	3·10	C	1·84
K_2O	...	1·03		
H_2O +	...	3·89	hy	26·49
H_2O —	...	0·22	ol	9·47
TiO_2	...	2·49		
P_2O_5	...	0·41	mg	1·86
MnO	...	0·31	il	4·71
BaO	...	*Nil*	ap	1·01
Cr_2O_3	...	*Nil*	py	0·14
FeS_2	...	0·14		
		100·26		

Analyst: R. T. Prider.

Chlorite-albite epidiorite (20532), 78 feet from east end of tunnel, Slate quarry, Armadale.

The most outstanding features of this analysis are the low CaO and the considerable Na_2O content which indicate that the felspar prior to metamorphism was moderately rich in the albite molecule and that the rock was approaching a spilitic type. It certainly differs considerably from the later quartz-dolerites which contain a much higher proportion of lime (see Table IV.). An unusual feature is the excess of alumina and the appearance of corundum in the norm—this excess of alumina is no doubt contained in the chlorite and its presence may be due to slight contamination of the epidiorite by the aluminous slates which is has intruded.

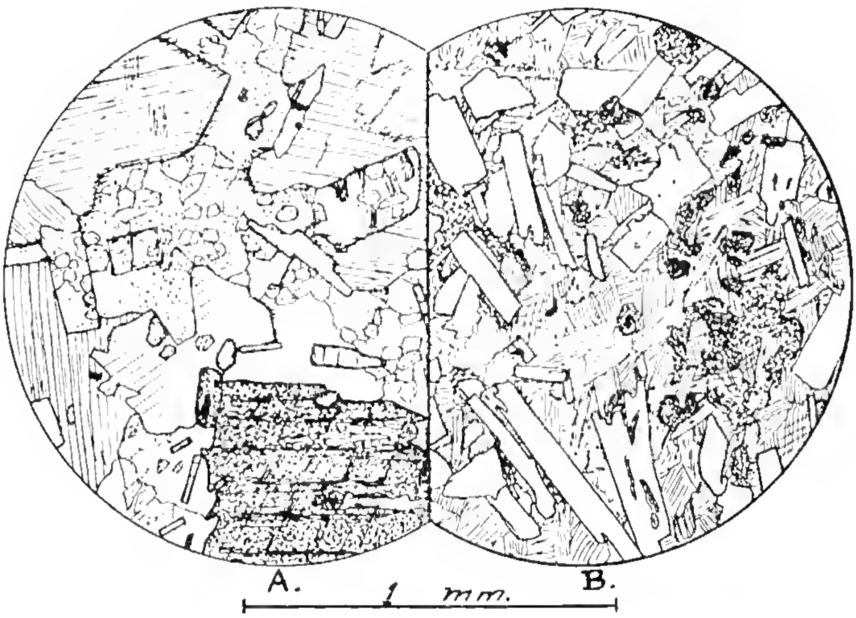

Figure 5.

The basic intrusives.

A. Uralitised quartz dolerite, showing subophitic relation of uralite and turbid plagioclase (dotted), plates of leucoxene after ilmenite and angular areas of end phase quartz with rods of apatite.

B. Albite epidiorite, showing clear laths of albite in a ground of biotite, uralitic amphibole and turbid epidotic material.

The field relations of this rock are shown in figure 4. Consideration was given, on a previous page, to the contact metamorphism effected by this sill on the Cardup sediments, and, in the development of chloritoid, it was considered that the post Cardup earth movements took place shortly after the intrusion of the chlorite-albite epidiorite. This rock then is a low grade epidiorite showing a grade of metamorphism comparable with that of the associated sediments. The quartz-dolerite group (to be described presently) appears to belong to a later period of intrusion, as a micro-porphyritic epidiorite (described under (iii) below) which is considered to be genetically related to the quartz-dolerites is intrusive into the chlorite-albite epidiorite.

(ii) *Uralitised quartz-dolerites.*

Rocks of this group form the bulk of the post Cardup intrusions and all are very uniform in character. Variations in granularity dependent on the position in the dyke are noticeable but the mineralogical composition remains constant with the exception that the end phase quartz and micro-pegmatite are somewhat more abundant in the central parts of the dykes than on the edges.

The characteristic ophitic to sub-ophitic texture of the quartz-dolerites is always developed, although somewhat obscured by uralitisation and epidotisation (figure 5A). A typical specimen from the large dyke striking south-east from the Roads Board quarry is a greenish, medium even grained rock, which consists of pale green uralite, epidote, zoisite, leucoxene, quartz and minor accessories including a little brown hornblende, biotite and apatite. A relict ophitic relation is visible between the uralitic amphibole plates and the zoisitic aggregates replacing plagioclase prisms, the only other noticeable textural feature being the angular patches of quartz and micropegmatite (in which the felspar is represented by turbid zoisitic aggregates).

The uralite is the most abundant constituent, occurring in plates up to 1 mm. diameter. It is a pale greenish fibrous variety with weak pleochroism, X very pale greenish (almost colourless), Y pale green, Z pale green, absorption $X < Y = Z$, extinction $Z \wedge c = 16°$ and (—) 2V large. It is often dusted with magnetite inclusions. No relict pyroxene is visible, nor has any been noted in any of the basic intrusive rocks of this area. In the vicinity of the quartz and micropegmatite areas the uralite shows a further change to pale green, weakly pleochroic, optically positive chlorite and more rarely to brownish hornblende.

The plagioclase is represented by granular aggregates of zoisite, epidote and fine granular plagioclase. Ilmenite has been replaced entirely by fine granular leucoxene which occurs in areas up to 1½ mm. diameter in which the skeletal structure of the original ilmenite is preserved. Occasionally the leucoxene is recrystallised to sphene, which occurs in rounded grains with central iron ore inclusions.

The quartz and micropegmatite areas in this rock, up to ½ mm. diameter, are similar to those of the normal quartz-dolerites except that the felspar is replaced by fine granular zoisite. These quartz and micropegmatite areas are penetrated by slender prisms of apatite. In specimens from the centre of this same dyke the micropegmatite areas vary in size to 1½ mm. diameter and the presence of brownish hornblende in its vicinity is more noticeable.

TABLE IV.

	1.	2.	3.	4.
SiO_2	48·83	49·13	49·22	50·52
Al_2O_3	13·46	13·13	12·62	13·76
Fe_2O_3	2·88	3·65	3·16	3·87
FeO	10·29	8·95	11·09	8·50
MgO	8·03	7·64	6·42	5·42
CaO	11·95	11·84	10·59	9·09
Na_2O	1·32	1·72	1·86	2·42
K_2O	0·50	0·16	0·30	0·96
H_2O + ...	1·39	1·72	2·24	1·51
H_2O —	0·08	0·04	0·12	0·76
CO_2	...	...	*Nil*	0·58
TiO_2	1·24	1·27	2·00	2·39
P_2O_5	0·07	0·14	0·09	0·26
MnO	0·18	0·15	0·33	0·16
BaO	*Nil*	...	*Nil*	0·03
FeS_2	Tr.	0·45	0·22	0·06 (S)
Cr_2O_3	0·08	...	Tr.	Tr.
V_2O_3	...	...	Tr.	0·05
	100·30	99·99	100·26	100·34
Analyst :	R. T. Prider.	R. T. Prider	—	—

TABLE IV.—*continued.*

	2.	3.	4.
Norms.			
Q	1·86	3·48	4·14
Or	2·78	1·11	1·78
Ab	11·00	14·15	15·74
An	29·19	27·52	25·18
di	23·86	24·88	22·15
hy	23·07	18·60	20·12
mt	4·18	5·34	4·58
cm	0·22	...	...
il	2·28	2·43	3·80
ap	0·34	0·34	0·34
py	...	0·45	0·22

1. Uralitised quartz-dolerite (20464), near Roads Board quarry, Armadale.
2. Uralitised quartz dolerite, Toodyay, Western Australia. (Prider, 1938, p. 95.)
3. Epidiorite (uralitised quartz dolerite), Bickley, Western Australia. (Clarke and Williams, 1926, p. 173).
4. Quartz dolerite (average of 6 analyses), Whin Sill, Northern England. (Holmes and Harwood, 1928, p. 530.)

These rocks are therefore best described as completely uralitised quartz-dolerites. An analysis of the typical specimen described above is given in Table IV. where it is compared with other uralitised quartz-dolerites from Western Australia and with the average composition of the Whin Sill.

It will be seen that the analyses of the three Western Australian quartz dolerites are very similar. So far as is known, these rocks all belong to the same period and are all intrusive into the granitic rocks of the Darling Range. In comparison with the normal quartz dolerites (as exemplified by the Whin Sill rocks), they are somewhat richer in iron, lime and magnesia and correspondingly slightly poorer in silica and soda.

(iii) *Microporphyritic epidiorite.*

The occurrence of this rock as a narrow intrusion into the chlorite-albite epidiorite has been noted above. The rock is greenish and extremely fine grained and has a microporphyritic texture with equidimensional phenocrysts of uralite (? after pyroxene) up to ½ mm. diameter (often aggregated to form glomerophenocrysts), and tiny plagioclase laths to ½ mm. long, in a fine grained ground of plagioclase, epidote, zoisite, uralite and pale brownish biotite. The fibrous uralite of the phenocrysts is very pale in colour with similar pleochroism to that in the quartz dolerites, and it shows patchy alteration to biotite. No original pyroxene is visible. This type appears to be closely related to the quartz dolerites, of which it is a fine grained porphyritic representative.

(iv) *Biotite epidiorites.*

This type of rock has been noted in two places only—as a narrow dyke (four feet wide) intrusive into the hybridised gneiss in the Roads Board quarry and as a narrow dyke (10 inches wide) intrusive into the slates in the Slate quarry. The occurrence in the Roads Board quarry appears to be an offshoot from the larger uralitised quartz dolerite to the south-east (described above) but this is by no means certain. It is definitely intrusive into the hybrid gneiss, for it truncates the banding sharply and cannot be one of the basic xenoliths (which it resembles mineralogically).

It is a fine even grained greenish rock showing little, if any, sign of schistose structure. Under the microscope it is seen to consist of a fine allotriomorphic granular aggregate of brownish-green biotite, plagioclase, epidote (and zoisite) and pale green amphibole with accessory leucoxene (after small ilmenite grains) and quartz in small angular grains.

The biotite is a brownish green variety with pleochroism X pale yellow-green, Y = Z deep brownish-green, and absorption X < Y = Z. The axial angle is very small (almost uniaxial) and $\beta = 1.628 \pm .002$. In parts of the rock it occurs in clotted aggregates with a decussate structure, appearing to be either xenolithic or replacing ferromagnesian phenocrysts.

The amphibole is a pale greenish, slightly pleochroic uralite with $Z \wedge c = 16°$. The plagioclase has mostly been replaced by granular epidote and zoisite, but rare small laths of untwinned albitic plagioclase remain.

This rock, in its high biotite content, differs considerably from the uralitised quartz dolerites of the area. An examination of specimens collected from across the dyke showed that the edges are very rich in biotite, which is present to the exclusion of the amphibole, the rock consisting of biotite, epidote (and zoisite) and minor amounts of leucoxene, albite and quartz. The biotite here is in flakes to 0.25 mm. diameter, which is large compared with flakes in the central parts of the dyke, and is often aggregated into clots. At three inches in from the edge the structure is the same with clotted biotites in a ground of biotite, epidote, zoisite and amphibole with accessory leucoxene and quartz. In the centre of the dyke the grain is slightly coarser and the main ferromagnesian is the pale bluish-green amphibole which is in excess of the brown-green biotite. Angular grains of quartz are also more abundant. The mineralogical variation throughout the dyke may be shown by the following estimates of the mineralogical composition of the different rocks examined (figures quoted are volume-percentages) :—

	Edge of dyke.	3in. in from edge.	Centre.
Biotite	65	50	22
Amphibole	*Nil*	15	40
Epidote + zoisite ...	30	30	30
Leucoxene	1	1	1
Albite + quartz ...	4	4	7

An analysis of the specimen from 3 inches from the edge of the dyke yielded the result shown in Table V. It will be seen from this table that chemically this rock appears to be more closely related to the chlorite-albite epidiorite than to the quartz dolerite, the only difference between analyses 1 and 2 being in the alkalies, the biotite epidiorite being exceptionally rich in potash while in the chlorite-albite epidiorite soda is considerably in excess of the potash—it may be noted here however that certain specimens of the chlorite-albite epidiorite that were examined showed considerably more biotite than the specimen analysed.

Wiseman (1934, p. 401) has noted the production of biotite in the peripheral parts of an epidiorite sill at Loch Fyne, Scotland, and he considers that both chlorite and biotite have been produced during the shearing of the epidiorite mass during which process some potash has been introduced by freely circulating solutions thus leading to the formation of biotite. In the Armadale rock there is but little evidence of shearing but the biotite rich peripheral parts of the dyke are similar to the occurrence described by Wiseman. This dyke is intrusive through a considerable mass of the biotitic hornfels in the south-eastern corner of the quarry and may have picked up some potash from this source. However the complete absence

TABLE V.

	1.	2.	3.
SiO_2	48·88	47·08	48·83
Al_2O_3	16·18	14·78	13·46
Fe_2O_3	3·06	1·32	2·88
FeO	11·00	13·80	10·29
MgO	6·87	7·45	8·03
CaO	4·79	4·24	11·95
Na_2O	0·96	3·10	1·32
K_2O	5·32	1·03	0·50
H_2O+	1·24	3·89	1·39
H_2O-	0·33	0·22	0·08
TiO_2	1·49	2·49	1·24
P_2O_5	0·14	0·41	0·07
MnO	0·16	0·31	0·18
BaO	0·14	*Nil*	*Nil*
Cr_2O_3	0·03	*Nil*	0·08
FeS_2	n.d.	0·14	n.d.
	100·59	100·26	100·30
Analyst:	R. T. Prider.	R. T. Prider.	R. T. Prider.

1. Biotite epidiorite (20188), three inches in from edge of dyke, Roads Board quarry, Armadale.
2. Chlorite-albite epidiorite, Armadale. (Quoted from Table III.)
3. Uralitised quartz-dolerite, Armadale. (Quoted from Table IV.)

of amphibole from the edges of this dyke seems to indicate that it has been entirely replaced by biotite and it seems most probable that end phase potassic solutions have been active in these narrow dykes. There is no definite evidence to say to which of the other types of basic intrusive this type is related but the chemical data indicate that it is most probably related to the chlorite-albite epidiorite.

The rock from the narrow dyke in the slate quarry is very similar to that occurring on the edges of the dyke described above with the exception that it is somewhat schistose and very rich in biotite.

(F).—*The quartz veins.*

In the granitic gneisses there are two sets of quartz veins as described in the first section of this paper. So far as can be seen by microscopical examination these veins are similar—they appear to be replacement bodies in shear zones in the granitic rocks, similar to those noted in the Darlington Area (Clarke and Williams, 1926, p. 174). Specimens from the north-west striking veins 300 yards south-west from the Narrogin Inn, show that in places it is a quartz sericite rock which in places has small ironstained cubic cavities from which pyrite has weathered. One specimen from here contained a considerable amount of a fine acicular mineral which is developed in numerous small radiating clusters. These small needles are colourless, have straight extinction and negative elongation and appear to be dravite similar to that described by Simpson (1931, p. 141) from various quartz veins in the granitic rocks of the Darling Range.

The large quartz outcrop near the south end of the area may be taken as representative of the north striking veins. At the surface it appears to be a coarse grained white quartz in some places containing darker coloured strings of slaty material which under the microscope is seen to consist largely of sericitic mica. This dark coloured material, xenolithic in the vein quartz, was analysed and the analysis is shown in table VI., and it will be seen

Table VI.

	1.	2.	3.	4.
SiO_2	47·54	43·37	65·22	65·22
Al_2O_3 ...	29·01	33·19	19·22	16·71
Fe_2O_3 ...	3·59	1·95	2·38	1·93
FeO	1·33	1·00	0·88	3·23
MgO ...	1·53	1·36	1·01	2·87
CaO	*Nil*	*Nil*	*Nil*	0·05
Na_2O ...	0·09	1·03	0·06	0·76
K_2O	10·25	10·17	6·79	5·98
H_2O+ ...	4·42	7·74 {Loss on ignition.	2·93	2·12
H_2O- ...	0·06		0·04	0·16
CO_2	0·03	...	0·02	0·05
TiO_2 ...	0·85	0·33	0·56	0·35
P_2O_5 ...	*Nil*	...	*Nil*	0·08
MnO ...	0·12	...	0·07	0·03
BaO ...	1·01	...	0·67	0·11
Cr_2O_3 ...	0·02	...	0·02	0·01
V_2O_3 ...	0·13	...	0·08	0·03
SO_3 ...	0·07	...	0·05	0·11
				0·05 (Graphite)
	100·05	100·14	100·00	99·85

Analyst: H. P. Rowledge. C. R. Le Mesurier.

1. Sericite schist (19481), (dark patches xenolithic in quartz vein, from which all vein quartz has been removed), near Bedfordale Road, Armadale, *Anal.* H. P. Rowledge.
2. Muscovite, Bamle, Norway. (*Amer. Jour. Sc., vol.* 24, p. 259, 1939).
3. Analysis 1 with SiO_2 made up to 65.22% and the remaining oxides recalculated to sum to 100.
4. White shale, Armadale, Western Australia (quoted from Table II.).

that it is very similar to the analysis of muscovite. A noticeable feature of the analysis is the high baryta content, and the presence of very little SO_3 indicates that it is not in the form of barite but must be in the mica. No barite was visible in the thin sections examined. Floaters of this sericitic material can be traced for some distance in a northerly direction and this appears to be a shear zone in the granitic rocks along which replacement quartz veins have been formed. The other possibility is that this band of sericitic material is an infolded portion of the Cardup slates along which quartz has been introduced. Comparing the analysis of the sericitic material with that of the white slate (table VI, col. 4) the main difference is seen in the amount of SiO_2. If silica is added to the sericite schist to bring it to 65.22% and the remaining oxides recalculated to sum to 100 (col. 3) there is seen to be a close agreement, the main differences being in the higher FeO and MgO in the slate (due to chlorite), the different proportions of the alkalies and the higher BaO content of the sericite schist (this seems to be a significant feature as the BaO in the sericite schist must be in the mica—in this connection it is interesting to note the comparatively high BaO content of the hybridised gneiss in table I.). It must be noted that the products of sericitisation of alkali felspar are similar to those accumulating in certain fine grained argillaceous sediments (especially illitic clays) so that a comparison of these analyses, which are both of highly sericitic rocks, does not convey any real information regarding the origin of the sericite schist. The presence of similar quartz-sericite rocks associated with the north-west system of quartz veins, which in view of their disposition in the field, cannot be regarded as infolded portions of the Cardup slates, would appear to indicate that both groups of veins are of similar origin, i.e., replacements along shear zones. This is supported by the absence in the vicinity of the quartz blow at the south end of the area of other remnants of the Cardup series, for if the slates were infolded then a considerable portion of the more arenaceous sediments underlying them must also have been infolded—no trace of these remains and the evidence is overwhelmingly against the possibility that this band represents an infolded portion of the Cardup slates.

A similar quartz vein in the granitic gneiss near the contact with the sediments of the Cardup Series has been noted near Kelmscott. This occurrence is exposed in a small road cutting on a road leading east from the townsite. The exact position of the sediment-granite contact cannot be located as exposures are very weathered and poor. The slaty Cardup rocks are exposed in several small pits and, as at Armadale, dip steeply to the west. The granite contact lies approximately 200 feet east of these pits and about 200 feet east of the contact there is a quartz vein which strikes 200° and dips steeply to the east. It is bordered by sheared material which at first sight appears to be slate but when closely examined is seen to have a "lensy" structure and not the well bedded character of the slate. Although the material was too weathered for microscopic examination it appears to be a sheared granitic rock rather than the Cardup slate and the occurrence is remarkably similar to that at Armadale. The shear zone in the Kelmscott occurrence is approximately 10 yards wide.

Returning to a consideration of the large quartz blow—in places it has a banded appearance where the quartz has been injected along the schistosity planes of the sericite schist (plate 2, fig 2A). Below the surface, the vein is represented by a quartz muscovite rock not unlike a fine grained greisen, the muscovite here having been recrystallised. The massive quartz of the vein has all been strained (plate 2, fig. 2B) and is, in this respect, similar to that of the north-west group. This straining may have been effected during the movements which tilted the Cardup Series.

All the evidence available, both chemical and petrological, suggests that the north-west and north groups of quartz veins in the gneissic rocks are similar in character and were formed during the same period along shear zones which are developed in a regular pattern and that these veins were subjected to post-crystallisation stress.

Turning now to a consideration of the quartz veins in the Cardup slates—no actual vein in situ was seen in this area, although the presence of heaps of quartz fragments in the slate quarry indicates its presence. Campbell (1910, p. 29) describes these quartz masses as "bunches of quartz veins up to 18 inches diameter." They are probably similar to a larger occurrence of vein quartz in the slates at Cardup, some miles to the south (Clarke, 1930, map on p. 166). The quartz from the Armadale slate quarry is fine, even grained, white, and under the microscope is seen to be an equigranular aggregate of allotriomorphic grains (Plate 2, fig. 2C) which have not suffered any post-crystallisation stress. This vein material therefore appears to have been formed at a later period than the quartz veins in the granitic rocks (which all show stress effects). The veins in the slates appear to be closely related to a thin seam of siliceous concretions which are developed along the east wall of the lower bench in the quarry (fig. 2)—these concretions occur as flattened ellipsoidal bulges averaging 9 inches diameter, projecting from the bedding surface. They have a concentric structure, are cut by numerous intersecting joints and are composed almost entirely of fine grained quartz. The texture is allotriomorphic granular, similar to that of the quartz veins but much finer in grain (average grain size of concretions 0.03 mm. diameter while that of the veins averages 0.15 mm.). Although exposures here do not permit a definite pronouncement that the concretions and quartz veins are genetically related it appears probable that the vein material represents a more complete segregation and coarser crystallisation of the silica than the concretions and that both have been formed by the same process. It is hoped that further light will be thrown upon the origin of these veins by work now in progress by Mr. B. Thomson in the Cardup area. One point however is clear—that the quartz veins in the slates are later than those in the granitic rocks and have not been strained during the movements which affected the Cardup Series.

Other veins:—In the east wall of the slate quarry some very thin veinlets of barite were noted in the highly weathered rock which appears to be one of the basic intrusives. This occurrence is interesting since it throws some light on the origin of the barite-fluor veins in the Cardup Series at Cardup (Clarke, 1930, map on page 166)—it indicates that the barite veins are later than the basic intrusives and were therefore probably derived from the greenstone magma rather than the granite magma. It is interesting to note here that Sweet (1930, p. 258) considers that the barite and fluor bearing veins of the north of England are genetically related to the quartz dolerites of the Whin Sill.

On the south side of the Bedfordale Road (outside the area described in this paper) quartz veins containing small amounts of galena and sphalerite have been found. These occurrences have not been closely examined but they appear to be similar to the silver-lead deposits of Mundijong (Esson, 1927) which are closely associated with a porphyritic albite epidiorite (albite porphyrite of Esson) which is similar to the albite epidiorite from Armadale. The suggestion is put forward here that these silver-lead veins and barite-fluor veins are genetically related to the basic magma rather than to the granitic magma.

IV. CONCLUSIONS.

(a) *The age of the Cardup Series.*

The evidence presented by the quartz veins (both in their field relations and petrology) indicates that the granitic rocks are older than the Cardup sediments. This conclusion is supported by a number of other facts:—(i) that the Cardup Series is a normal erosion sequence and is constant in character along the strike; (ii) that nowhere have the "granitising" solutions been seen to traverse the basal beds of the series nor have any apophyses (such as pegmatites or quartz veins) been seen to pass into the sediments; (iii) that there are no remnants (xenoliths) of the sedimentary series in the gneisses, the only remnants being of older basic igneous rocks; (iv) that no variation in character of the gneiss across the strike, such as would be expected if a series of varying lithology were granitised, has been noted, and (v) the slight contact metamorphic effects noted in the Cardup Series are due to the basic intrusions. Indeed, the only evidence that has been found which in any way favours a pre-granite age for the Cardup Series, lies in the presence in the slates of small amounts of idioblastic tourmaline, which as described above, may equally well be explained as due to crystallisation of components of the original sediment during the earth movements which tilted the Cardup Series.

The position of the Cardup Series in the Pre-Cambrian succession of Western Australia (as deduced from all the evidence available in this area) is therefore later than the final granite intrusions and earlier than the basic igneous intrusions of the Nullagine period (late Pre-Cambrian). I have recently had occasion to examine a collection of rocks from the Stirling Range Series and from the evidence at present available these rocks appear to belong to the same period as the Cardup Series—the field relations of the Stirling Range Series have been investigated by Professor E. de C. Clarke and further details regarding these rocks will be given in a future paper.

(b) *The Darling "Fault" Scarp.*

The area described above includes one of the numerous flat spurs which extend out from the present line of the scarp. If the Darling Scarp is a fault scarp then the fault should be situated somewhere in the vicinity of the tip of these projecting spurs. Movements of the magnitude required to produce a downthrow to the west of several thousands of feet (as required to explain the structure of the coastal plain) should surely be reflected in the comparatively weak slates forming these spurs. Observation of all the minor structures in the slates of the Armadale area indicates in every instance, that the western side has been pushed up and over the rocks lying to the east and appears to negative the possibility of any large faults with a downthrow to the west in the vicinity. The structures are consistent with an extensive downwarp to the west involving a tilting of the Cardup Series to the west and minor upthrusting along the eastern margin of the downwarp. If this be the case (and it will only be proved or disproved by close investigation of the structures in the Cardup Series all along the face of the scarp) then the Darling Scarp, which is one of the most pronounced physiographic features of south-western Australia, must be an erosion feature due to differential erosion of a monoclinal fold rather than a fault structure.

(c) *The Geological History of the Area.*

The geological history of the area, from the evidence presented in the foregoing pages, may be summarised as follows:—

1. Period of granitisation during which pre-existing basic rocks were permeated by granitic emanations and the hybrid gneisses produced.
2. Period of granite intrusion (aplogranite).
3. Earth movements, causing development of shear zones and joint pattern in the granitic gneisses, followed by the formation of the quartz veins in the gneisses.
4. Deposition of the Cardup sediments.
5. Formation of an extensive downwarp parallel to the present Darling Scarp and some distance to the west, involving upthrusting along the eastern margin, development of fracture cleavage in the slates and tilting of the sediments to the west.
6. Intrusion of albite epidiorite sill into Cardup Series, probably contemporaneous with (5).

7. Intrusion of the quartz dolerite series of dykes consequent upon earth movements affecting the Cardup Series.
8. Formation of barite veins as end phase effects of the basic intrusions (galena-sphalerite-quartz veins also probably belong to this period).

End of Pre-Cambrian.

9. Downwarping continuing and sediments being constantly deposited in the depression—the only evidence regarding this long period of geological time being the two thousand feet (at least) of Cainozoic sediments which underlie the coastal plain and cover up all intervening formations. Block faulting may have taken place (as suggested by Jutson, 1935, p. 469) during the uplift of the Western Australian plateau in late Miocene times but differential erosion of hard rocks of the plateau and the soft rocks to the west of the scarp seems capable of explaining the present physiographic features.

V. ACKNOWLEDGMENTS.

I desire to express my thanks to Mr. H. A. Ellis who suggested that the possibility of granitisation of the Cardup Series should be investigated and who was instrumental in having analyses of a number of the rocks made in the Government Chemical Laboratory. My thanks are due also to Mr. H. Bowley, Government Analyst and Mineralogist, for permission to publish these analyses. Chemical analyses made by myself in the Department of Geology were made possible by funds from the Commonwealth Research Grant and this assistance is gratefully acknowledged. I also desire to thank the Senior Students of the University Geology Department (Messrs. Crabtree, Davis, Elvish, O'Driscoll, Telford and Thomson) who, under my supervision, made the survey of the area as part of their field course. Finally I wish to thank Professor E. de C. Clarke for assistance during the revision of the text.

VI. LIST OF REFERENCES.

Agrell, S. O., 1939: "The Adinoles of Dinas Head, Cornwall." *Min. Mag.* **XXV.**, pp. 305-337, 1939.

Campbell, W. D., 1910: "Report on an excursion to Armadale," *Jour. Nat. Hist. and Sc. Soc. of West. Austr.*, Vol. **III.**, No. 1, pp. 28-29.

Clarke, E. de C.—

1926: "The Geology and Physiography of the Neighbourhood of Perth, Western Australia." A.A.A.Sc. Handbook for Perth Meeting, 1926, pp. 23-30.

1930: "The Pre-Cambrian Succession in some parts of Western Australia," Rept. A.N.Z.A.A.Sc. for 1930, pp. 155-192.

and Williams, F. A., 1926: "The Geology and Physiography of parts of the Darling Range near Perth," *Jour. Roy. Soc. W.A.*, **XII.**, pp. 161-178.

Ellis, H. A., 1939: "The Geology of the Yilgarn Goldfield, South of the Great Eastern Railway," *Geol. Surv. W.A. Bull* 97.

Esson, A. G. D., 1927: "The silver-lead deposits at Mundijong." *Geol. Surv. W.A. Ann. Rept.* for 1926, pp. 4-9.

Forman, F G., 1937: "A Contribution to our Knowledge of the Pre-Cambrian Succession in Some Parts of Western Australia," *Jour. Roy. Soc. W.A.*, **XXIII.**, pp. xvii-xxvii.

Goldschmidt, V. M., and Peters, Cl., 1932: "Zur Chemie des Bors II," *Nachrichten von der Gesellschaft der Wissen, Mat. Phys. Klasse*, iii., No. 28, iv., No. **31**, pp. 528-545.

Holmes, A. and Harwood, H. F., 1928: "The Age and Composition of the Whin Sill and related dykes of the North of England," *Min. Mag.*, **XXI.**, pp. 493-542.

Honman, C. S., 1912: "The Extension of the Kelmscott Clay Deposit," *Geol. Surv. W.A. Bull. No.* 48, pp. 63-65.

Jutson, J. T.—

1934: "The Physiography (Geomorphology) of Western Australia," *Geol. Surv. W.A. Bull* 95.

1935: Report of the Australian and New Zealand Assoc. Adv. Sc., Vol. 22 (Melbourne, 1935).

MacGregor, M., and Wilson, G., 1939: "On Granitisation and associated processes," *Geol. Mag.*, Vol. 76, pp. 193-215.

Miles, K. R., 1938: "The Geology and Physiography of the Lower Chittering Area," *Jour. Roy. Soc. W.A.*, Vol. **XXIV.**, pp. 13-41.

Prider, R. T.—

1934: "The Geology and Physiography of the Jimperding Area," *Jour. Roy. Soc. W.A.*, Vol. **XX.**, pp. 1-16.

1938: "The Petrology of part of the Toodyay District, Western Australia." Unpublished dissertation for the Ph.D., Cambridge, 1938.

1939: "The Petrology of part of the Toodyay District, Western Australia," *Abst. Diss. Univ. Cambridge* for 1937-8, p. 93.

Read, H. H., Phemister, J., and Ross, G., 1926: "The Geology of Strath Oykell and Lower Loch Shin," *Geol. Surv. Scot.* Explanation of sheet 102.

Saint-Smith, E. C., 1912: "A Geological Reconnaissance of a portion of the South-West Division of Western Australia," *Geol. Surv. West. Aust. Bull.* 44.

Simpson, E. S., 1931: "Contributions to the Mineralogy of Western Australia, Series VI.," *Jour. Roy. Soc. W.A.*, Vol. **XVII**, pp. 137-149.

Sweet, J. M., 1930: "Notes on British Barytes," *Min. Mag.*, Vol. 22, pp. 257-270.

Wiseman, J. D. H., 1934: "The Central and South-West Highlands Epidiorites: a Study in Progressive Metamorphism," *Quart. Jour. Geol. Soc.*, Vol. **xc.**, pp. 354-417.

EXPLANATION OF PLATE 2.

Figure 1—

Hybrid gneiss from the Roads Board quarry, Armadale, showing xenolithic character of the gneiss. The xenoliths are of biotite-hornblende-epidote hornfels (dark coloured) and epidotic material (light coloured). The banded character of some of this gneiss is seen in the top left hand side of the boulder. Quartz xenoliths are present (the coin is lying on one) but they are indistinct in the photo. The clinometer gives the scale.

Figure 2.—Photomicrographs of quartz veins.

A. Sericitic rock from shear zone in gneiss, with secondary veinlets of quartz (from large quartz blow near the Bedfordale Road). Ordinary light x 40.

B. Strained quartz from the same locality as (A). The entire field (and almost all of the slide from which this photo was taken) is part of the same crystal. The strain pattern is interesting, consisting of subparallel lines along which actual granulation has taken place arranged obliquely to the direction of "slicing" or gliding shown by the strain shadows. Nicols crossed x 40.

C. "Vein" quartz from the slate quarry. Occurs as masses in the slates. Shows unstrained character and even granular mosaic structure. Nicols crossed x 40.

Plate 2.

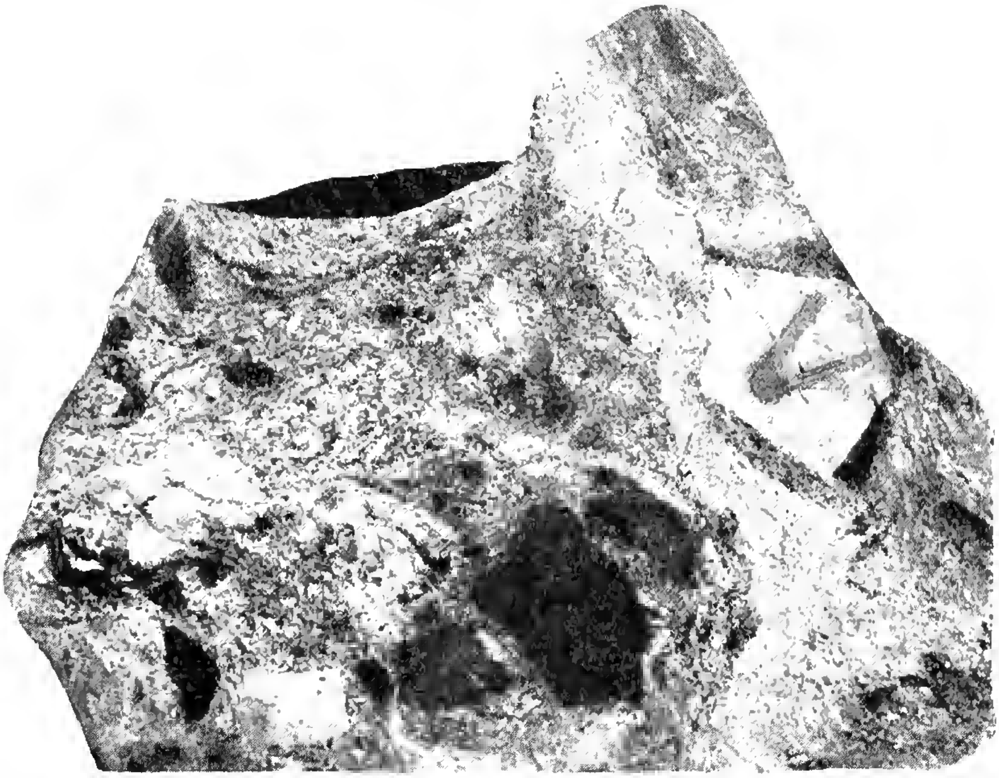

Figure 1.

A B C

Figure 2.

4.—FURTHER PERMIAN CORALS FROM WESTERN AUSTRALIA.

By Dorothy Hill, M.Sc., Ph.D.

Communicated by Curt Teichert, Ph.D.

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The corals described in this paper are from the *Cyathaxonia* faunas in the Permian of Western Australia. These faunas are:—

NORTH-WEST.[1]

KENNEDY SERIES.

WANDAGEE SERIES:—

	Page
Linoproductus stage:	
? *Euryphyllum reidi* Hill	61
Favosites, sp.	64
Thamnopora immensa Hill	65
Thamnopora aff. *marmionensis* (Etheridge)	66
Lamellibranch stage.	
Calceolispongia stage:—	
Allotriophyllum, sp.	60
Euryphyllum reidi Hill	61
? *Euryphyllum*, sp.	62
Verbeekiella mersa, sp. nov.	63
Thamnopora aff. *marmionensis* (Etheridge)	66

CUNDLEGO SERIES:—

Plerophyllum, sp.	62
Verbeekiella mersa, sp. nov.	63

BULGADOO SERIES.

WOORAMEL SERIES.

CALLYTHARRA SERIES:—

"*Amplexus*" pustulosus Hudleston	59
Euryphyllum minutum Hill.	
Plerophyllum australe Hinde.	
Tachylasma, sp.	
Verbeekiella talboti (Hosking)	64
Thamnopora insculpta, sp. nov.	67
? *Thamnopora*, sp.	68
Cladochonus striatus, sp. nov.	70

LYONS SERIES (GLACIALS).

KIMBERLEY.[2]

ERSKINE SERIES.

LIVERINGA SERIES:—

Tachylasma densum Hill.

NOONCANBAH SERIES:—

Thamnopora marmionensis (Etheridge).	
Cladochonus nicholsoni (Etheridge)	69
(*Calceolispongia* occurs with the two latter).	
Thamnopora immensa Hill from Christmas Ck. homestead may have come from this series.	

NURA NURA SERIES.

POOLE RANGE OR GLACIAL SERIES.

[1] The succession here given is that given by Teichert (1939, p. 6) and personal communication.
[2] The succession given here is after Wade in Clarke (1938, p. 420).

IRWIN RIVER.[3]

Species to which no page reference has been given in the above lists have already been described (Hill, 1937a).

The *Cyathaxonia* Fauna of the Palaeozoic consists of small, solitary Rugosa without dissepiments, and of Cladochonids, Favositids, and Palaeacids. It appears very important in the Artinskian of the Urals and Timor, and the Middle Permian of Timor, and it is the only coral fauna known from the Kamilaroi Series (mostly Permian, but possibly in part Uralian) of Australia. Its occurrence in the Lower Carboniferous has already been summarised (Hudson, 1935; Hill, 1938a, p. 5). Species belonging to it have recently (Dobrolyubova, 1936) been described from the Moscovian and Uralian of Russia, so that its continuous existence from the Lower Tournaisian to the Middle Permian is proved. Evidence that it was already in existence in the Devonian and even in the Silurian is accumulating. It is characteristic of a particular facies of deposition, described by Hill (1938a, p. 5). The long range of the Tabulate genera in this fauna has long been known, and it may be that morphologically similar Rugose forms from different periods, at present regarded as different generically, are really one and the same genus. These morphologically similar forms have already been indicated (Hill, 1938a, p. 8). This possibility weakens the reliance which may be placed on the genera as indicators of horizon. The species from both the Wandagee Stage and the Callytharra Stage, however, are comparable with Artinskian or Middle Permian-Basleo species, rather than with Uralian or Upper Permian species, and *Euryphyllum* is so far known, outside Australia, only in Artinskian beds. In the absence of species common to the Western Australian faunas and the Timor or Russian faunas, we cannot at present indicate the precise age of our faunas. Two species from the Wandagee Stage, *Euryphyllum reidi* (Hill) and *Thamnopora immensa* (Hill), are associated at Castle Creek, Theodore, Queensland, at an unknown horizon in the Bowen sequence. *Cladochonus nicholsoni* (Etheridge) from the Nooncanbah series, occurs in the Condamine Fault Block and in the Coral Stage of the Bowen Marine Series in the Springsure District, Queensland.

ZOANTHARIA MADREPORARIA RUGOSA
AMPLEXIMORPHS.

Ampleximorphs; Hill, 1940, p. 390.

These simple, cylindrical, or fasciculate Rugose corals with short, equal lamellar septa, and complete tabulae, and without dissepiments, are common in the Silurian, Devonian, Carboniferous, and Permian, and probably represent the endpoints of trends of simplification in many stocks. In the Permian of

[3] Succession after Teichert (1939, p. 6), and Clarke (1938, p. 429).

Timor a group occurs which differs from the earlier amplexmorphs in having dilated septa usually swollen a little axially, and continuous vertically throughout that outer part of the tabularium where the edges of the tabulae are downturned. Small septal ridges may continue for a short distance over the upper flat surfaces of the tabulae. Usually minor septa are absent. Such are some small specimens in the Sedgwick Museum, Cambridge, and a large form figured as *Amplexus coralloides* by Gerth (1921, pl. cxlvi, figs. 22. 23) from the Upper Artinskian of Bitauni, Timor. Other Permian amplexmorphs, which appear to have been derived from zaphrentoids by the withdrawal of the septa from the axis have been called *Paracaninia* Chi (1937, p. 93) ; but these have thin, unequal septa, not swollen at their axial edges. Others again, which appear to have an aulos, have been called *Amplexocarinia* Soshkina (1928, p. 379). Yet others, with unequal, rhopaloid septa, have been called *Amplexus* by Gerth (1921) and Heritsch (1937).

" **Amplexus** " **pustulosus** Hudleston. (Plate I., fig. 1.)

Amplexus? pustulosus Hudleston ; for references, see Hill, 1937a, p. 45, pl. i, fig. 1 ; text-fig. 1 ; " Fossil range," Gascoyne River, Permian.

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

Remarks : One specimen from the upper part of the Callytharra series near Trig. Station K52, Kennedy Range, near Williambury—Middalya road, W.A., is probably a member of this species, although it is curved rather than erect, and cylindrical rather than turbinate. It is flattened in the plane of the cardinal septum, probably by crushing, as the tabulae seen in a vertical section are somewhat shattered. There are 33 septa at a diameter of 15mm. x 18mm., extending a little over half way to the axis, sub-equal, some with sharp axial edges, and some with swollen axial edges, all dilated so as to be almost in contact laterally. The cardinal septum is shorter than the rest and is on the longest side of the corallum. No minor septa are developed. The tabulae are complete, shallow domes. Etheridge has already mentioned this species from Williambury Station, Minilya River.

" **Amplexus** " sp. (Plate II., fig. 1.)

Material : One specimen from the Permian of Fossil Cliff, Irwin River, in the collection of the University of Western Australia.

Description : The specimen is an obliquely broken fragment 60 mm long, and 32 mm in diameter. There are about 50 slightly dilated major septa, continuous vertically for about 5 mm. from the epitheca, and then extending for a short distance over the upper flat surfaces only of the tabulae as faintly marked ridges. The septa appear to be slightly rhopaloid, *i.e.*, swollen at the inner edge of their vertically continuous portions ; as far as can be seen from the fragment, they are equal, and there are no minor septa. There is a peripheral stereozone about as thick as the septa. The tabulae are complete, unequally distant, up to 3 mm. apart, and with an edge 5 mm. wide, downturned to the stereozone at about 45°. It is in this area of downturning that the septa are vertically continuous.

Remarks : As far as one can ascertain from the fragment, the septa are equal, so that the specimen does not belong to *Paracaninia* ; neither is there an internal wall, so that it is not *Amplexocarinia*, and pending further investigations in Carboniferous and Permian amplexmorphs, it is referred to

"*Amplexus.*" It seems close to *Amplexus coralloides* of Gerth *non* Sowerby, from the Upper Artinskian of Bitauni, Timor, but it differs from the Lower Carboniferous *Amplexus coralloides* J. Sowerby in having the septa dilated and not attenuate, and in having the vertically continuous segment of the septum much wider.

ZAPHRENTIMORPHS.

Zaphrentimorphs have been discussed recently (Grabau, 1928 ; Hill, 1938).

Genus **ALLOTROPIOPHYLLUM** Grabau.

Allotropiophyllum Grabau, 1928, p. 130.

Genotype (by designation) : *Amplexus spinosus* de Koninck var. *sinensis* Grabau, 1922, p. 64, pl. i, figs. 22a, 22b, 23. Chihsia Limestone Chihsiashan, Central China (= Artinskian).

Diagnosis : Simple Rugose corals, typically curved, and bearing scattered spines. The septa of the counter quadrants and sometimes the alar and first meta-septa are grouped in a narrow crescentic area embracing the counter side of the corallum ; the remaining septa of the cardinal quadrants are directed towards a point or points on its inner side, which is roughly midway between the axis of the corallum and the epitheca. The septa become amplexoid in late stages. Tabulae are usually far apart, complete and oblique, with a downturned border of the same width as the crescent : they slope downwards from the convex to the concave side of the corallum. There are no dissepiments, and minor septa are developed very late or not at all.

Remarks : The genus is known in the Tournaisian of Belgium, the Dinantian and Lower Namurian of Scotland, the Artinskian Chihsia limestone of China, and the Upper Permian of Djoulfa in Armenia. Possible synonyms of the genus are discussed in the authors "Carboniferous Rugosa of Scotland, Part III.", in course of publication by the Palaeontographical Society of London.

ALLOTROPIOPHYLLUM, sp. (Plate I., fig. 2.)

Material : One specimen in the collection of the University of Western Australia, from the lowest horizon with large species of *Calceolispongia*, middle *Calceolispongia* stage, east limb of syncline west of Coolkilya Pool, Minilya River.

Description : The specimen is broadly trochoid, with a talon, and a very deep calice. The epitheca is longitudinally ribbed but somewhat weathered, the deep grooves corresponding to the major septa having shallow grooves between then indicating the potential presence of minor septa. Spines were not observed. Six major septa in each counter-quadrant are joined with the counter septum in a crescentic curve on the counter side of the corallum. Six straight metasepta in each cardinal quadrant join at their axial edges at a point on the edge of the crescent, leaving a wide closed fossula expanded axially. The long cardinal septum wanders over the fossula to join it at one side of the crescent. The septa are all slightly and equally dilated, and there is a narrow peripheral stereozone. No minor septa are visible. The arrangement of the tabulae is not known.

Remarks : The one specimen is insufficient for a full specific description or comparison with other species. The age indicated is that of the genus, Carboniferous and Permian.

Genus EURYPHYLLUM Hill.

Euryphllum Hill, 1937, p. 150 ; 1937, a, p. 50 ; 1938. p. 25.

Genotype : Euryphyllum reidi Hill, 1937, p. 150 ; 1937, a, p. 50 ; 1938, p. 25 ; Permian (? Artinskian) Bowen Marine series of Queensland.

Diagnosis : Simple, turbinate to ceratoid Rugose corals, erect except at the tip, which is turned aside : with well-marked interseptal ridges, and typically an oblique calical floor. The major septa, which are never carinate or serrate, extend to the axis and are pinnately grouped about a long, closed fossula, bisected by a long cardinal septum on the concave side of the corallum ; alar fossulae are present. The septa are dilated, and at first are laterally contiguous throughout, but during ontogeny dilatation decreases in a widening zone midway between the periphery and the axis, leaving a wide peripheral stereozone, and an axial structure formed by the conjoined dilated axial ends of the septa. Very short minor septa appear late, and remain buried in the stereozone. Tabulae are distant, usually dilated, complete or incomplete, and there are no dissepiments.

Euryphyllum reidi Hill. (Plate I., fig. 3 ; Plate II., fig 2.)

Euryphyllum reidi Hill, 1937, p. 150 ; 1937a, p. 50 ; 1938, p. 25, pl. i. Permian (? Artinskian) of Queensland.

Holotype : F3243, University of Queensland collection, from the ?Artinskian Upper Dilly Stage of Cabbage Creek, Springsure District.

Diagnosis : Euryphyllum with oblique calice, the cardinal quadrants being wider than the counter ; the peripheral stereozone is irregular and very wide, and septal dilatation does not decrease until very late.

Remarks on North-Western Australian Specimens : There are in the Collection of the University of Western Australia, 5 specimens from the *Strophalosia-Calceolispongia* horizon, just below the horizon with *Allotriophyllum*, sp., middle *Calceolispongia* stage, 1 specimen from the horizon just below the *Dictyoclostus gratiosus* zone, upper *Calceolispongia* stage, 6 specimens from just above the " worm track " horizon, upper Calceolispongia stage, all from the east limb of the syncline west of Coolkilya Pool, Minilya River, and 1 specimen from the main *Calceolispongia* horizon, 6 specimens from the *Cleiothyridina-Calceolispongia* horizon, all from the upper *Calceolispongia* stage, west limb of the same syncline. The specimens on the whole are rather larger than those from the Springsure area, but those from the first named horizon are identical in size with Queensland specimens from Castle Creek, Theodore. The species may prove divisible. I have not yet made a detailed study of zaphrentimorphs from the Upper Marine of New South Wales, but from Etheridge's figures none appears to be *E. reidi*, though *Z. gregoriana* is possibly a member of the genus.

Thirteen specimens from the highest *Calceolispongia* horizon, at the top of the Wandagee series, are identified as *Euryphyllum reidi* Hill. They are of the morphology of that sub-group from Castle Creek, Queensland, and from the locality J3, in the middle or upper parts of the *Calceolispongia* zone in the Wandagee Series, west or south-west of Coolkliya Pool, Minilya River. The localities of these 13 thirteen specimens are :—

south-west side of Wandagee Hill, near mouth of South-West Creek ;
near south-east corner of Wandagee Hill, at crossing of Wandagee Woolshed—Middalya road over highest *Calceolispongia* horizon ;
north-east corner of Wandagee Hill.

Two specimens from the uppermost *Pseudogastrioceras* horizon of *Linoproductus-Fenestella* stage of Wandagee series, are identified as *Euryphyllum reidi* Hill, but they may represent a variant from the morphology characteristic of the *Calceolispongia* zone, for their septa are without any curvature. Nevertheless, a similar morphology is known in specimens from Castle Creek, Queensland.

? **EURYPHYLLUM,** sp. (Plate I., fig. 4.)

Material : One specimen from locality H_4E, in the Collection of the University of Western Australia from the lowest horizon with a species of large *Calceolispongia*, middle *Calceolispongia* stage, east limb of syncline west of Coolkilya Pool, Minilya River.

Description : The specimen is small and trochoid, the diameter at the upper edge of the calice being 18 mm, with a deep calice and strong longitudinal ribbing. One side of the corallum, about an alar fossula, is excavate, but whether from injury or attachment it is impossible to say. Major septa only are developed, and they are considerably dilated ; there are 7 in each cardinal quadrant and 7 in each counter quadrant ; the axial edges of those in the cardinal quadrants all meet the axial edge of the short counter septum, or join the two parallel septa about the cardinal fossula. There is a lozenge-shaped gap filled with matrix in the middle of the coral, where the septa of the cardinal and counter quadrants are parted, the greatest width being in the plane of the alar fossulæ, and the opposite diameter being between the axial edges of the cardinal septum and the counter septum.

Remarks : Whether this gap is a specific character or a pathological condition cannot be determined without further specimens. In the meantime the specimen is placed doubtfully in *Euryphyllum*. It might, however, be an aberrant *Allotropiophyllum*.

Genus **PLEROPHYLLUM** Hinde.

Plerophyllum Hinde, 1890, p. 195 ; for references, etc., see Hill, 1937, a, p. 47.

Genolectotype (chosen Grabau) *: Plerophyllum australe* Hinde, 1890, p. 196, pl. viiiA, figs 1a-f ; Permian. Gascoyne River ; Irwin River ; Western Australia.

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.

Plerophyllum sp. (Plate II., fig. 3).

Material : One specimen from the Cundlego Series, in the fossiliferous horizon above Coolkilya Pool, Minilya River.

Description : The specimen is cylindrical and very small, being the calical end (8 mm.) of a specimen, with a constant diameter of 3 mm. Longitudinal and growth striations are well-marked. The two counter-lateral septa, the alar septa and the cardinal septum are dilated and meet at the axis, and are almost equally spaced. Shorter septa can be distinguished between them, the counter septum clearly, but others less clearly. There is a stereozone about 0·75 mm. wide at the periphery.

Remarks : This small specimen may be only a young individual of *Plerophyllum australe*, and so pending the discovery of more material it is left unnamed. No adult *P. australe* are known from the Wandagee Series.

Genus **VERBEEKIELLA** Gerth.

Verbeekiella Gerth, 1921, p. 81 ; nom. nov. for *Verbeekia* Penecke, in Verbeek, 1908, p. 673 ; *Verbeekia* was pre-occupied by Fritsch, 1877, for a Tertiary echinoid.
Verbeekia ; Hill, 1937, a, p. 54.

Genotype : *Verbeekia permica* Penecke *loc. cit.* = *Clisiophyllum australe* Beyrich.

Diagnosis : Simple Rugose corals typically with much dilated vertical skeletal elements ; with a clisiophylloid axial column, with domed tabulae, and without dissepiments.

Remarks : The genus is reported from the Moscovian and Artinskian of Russia and the Permian of Timor, and *V. talboti* (Hosking) occurs in the Callytharra Stage of the North-West of Western Australia. *Zeliaphyllum* Heritsch (1936, p. 130, genotype *Z. suessi* Heritsch, *id.*, text-fig. 34, pl. xviii., fig. 24) from the Lower *Schwagerina* limestone of the Carnic Alps may be synonymous. *Cravenia* Hudson (1928, p. 252, genotype *rhytoides* Hudson, *id.*, pl. i., figs. 1a-g), a Tournaisian form of England, may be related or synonymous. It is difficult to know whether genera of solitary coralla with axial columns but without dissepiments should be considered as members of the family Clisiophyllidae or not ; and for the present they are left as Rugosa incertae sedis.

Verbeekiella mersa sp. nov. (Plate I., figs. 5, 6 ; plate II., fig. 4).

Holotype : From *Linoproductus-Calceolispongia* horizon, just below lowest *Propinacoceras* zone, lower *Calceolispongia* stage, east limb of syncline west of Coolkilya Pool, Minilya River. Four other specimens from just above the "worm track" horizon, upper *Calceolispongia* stage, same locality. Another is from the fossiliferous Cundlego horizon above Coolkilya Pool.

Diagnosis : *Verbeekiella* with septa greatly dilated at first, without minor septa, with the axial structure quite dense, of dilated lamellae attached to the counterseptum.

Description : Trochoid coralla, about 40 mm. tall with a slightly irregular curvature and a calical diameter of 20 mm. The diameter is longer along the cardinal-counter line than at right angles to it. The epitheca is without longitudinal striation, but shows growth annulation. The cardinal septum is on the longer side, but is not necessarily in any plane of symmetry of the corallum. When the epitheca is weathered away, slender grooves are seen up the middle of each septum. The distal edges of the septa are curved, rising up slightly from the epitheca, and then descending a little in a long curve towards the axial edge ; when the corallum is broken vertically down a septum, lines of growth are seen parallel to this curve of the distal edge. The axial structure projects as an elongate boss, which may show lateral ridges. Only major septa are developed, 20 at a diameter of 12 mm., up to 26 at greater diameters. There is always at least one more septum in each counter quadrant than in each cardinal quadrant, so that the alar fossulae tend to be on the cardinal side of the corallum. The septa are dilated so as to be in contact throughout the young stages, but as the corallum grows the dilatation lessens somewhat ; a narrow peripheral stereozone is always left, and the thinnest part of a septum is just inside this stereozone, so that the septa tend to be rhopaloid. The counter septum is joined with the axial structure, which is made up of a median lamella and a few lateral lamellae so dilated as to be in contact ; very occasionally spaces may be seen between the lamellae ; the sides of the structure may be smooth, so that it is oval in section, or ridged by the outer edges of the lateral lamellae; it is always joined to the counter septum, but is not a continuation of the counter septum. The tabulae are thin, complete and incomplete, and domed. No dissepiments are developed.

Remarks: The oval section of the axial structure and its confluence with the counter septum suggests that this species should be placed in *Lophophyllum* or *Lophophyllidium*, or other genera with a columella formed simply by dilatation of the axial end of the counter septum. But sections show that this axial structure is really compound, an axial column formed by dilatation of its constituent medial and lateral lamellae, so that the affinities of the species are with *Verbeekiella* or *Sinophyllum* Grabau. In *Sinophyllum* the formation of the compound axial structure by the association of the dilated axial ends of the other major septa with the prolonged, swollen axial end of the counter septum is evident, but in *Verbeekiella* the compound axial structure is dissociated from the axial ends of the septa (except the counter and cardinal septa in some species) throughout the corallum. *V. mersa* has this dissociated type of structure. It is the only species of the genus which is homeomorphic with *Lophophyllum*. It differs from *V. talboti* from the Callytharra Series (somewhat lower than the Wandagee Series) of the North-West, chiefly in the general absence of spaces in its axial structure and in the absence of irregularity in dilatation.

Verbeekiella talboti (Hosking) (Plate I., fig. 7).

Clisiophyllum talboti Hosking; for references, etc., see Hill, 1937, a, p. 55, pl. i., figs. 13–17; text-figs. 6, 7; Permian, Callytharra Series, creek half a mile west of Callytharra Springs, Wooramel R.

Diagnosis: *Verbeekiella* with dibunophylloid axial structure containing few septal lamellae.

Remarks on a specimen from Callytharra Springs: A large specimen with a height of 50 mm., and a calical diameter of 25 mm. differs from previously described specimens of this species not only in these larger dimensions, but also in having near the calice a clisiophylloid rather than a dibunophylloid section of the axial column. Instead of there being a maximum of nine lamellae on each side of the median lamella, there are in one transverse section eighteen, nine shorter lamellae alternating with the nine long ones touching the axial lamella; but in a transverse section about 3 mm. below, most of these shorter lamellae are not present. It is not thought that this difference from the earlier described species is specific, although the boss in the calice also shows the eighteen lamellae on either side of the median lamella. This large number of lamellae is that characteristic of *V. rothpletzi* (Gerth, 1921, pl. cxlvii, figs. 10, 11) from the Lower and Middle Permian of Bitauni, Mandeo and Basleo, Timor.

ZOANTHARIA MADREPORARIA TABULATA.

FAMILY FAVOSITIDAE.

Genus FAVOSITES Lamarck.

Favosites Lamarck, 1816, p. 204; for references, etc., see Jones, 1936, p. 2.

Genolectotype (see Edwards and Haime, 1850, p. lx): *F. gothlandicus* Lamarck, 1816, p. 206, Silurian, Gotland.

Diagnosis: Cerioid tabulate corals forming massive or ramose colonies, in which the contiguous corallites have thin or moderately thin walls, spinose or obsolete septa, and complete or mainly complete horizontal tabulae.

Remarks : The genus is widespread, from the Upper Ordovician to the end of the Devonian ; forms like *Favosites* in the Carboniferous have usually been referred to *Emmonsia*, but Gerth (1921) has described as *Favosites* three Permian species from Mandeo and the Middle Permian of Basleo, Timor.

FAVOSITES, sp. (Plate II., fig. 5.)

Material : Two specimens from the base of the *Linoproductus* stage of the Wandagee series, centre of syncline west of Coolkilya Pool, Minilya River (one near Station 4A, the other 12 chains from Station f of 1939 survey).

Description : The corallum is tuberose, 30 to 40 mm. in diameter, and 50 mm. or more long. The individual corallites diverge outwards from the axis, each being about 1·5 to 2 mm. in diameter, though smaller ones occur. Owing to the processes of fossilisation, neither specimen is worth sectioning. Neither mural pores nor septal spines were proved, but one surface suggests a single vertical row of pores per wall. Tabulae are thin, slightly domed, and rather distant, 3 in 2 mm.

Remarks : The specimens do not appear to be conspecific with the species described by Gerth from Timor, or with any other species known to me.

Genus **THAMNOPORA** Steininger.

Thamnopora Steininger, 1831, p. 10 ; 1834, p. 337 ; for references, etc., see Hill, 1937 a, p. 56.

Genolectotype : *Thamnopora madreporacea* Steininger = *Alveolites cervicornia* de Blainville, 1830.

Diagnosis : Ramose Tabulate corals in which the cylindrical branches may be flattened and coalesced ; the corallites are typically polygonal, they diverge from the axis of the branch and usually open normal 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.

Range : Silurian, Devonian, Permian, and rare in the Trias.

Thamnopora immensa Hill (Plate I., fig. 8 ; Plate II., fig. 6).

Thamnopora immensa Hill, 1937a, p. 58, pl. i., figs. 21, 22, text-fig. 9 ; Permian, two miles East of Christmas Creek Homestead, south of Rough Range, Kimberley.

Holotype : H 25, Geological Survey of Western Australia.

Diagnosis : Large *Thamnopora*, in which the corallites have calices of two sizes opening at right angles to the surface of a branch, excessively dilated walls, thin tabulae, and numerous large, regular mural pores, frequently further excavated by boring organisms.

Remarks : Additional specimens, from Boolgadoo Pool, Minilya River, and from Coolkilya Flat, south of the Minilya River, probably from the lower part of the *Linoproductus* stage of the Wandagee series, were sent by Dr. Teichert. They have allowed an expansion of the diagnosis given in 1937. The specimen from Boolgadoo is unweathered, and large corallites are seen between smaller ones on the calical surface. The calices show eight or nine coarse radial ridges, somewhat as in *Striatopora* Hall ; the ridges are without spines. In all specimens the corallites open at right angles to the surface, thus differing from *T. marmionensis,* where they open obliquely. In the M 16 specimen, dilatation is not so excessive as in the others, and thin tabulae can be seen. Individual septal spines or trabeculae have not been distinguished, though the sclerenchyme is fibrous. Etheridge may have included some specimens of *T. immensa* in his *T. marmionensis,* as his description of the latter covers coralla with corallites opening at right angles to the direction of growth as well as those with corallites opening obliquely. The only two syntypes of *T. marmionensis* which I have seen, however, had their corallites opening obliquely. *T. immensa* or a very closely similar form occurs in association with *Euryphyllum reidi* at Castle Creek, Theodore, in an unknown horizon in the Queensland Bowen succession.

Thamnopora marmionensis (Etheridge).

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.

Diagnosis : *Thamnopora* forming large lobate masses, with corallite 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 pores, frequent tabulae, and without septal spines.

Remarks : The species differs from the eastern Australian *T. wilkinsoni* (Etheridge) in being lobate rather than ramose, and in having the calices closer, while the projection of the calical rim is low compared with that of *T. wilkinsoni.*

Thamnopora *aff.* **marmionensis** (Etheridge) (Plate II., fig. 7).

Material : A fragment in limonite (g) from the lower part of the *Linoproductus* stage somewhat east of the *Heliocoprion* locality of Coolkilya Flat ; only the calical surface can be studied, and this shows corallites of two sizes, most of the openings have one-half of their outline semicircular, representing the lower lip, which, however, does not project, and the upper half polygonal, two or three short edges meeting at angles. This specimen is probably *T. marmionensis,* but the internal structure is obscured. A small lobate fragment (i) from high in the *Calceolispongia* stage at Station 25A, " Upper worm track " horizon north of Minilya River, with thin walls and oblique calices, which is probably *T. marmionensis,* but the calices are not clearly distinguishable into two sizes, and vary between 1 mm. and 1·5 mm. A worn, lobate fragment (b) from the highest beds exposed north-west of Station 23, in the lower part of the *Linoproductus* stage, Minilya River, which is probably *T. marmionensis,* although the corallite walls are thicker than in the syntypes, being 1 mm. or nearly 1 mm. throughout, and the septa appear to have denticulations resembling spines on their inner edges. A cylindrical fragment (d) from the lower part of the *Linoproductus* stage near Station 4A, north of Minilya River, whose internal structure is similar to that of (b). A cylindrical fragment (c) from the same horizon at Station 4A, north of Minilya River, closely resembling (b) and (d). All these are from the Wandagee beds.

Remarks : One cannot be certain that these specimens, which are probably conspecific, are *T. marmionensis,* because of their fragmentary nature, and because our knowledge of syntypes is very limited ; but the small, oblique corallites suggest that they are. I have seen nothing similar from eastern Australia.

Thamnopora insculpta sp. nov. (Plate I., figs 9 a-d ; Plate II., figs. 8 and 9).

Type material : Eleven fragments, possibly from one specimen, from the Callytharra beds near Callytharra Springs, W.A., collected by C. Teichert.

Diagnosis : Slender branching *Thamnopora* with the corallites opening a little obliquely to the surface, dilatation of the walls increasing greatly towards the surface, so that the openings are distant, and sunken into the unridged, faintly tuberculated wall tissue.

Description : The diameter of the cylindrical branching fragments varies between 3 mm. and 10 mm. The calical openings are unequal, the largest being 1·5 mm., some being 1 mm., and a few 0·5 mm. in diameter. They are unequally spaced, the smaller being in the angles between the larger, which tend to be arranged in vertical rows. The openings are occasionally surrounded by a raised rim, especially near the growing tips of the branches, its height being greatest on the under side of the opening, but in the older branches there is usually only a very faint trace of this rim, and that on the under side of the opening. Between the openings there is instead from 0·5 to 3 mm. of dense sclerenchyme, which is lightly tuberculate, and no trace of the junction between the walls of neighbouring corallites can be seen. Faint septal ridges are observable in one or two calices, twelve being counted. The corallites are almost vertical in the axial parts of the branch, and very small, being from 0·1 to 0·5 mm. in diameter, with but slightly thickened walls. Outside this axial part of diameter about 2 mm., the corallites bend rather rapidly outwards, opening to the surface at less than 30° to the horizontal. As they proceed to the surface they increase in diameter, but the greatest part of this increase is due to an increase in the thickness of the walls, the lumen never becoming wider than 1·5 mm. The walls may be very thick, from the dark line representing the junction of two corallites to the inner edges of the septa may be as much as 1·5 mm. The fibrous structure of this thickened tissue shows that it consists of twelve equal septa so dilated as to be in contact laterally. The vertical sections suggest that they have denticulate inner edges ; but individual trabeculae are not distinguishable in the fibrous tissue, as septal spines. Mural pores are fairly frequent, small and regular. Tabulae are thin and distant.

Remarks : The generic position of this species is doubtful. The occurrence of twelve equal septa is a character suggestive of generic difference from *Thamnopora cervicornis,* since neither septa nor septal spines are known in the types of *T. cervicornis.* Species with septal spines have been included in *Thamnopora*, but possibly this Western Australian species with lamellar septa should be placed in a separate genus with the eastern Australian *Trachypora wilkinsoni* Etheridge, to which it is very close. *T. wilkinsoni* has the twelve lamellar septa much more clearly developed, and in it the outer boundaries of the individual corallites are distinguishable by ridges on the surface. *T. wilkinsoni* occurs in the Upper Marine of Mulbring, and of Ellalong, N.S.W., in the Coral Stage of the Bowen Marine of the Springsure Basin, Queensland, and in the Condamine Fault block, near Silverwood, Queensland. I have not seen it from Western Australia, but *T. insculpta* appears to me to be a related form. *Favosites permica* Gerth (1921, p. 101, pl. cxlix., figs. 1, 2, 3, pl. cl., fig. 1) from the Basleo Beds, also has twelve septa, lamellar in the upper part of the calice, but this form is encrusting. Its septa consists of spines fused together at their bases, forming a series of stripes on the calical floor, but with separate spine ends in the lumen. Twelve septa, sometimes acanthine, but frequently with the spines fused at their bases to form lamellar septa, in the form of stripes on the corallite walls, appears to be the highest number possible in *Pseudofavosites stylifer* var. *septosa* Gerth (1921, p. 104, pl. cxlviii., figs. 7, 8) from Basleo, and this number is usually attained. But this genus is without tabulae.

? **Thamnopora** sp. (Plate I., fig. 10; Plate II., fig. 10).

Material: One specimen, collected by C. Teichert, from Callytharra Springs.

Description: The corallum is partly encrusting, extensiform but of crumpled growth, with stumpy branches on the upper surface, which has been pitted by rain weathering. Its size is 60 x 60 x 15 mm., the branches being mostly broken off at a height of 5 to 10 mm., and being about 8 mm. in diameter. The corallites are unequal, up to 2 or 2·5 mm. in diameter. The walls of the corallites in the branches are much dilated, but those in the basal layers and in the parts in which the branches are set are thin. The walls of the corallites in the axes of the branches are also thin. When analysed microscopically, the dilatation is seen to be septal in origin; the individual trabeculae of each septum are dilated and in contact so that lamellar septa are formed, from the axial edges of which denticulations may nevertheless arise; and the dilatation is so great that neighbouring septa are in contact laterally, to form a dense wall. The number of the septa per corallite is unknown. The calices probably open obliquely to the surface of the branch, but this is unproved. Mural pores are numerous, and occur both between and piercing the septa. Tabulae are distant and very thin.

Remarks: In its manner of growth this specimen resembles some of the Devonian *Alveolites*, but the weathering does not permit us to study the outline of the calices. It may perhaps represent the basal portion of the branching *Thamnopora insculpta*, but further knowledge of the number of septa and obliquity of corallites is needed before this may be regarded as more or less than a possibility.

FAMILY **CLADOCHONIDAE**.

Genus **CLADOCHONUS** M'Coy.

Cladochonus M'Coy, 1847, p. 227.

Monilopora Nicholson and Etheridge, 1879, p. 293, genotype *Jania crassa* M'Coy, 1844, p. 197, Lower Carboniferous of Ireland.

Cladochonus: Hill and Smyth, 1938, p. 126.

Genolectotype (chosen Edwards and Haime): *Cladochonus tenuicollis* M'Coy, 1847, p. 227, pl. xi., figs. 8, Lower Carboniferous of New South Wales.

Diagnosis: Corallum compound, with a reptant ring of corallites proximally, from which free branches arise; individual corallites are trumpet or pipe-shaped, and in contact only at the point of origin, each giving rise to another by lateral increase through the wall of the expanded calice; each has a thick peripheral stereozone of laminar, sometimes reticulated sclerenchyme; neither tabulae nor septal spines are seen in the narrow lumen, but longitudinal (? septal) ridges may appear in the calices.

Remarks: Hill and Smyth (*loc. cit.*) have shown that the genotype of *Monilopora* was but the reptant portion of a coral whose free branches are *Jania bacillaria* M'Coy, a species of *Cladochonus*, and that *Cladochonus* has priority over *Monilopora*. The genus extends from the Devonian through the Carboniferous to the Permian, and characterises the *Cyathaxonia* phase of sedimentation.

Cladochonus nicholsoni (Etheridge).

Monilopora nicholsoni Etheridge, 1914, p. 14, pl. i., figs. 2–4 ; pl. vii., fig. 4 ; Permian (? Upper Artinskian), Mt. Marmion, Kimberley, W.A.

Monilopora nicholsoni ; Etheridge, 1918, pl. xxxix., figs. 2, 3, Permian, Balmaningarra, Mt. Marmion, W.A.

non Monilopora ? nicholsoni ; Hill, 1937. a, p. 59, pl. i., figs. 23, 24, text-figs. 10, 11, from Callytharra, which is *Cladochonus striatus* sp. nov.

Type Material : Of the syntypes, only a fragment, Australian Museum F16418, has so far been found. From it was cut the section figured Etheridge, 1914, pl. vii., fig. 4. The specimens figured Etheridge, 1918, pl. xxxix., figs. 2, 3, are Australian Museum F16820 and F16712 respectively from Balmaningarra, Mt. Marmion. These are conspecific with the type material, and are described below.

Diagnosis : Bifurcating, free branches, 4·5 to 7 mm. thick, with successive corallites on opposite sides of a branch, the diameter at the edge of the calice being constantly 4·5 mm.

Description (of specimens from Balmaningarra) : The diameter of the free branches, measured at right angles to the plane of the calices, is from 4·5 mm. to 7 mm., most fragments having approximately the same diameter top and bottom, except at the point where bifurcation occurs ; a branch of 7 mm. average diameter expanded to 8·5 mm. at such a point. The angle between the products of bifurcation is about 30° ; the distance between bifurcations varies, and new branches are in a plane at right angles to the plane of the calical openings. Calical openings are circular, and fairly regularly 4·5 mm. in diameter, even when the branches are slender. They are also fairly regularly spaced, there being from 8 mm. to 10 mm. between the edge of the lower lip of one corallite to that of the next above. The lower lip of the calice is sharp, but not continued into a ledge, the sharpness being due to the obliquity of the lumen to the branch, which is about 45°. The calices alternate on opposite sides of a branch, each branch usually having two vertical rows of calices, though just before bifurcation there may be irregularity. Each calice arises from the upper part of the base of the one below. The calical opening extends inwards with a very gradual and regular decrease in diameter for at least 4 mm., and there are signs of septal ridges in its upper parts. Etheridge's thin section shows reticular tissue lining its lower parts.

Remarks : The reptant parts of the corallum from which these free branches are presumed to have arisen, are as yet unknown. In the Condamine fault block, near Silverwood, Queensland, and in the Coral Stage of the Springsure District, Queensland, fragments whose dimensions correspond to those of the Balmaningarra specimens except that the calical edges may be 5 mm. in diameter rather than 4·5 mm. occur, associated with other Cladochonid fragments of different proportions, but which yet may prove to be this species, and with *Thamnopora wilkinsoni* (Etheridge). In view of the abundance of specimens of different proportions with those with characteristic proportions at these two Queensland localities, it is important to obtain more syntypes of *C. nicholsoni*, in order to define the range of variation possible in the species. *Cladochonus beecheri* (Grabau, Gerth, 1921, pl. cxlix., fig. 12) and *C. magnus* Gerth (*id.* figs. 10, 11) from the Middle Permian of Basleo, Timor, are even larger than this Australian species, but their dimensions are attained by a specimen in the University of Queensland from Cressbrook Creek, near Esk.

Cladochonus striatus sp. nov. (Plate II., fig. 11).

Monilopora ? nicholsoni Etheridge, Hill, 1937, a, p. 59, pl. i., figs. 23, 24, text-figs. 10, 11, Permian, Callytharra, W.A.

Holotype : Specimen figured Hill, *loc. cit.*, text-fig. 10, in the Collection of the University of Western Australia, from the Permian of the creek half a mile west of Callytharra Spring, Wooramel River, W.A.

Diagnosis : Slender *Cladochonus*, with corallites widest at the calical rim, which is 3 or 4 mm. in diameter, and with 18–20 faint longitudinal striations on the epitheca.

Remarks : The specimens previously described were reptant portions of coralla, but I now have fragments of erect branches from the Callytharra beds near Callytharra Springs. The species has much slenderer proportions than the later *C. nicholsoni*, and the longitudinal striation on its epitheca has not been noted in any other species.

ACKNOWLEDGMENTS.

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BIBLIOGRAPHY.

Chi, Y. S., 1937 : On some Simple Corals from the Permian of Yungsin, Kiangsi. *Bull. Geol. Soc. China*, XVII., pp. 83–108, pls. i–iv.

Clarke, E. de C., 1938 : Correlation of the Carboniferous and Permian Formations of Australia. II., Western Australia. *Rept. A.N.Z. Ass. Adv. Sci.*, XXIII., pp. 426–430.

Dobrolyubova, T. A., 1936 : Rugosa Corals of the Middle and Upper Carboniferous and Permian of the North Ural. *Acad. Sci. U.S.S.R., Trans. Polar Comm.* Fasc. 28, pp. 77–158, 81 text-figs.

Etheridge, R. :

1914 : Western Australian Carboniferous Fossils, chiefly from Mount Marmion, Lennard River, West Kimberley. *Bull. Geol. Surv. W.A.* 58, 59 pp., 9 pls.

1918 : Observations on Carboniferous and other Fossils collected by Dr. Herbert Basedow at various localities in North-west Australia. *Proc. Roy. Geogr. Soc. Australasia (S.A. Branch)*, 1916–1917, 13 pp., pls. xxxix–xl.

Gerth, H., 1921 : Die Anthozoen der Dyas von Timor. XVI., in J. Wanner, Paläontologie von Timor ; Lief. IX., pp. 65–147, pls. cxlv–cl. Stuttgart.

Grabau, A. W., 1922 and 1928 : Palaeozoic Corals of China, Part I., Tetraseptata. *Palaeont. Sinica* (B), II., Fasc. 1 (1922), 76 pp., 1 pl. ; Fasc. 2 (1928), 175 pp., 6 pls.

Heritsch, F. :

1936 : Korallen der Moskauer-, Gshel- und Schwagerinen-Stufe der carnischen Alpen. *Palaeontogr. Stuttgart*, LXXXIII. (A), pp. 99–162, pls. xiv–xviii, 50 text-figs.

1937 : Rugose Korallen aus dem Salt Range, aus Timor und aus Djoulfa mit Bemerkungen über die Stratigraphie des Perms. *Sitz. Akad. Wiss. Wien* Math.-naturw. Klasse Abt. I., CXLVI., pp. 1–16, pls. i, ii.

Hill, D. :

1937 : Type Specimens of Palaeozoic Corals from New South Wales in W. B. Clarke's First Collection, and in the Strzelecki Collection. *Geol. Mag. London*, LXXIV., pp. 145–153, text-figs. 1–9.

1937, a : The Permian Corals of Western Australia. *Jour. Roy. Soc. W.A.*, XXIII., pp. 43–63, pl. i, text-figs. 1–11.

1938: *Euryphyllum*: A new Genus of Permian Zaphrentoid Rugose Corals. *Proc. Roy. Soc. Queensl.*, XLIX,. pp. 23–28, pl. i.

1938, a: The Carboniferous Rugose Corals of Scotland, Part I. *Palaeontogr. Soc. Monogr.*, pp. 1–78, pls. i, ii.

1940: The Silurian Rugose Corals of the Yass-Bowning District, New South Wales. *Proc. Linn. Soc. N.S.W.*, LXV., pp. 388–420, pls. xi–xiii.

Hill, D., and Smyth, L. B., 1938: On the Identity of *Monilopora* Nicholson and Etheridge, 1879, with *Cladochonus* M'Coy, 1847. *Proc. Roy. Irish Acad.*, XLV. (B), pp. 125–138, pls. xxii–xxiii.

Hudson, R. G. S.:

1928: On the Lower Carboniferous Corals—*Cravenia rhytoides* and *Cravenia tela*, gen. et spp. n. *Proc. Leeds Philos. Soc.* (Sci.) I., pp. 252–257, pl. i.

1935: On the Lower Carboniferous Corals: *Rhopalolasma*, gen. nov., and *Cryptophyllum*, Carr. *Proc. Yorks. Geol. Soc.*, XXIII., pp. 90–102, pls. iv, v.

Jones, O. A., 1936: The Controlling Effect of Environment upon the Corallum in *Favosites*; with a Revision of some Massive Species. *Ann. Mag. Nat. Hist.* (10), XVII., pp. 1–24, pls. i–iii.

M'Coy, F.:

1844: A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland, pp. VIII, 207, 29 pls.

1847: On the Fossil Botany and Zoology of the Rocks associated with the Coal of Australia. *Ann. Mag. Nat. Hist.*, XX., pp. 145–157, 226–236. 298–312, pls. ix–xvii.

Nicholson, H. A., and Etheridge, (Jr.) R., 1879: On the Microscopic Structure of three Species of the Genus *Cladochonus* M'Coy. *Geol. Mag. London* (2), VI., pp. 289–296, pl. vii.

Penecke, K. A., 1908: Über ein neue Korallengattung aus der Permformation von Timor. in R. D. M. Verbeek, Rapport sur les Moluques. Batavia. *Jaarb. v.h. Mijnwezen*, xxxvii. pp. 672–674, text-figs.

Soshkina, E., 1928: The Lower Permian Corals of the Western Parts of the Northern Urals. *Bull. Soc. Nat. Moscou* (Geol.) VI., (NS), XXXVI.

Teichert, C., 1939: Recent Research Work on the Permian of Western Australia. *Austral. Jour. Sci.*, II., pp. 5–7.

EXPLANATION OF PLATES.

Plate I.

Permian Corals from Western Australia.

All specimens are in the Collection of the University of Western Australia.

All figures by 2 diameters, approximately.

Fig. 1. "*Amplexus*" *pustulosus* Hudleston. Transverse section. Upper part of Callytharra Series near Trig. Station K52, Kennedy Range, near Williambury-Middalya road. No. 41071.

Fig. 2. *Allotropiophyllum*, sp. Transverse section. Middle part of the *Calceolispongia* Stage in the Wandagee Series, near Coolkilya Pool, Minilya R. No. 41072.

Fig. 3. *Euryphyllum reidi* Hill. Transverse section. Upper part of the *Calceolispongia* Stage in the Wandagee Series, north side, Minilya R., W. of Coolkilya Pool. No. 41073.

Fig. 4. ? *Euryphyllum*, sp. Transverse section. Locality and horizon as for fig. 2. No. 41074.

Fig. 5. **Verbeekiella mersa**, sp. nov. Transverse section of holotype. Lower part of the *Calceolispongia* Stage in the Wandagee Series, north side, Minilya R., W. of Coolkilya Pool. No. 41075.

Fig. 6. **Verbeekiella mersa**, sp. nov. Vertical section. Upper part of the *Calceolispongia* Stage in the Wandagee Series, north side Minilya R., W. of Coolkilya Pool. No. 41076.

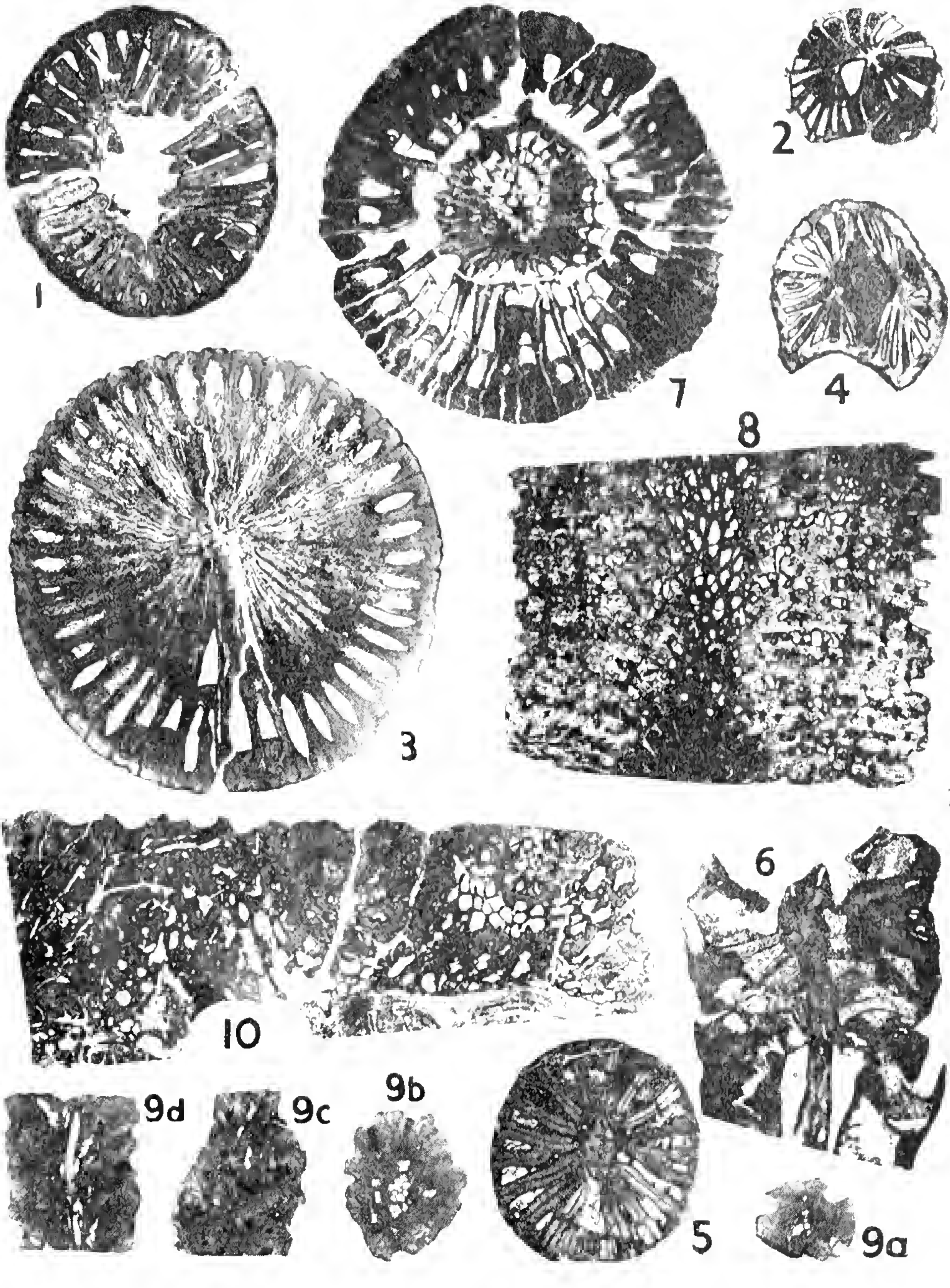
Fig. 7. *Verbeekia talboti* (Hosking). Transverse section. Callytharra Series, Callytharra Springs. No. 41077.

Fig. 8. *Thamnopora immensa* Hill. Vertical section. Bulgadoo Pool, Minilya R. No. 41069 (20204).

Fig. 9. **Thamnopora insculpta**, sp. nov. Type material. Callytharra Series near Callytharra Springs, a, b, transverse section; c, tangential and d, median vertical section. No. 41078 a, b, c, d.

Fig. 10. *Thamnopora* sp. Section. Callytharra Stage, Callytharra Springs. No. 41079.

Plate I.



i 140/41.

Plate II.

Permian Corals from Western Australia.

All figures natural size, approximately.

Fig. 1. "*Amplexus*" sp. Irwin River, Fossil Cliff. No. 20212.

Fig. 2. *Euryphyllum reidi* Hill. Middle or part of *Calceolispongia* Stage in the Wandagee Series, north side of Minilya R., W. of Coolkilya Pool. No. 20213.

Fig. 3. *Plerophyllum* sp. Upper Cundlego Stage, fossiliferous horizon, above Coolkilya Pool, Minilya R. No. 20214.

Fig. 4. **Verbeekiella mersa,** sp. nov. Specimen vertically split. Shows complexity of "columella." Upper part of the *Calceolispongia* Stage of the Wandagee Series, north side of Minilya R., W. of Coolkilya Pool. No. 20215.

Fig. 5. *Favosites* sp. Lower *Linoproductus* Stage of the Wandagee Series of f, 12 chains from Station f, north of Minilya R. No. 20216.

Fig. 6. *Thamnopora immensa* Hill. Shows calices of two sizes. Bulgadoo Pool, Minilya R. No. 41069.

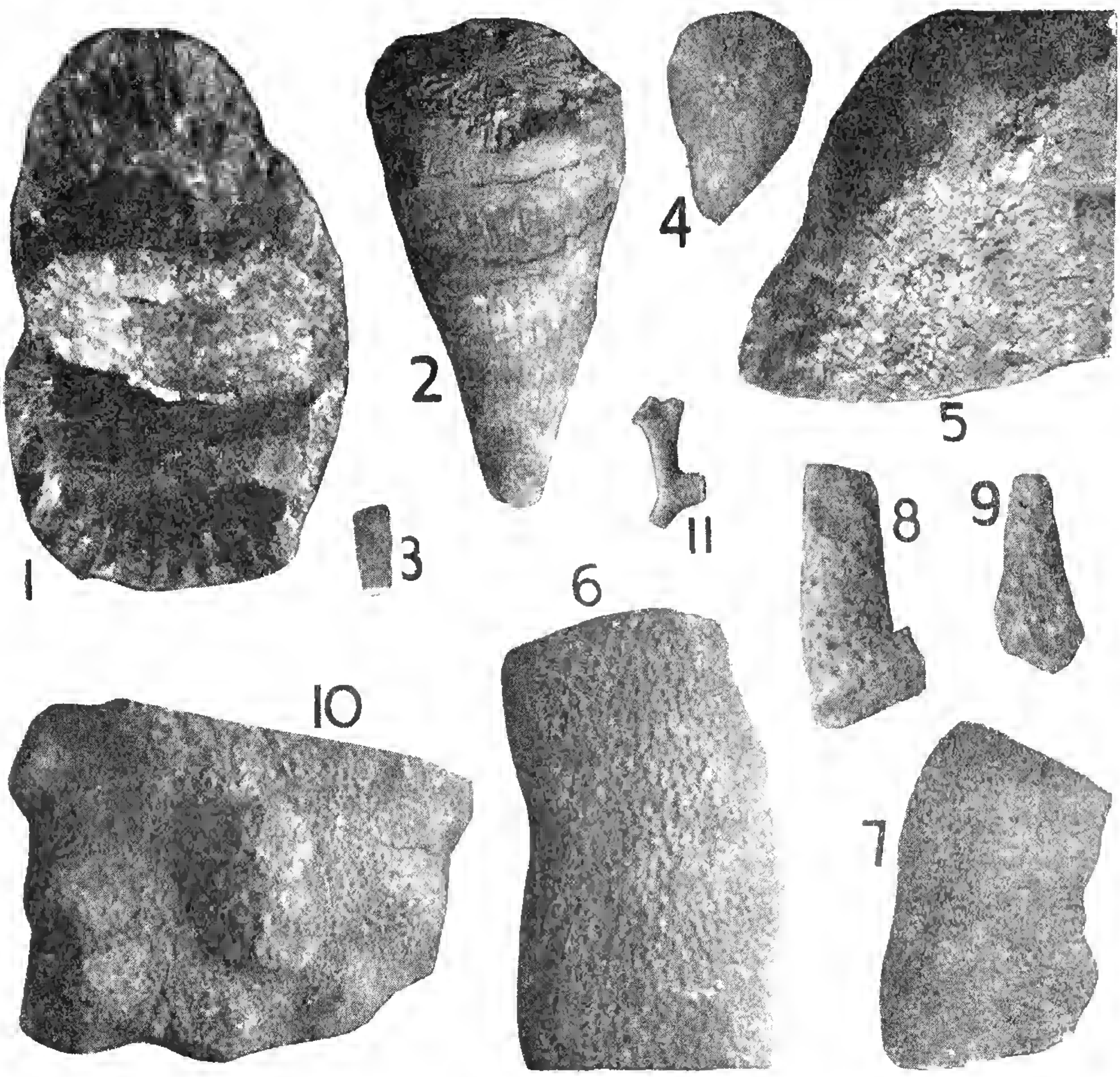
Fig. 7. *Thamnopora* aff. *marmionensis* (Etheridge). Lower *Linoproductus* stage of the Wandagee Series, N.W. of Station 23, Minilya R. No. 20217.

Figs. 8, 9. **Thamnopora insculpta,** sp. nov. Type material. Callytharra Stage near Callytharra Springs. 9 is the young part of a branch, and shows sharp ridges between some of the calices. Nos. 20218, 20219.

Fig. 10. *Thamnopora* sp. Callytharra Stage, Callytharra Springs. No. 20211.

Fig. 11. **Cladochonus striatus,** sp. nov. The longitudinal striation characteristie of the species does not show up very well. No. 20220.

PLATE II.



5.—NEW FORMS OF AUSTRALIAN BIRDS.

BY GREGORY MATHEWS, C.B.E.

Communicated by L. Glauert.

Read 10th September, 1940; Published 12th February, 1942.

While examining the collection in the Perth Museum with the Curator Mr. L. Glauert, to whom my thanks are here tendered, I found the following new subspecies.

Colluricincla brunnea julietae sub. sp. nov.

The form differs from typical birds in its smaller size, wing 116 mm.; tail 95; culmen 20; tarsus 31.

Type in the Perth Museum, No. A4004, a female collected by Mr. O. H. Lipfert on the Canning Stock Route, Sturt Creek, on 6th January, 1931.

Typical birds measure wing 133 mm.; tail 110; culmen 20; tarsus 31.

Remarks: Apparently this smaller form inhabits the country far inland.

The rather large series of over fifty skins of *Meliphaga virescens* in the Perth Museum shows that we must admit the subspecies, *M. v. murchisoni* and new forms.

M. V. MURCHISONI AND NEW FORMS.

1. **Meliphaga virescens glauerti** sub. sp. nov.

Differs from typical birds in being paler above and in having the stripes on the feathers on the breast not so noticeable.

Type in the Perth Museum, No. 6912, a male, collected by Mr. C. P. Conigrave at Ebano in October, 1904.

Remarks: Six specimens examined.

2. **M. v. lipferti** sub. sp. nov.

Differs from other form of *M. virescens* in being distinctly paler above and below.

Type in the Perth Museum, No. A4077, a male, collected by Mr. O. H. Lipfert at Well 33 on the Canning Stock Route on 13th October, 1930.

Remarks: Six specimens in the Perth Museum and six in Adelaide examined. Two skins from Marble Bar are considered identical.

3. **M. v. lewisi.**

Differs from *M. v. lipferti* in having the throat whiter and the feathers on the chest brown, forming an indistinct band; the feathers on the under-surface being not so heavily streaked.

Type in the Perth Museum, No. 7729, a male, collected by Mr. John T. Tunny on Lewis Island, Dampier Archipelago, on 27th June, 1901.

Remarks: The birds from Barrow Island seem identical.

Sericornis maculata.

Examination of the material in the Adelaide and Perth Museums shows that two new forms occur.

1. **Sericornis maculata condoni** sub. sp. nov.

Differs from *S. m. maculata* in lacking the yellowish tinge on the belly, this part being almost uniform brown like the flanks; the spotting on the chest is not so pronounced as in *maculata*.

Type in the Adelaide Museum, No. B9131, a female, collected at Hopetoun in Western Australia by Mr. John T. Tunny on 12th July, 1906.

Remarks: This bird was only found in dense shrub and was mostly in pairs. This form should be compared with the form from Mondrain Island.

2. **Sericornis maculata mondraini** sub. sp. nov.

Differs from *S. m. maculata* from Albany in its larger size and in lacking the dark brown flanks and the yellowish tinge on the belly, this part being whitish. Wing 58 mm.; tail 50; culmen 10; tarsus 23.

Type in the Perth Museum, No. 7125, a male, collected on Mondrain Island, Recherche Archipelago, on the south east coast of Western Australia, on 27th October, 1904, by Mr. John T. Tunny.

Remarks: This form should be compared with *condoni*. It was shot in dense scrub. Three specimens examined.

Aegintha temporalis cardwelli sub. sp. nov.

Differs from *A. t. macgillivrayi* in lacking the golden yellows in the back and in having the under surface more uniform grey, especially on the throat and head.

Type in the Queensland Museum, collected at Cardwell, North Queensland, by Kendal Broadbent.

Cervinipitta kimbleyensis sp. nov.

Head black, this colour extending from the lower base of the lower mandible, above the eye and including the lores, to the nape of the neck; forehead and a ring of feathers round the crown buffish brown; centre of crown black; back green; lower rump and upper tail coverts ultra-marine blue, like the greater wing coverts; tail black, central feathers fringed with greenish-blue; chin whitish; chest, sides of the body and flanks isabelline or buffish; abdomen and under tail coverts crimson; middle and primary coverts black like the secondaries, some of these latter edged with greenish; primaries white with black bases; first primary with the white on the outer web about half an inch in length and the tip black for about an inch, in the second the white is more extensive on both webs and the black tip is less; the black tips get less on each primary till the sixth where the black is reduced to a narrow fringe on the inner web; in the next three the black bases increase but the remainder of the feather is white; on the tenth the white on the inner web is surrounded by a broad black fringe to the tip; total length 205 to 210 mm.; wing 121-126; tail 40–45; tarsus 41–42; culmen 23.

This bird differs from *Pitta megarhyncha* Schlegel in having the crown of the head black, and in its smaller bill.

The type is an unsexed adult in the Perth Museum, Western Australia, No. A3767, collected in the Derby District of North-Western Australia. Another example of the same locality is a mummy, but in good condition. The bill was black and the legs and feet in these examples are light and in life were probably fleshy.

This bird may be a subspecies of *Cervinipitta moluccensis* of Muller, 1776.

6.—SOME BASALTS FROM THE NORTH KIMBERLEY, WESTERN AUSTRALIA.

By A. B. Edwards, Ph.D., D.I.C.

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CONTENTS.

INTRODUCTION.

The following notes are intended to supplement our meagre knowledge concerning the petrology of the basalts of the North Kimberley region of Western Australia (Fig. 1). They are based on an examination of two small collections, one of which was made by Messrs. A. Gibb Maitland and C. G. Gibson, in 1901, when they were attached to the Brockman Exploring Expedition (Brockman and Crossland, 1901), and the other by Mr. W. V. Fitzgerald, who accompanied the Crossland Expedition in 1905. (Fitzgerald, 1907).

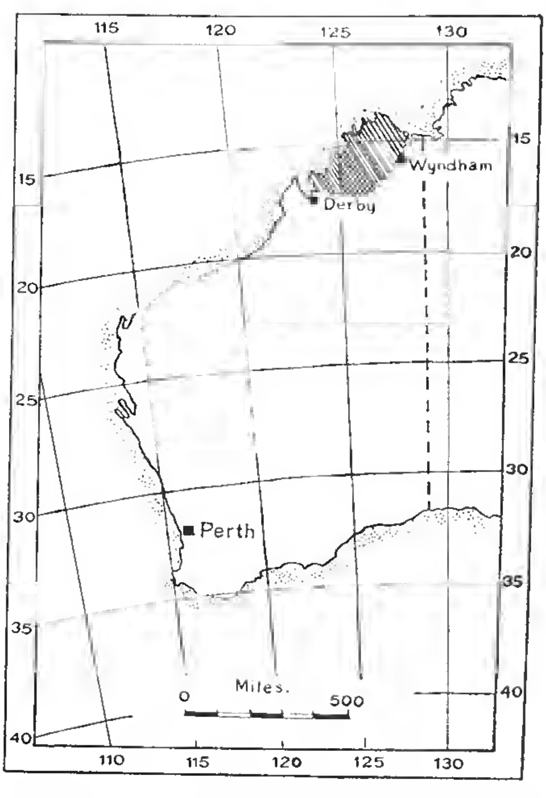

Figure 1.
Locality Map, showing the position of the North Kimberley (shaded).

Maitland and Gibson explored the country in the neighbourhood of Wyndham ; the gorge of the Isdell River ; the land to the west, north-west and north of the Synnott Tableland, including the Synnott Creek, the Charnley

River Gorge, and the Calder River Gorge ; the vicinity of Mount Kitchener, Mount Lyell, and Mount Trevor ; the upper reaches of the Prince Regent River, and Mount Hann ; and some of the hills overlooking Napier Broome Bay (Fig. 2).

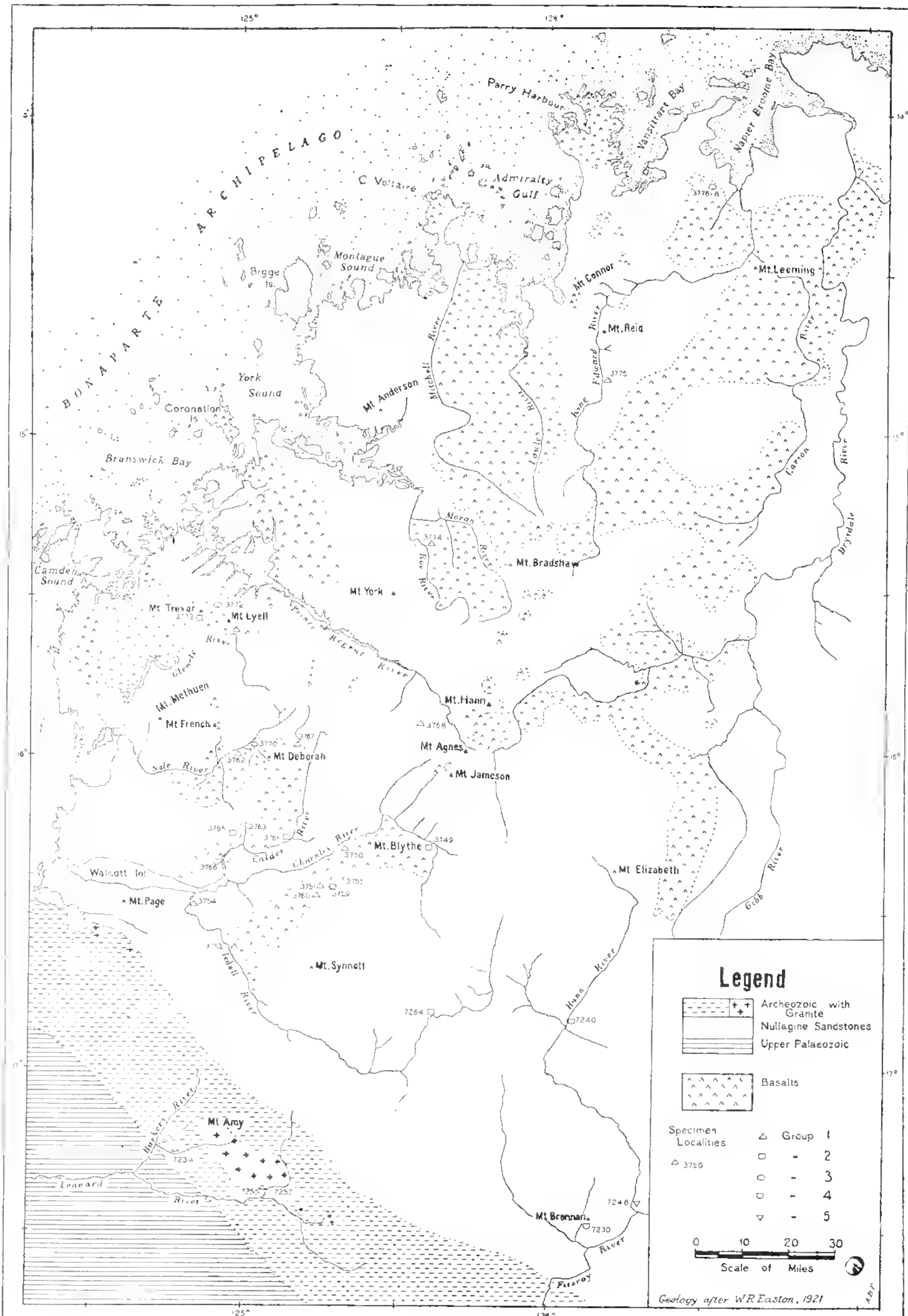

Figure 2.

2. Geological Sketch Map of the North Kimberley, showing the localities from which the specimens were obtained.

Fitzgerald examined the country along the May, Lennard, Barker, Adcock, Throssell, Upper Fitzroy, Hann, Barnett, Isdell, Sprigg, Lower Charnley, and Lower Calder Rivers.

The localities from which the specimens were obtained are shown in Figure 2, which is copied from Easton's (1922) geological map of the region, as reprinted, to accompany Jutson's " Physiography of Western Australia " (Jutson, 1934). No information is available as to the field occurrences of most of the specimens, and, as will be indicated, this is a matter to which any future expedition might give attention.

The collection is the property of the Geological Survey of Western Australia, and my thanks are due to Mr. H. A. Ellis, who was Acting Government Geologist in 1939, and who, at the instance of Professor E. de C. Clarke, not only gave me permission to examine it, but went, personally, to much trouble to put it in order and to collect all the field notes regarding the specimens which could be found in the official records. Mr. Ellis also allowed me to make use of a manuscript report on these and other rocks from the North Kimberley, which was written many years ago by R. A. Farquharson. The present study has been carried out in the Geology Department, University of Melbourne, by kind permission of Professor E. W. Skeats.

GENERAL GEOLOGY.

The North Kimberley District of Western Australia lies between longitudes 124° and 128° and between latitudes 14° and 18° (Fig. 1), and is an inaccessible, and therefore little known, part of Australia. Our knowledge of its geology is based chiefly on the accounts and collections of the parties led by the surveyors Hardman (1885), Brockman and Crossland (1901), Fitzgerald (1907) and Easton (1922).

Over the greater portion of this region the outcropping rocks consist of lava flows interbedded with massive sandstones of Nullagine age, which are either horizontally bedded, or only gently folded. The sandstones appear to overlie the lava flows to a large extent, but Maitland (1902) indicates that some of the igneous rocks occur as sills. He refers to them briefly as "a series of bedded and intrusive igneous rocks, the prevailing types being andesite, dolerite, and diabase," sometimes accompanied by beds of volcanic ash and breccias. In places he reports that "the sandstones are sometimes altered into hard compact quartzite, portions of which have been caught up in the body of igneous rock," while some sections "indicate quite clearly that the igneous rocks have (in these localities) found an easy passage along the bedding planes of the sedimentary beds and . . . . occur in the form of sills."

According to Jutson (1934), the North Kimberley is an extensive plateau which is undergoing rapid dissection by a number of streams. These streams are arranged radially about Mount Hann (2,800 feet), which lies near the centre of the plateau, and rises about 800 feet above it. The "ranges" marked on most maps of this region are really the ridges or plateau remnants forming the interfluves between the deep narrow gorges occupied by these streams. In their lower tracts the river valleys broaden, but they retain their steep walls throughout their courses. The coastal region has undergone submergence, giving rise to an extremely broken coastline of the rias type, the harbours being flanked by precipitous cliffs, often several hundreds of feet high.

PETROLOGY.

In the hand specimen the basalts can be divided into two distinct varieties, a group of relatively coarse-grained rocks, and a group of extremely fine-grained rocks. Examination of thin sections under the microscope shows that the coarse-grained rocks are a uniform group of ophitic two-pyroxene dolerites. The fine-grained rocks, on the other hand, comprise basalts of several varieties that can be distinguished mineralogically and texturally.

1. *Two-pyroxene dolerites.*

[3750],* from Camp F. B. 31, Charnley River.
[3751], from Camp F.B. 32, Charnley River (analysed).
[3753], from the Isdell River (analysed).
[3760], from Camp F.B. 32, Synnott Creek, Charnley River (analysed).
[3762], from a large hill between Camps F.B. 37 and 38.
[3767], from a "pocket" near Camp F.B. 47.
[3769], from a hill near Crossland's Wart, Prince Regent River.
[3771], from 3 miles south-east of Mt. Lyell (analysed).
[3775], from Camp F.B. 73.
[7234], dyke in granite, from the right-hand branch of Barker River.
[7255], dyke in the Lennard River, 10 miles below Mt. Eliza.

Similar, but with granophyric intergrowths of quartz and felspar :—

[3754], from Camp C. 5, Isdell River.
[3768], from gorge below F.B. 52 (analysed).
[3774], from 4 miles south-west of F.B. 66 (analysed).

This group comprises 14 of the 35 specimens forming the collection, and includes the freshest specimens. As will be seen from Figure 2, the localities from which the specimens come are widely scattered over the North Kimberley, so that there can be little doubt that this variety of basalt is one of the widespread types of the region.

Two sub-varieties can be recognised, a slightly more acid group with intersertal patches of granophyric quartz and orthoclase (*quartz-dolerites*), and a more basic one in which such granophyric intergrowths are lacking. Apart from this minor difference, the rocks appear to be identical. They are coarse-grained (Plate 1, Fig. 1), and consist essentially of pyroxene and basic plagioclase, with some chloritized biotite, and iron ore. The pyroxene is the coarsest-grained constituent, and forms crystals about 1 to 2 mm. across, which are in ophitic relation with the felspar laths.

Two varieties of pyroxene are present, in intimate association. One shows a (+) 2V of about 50°, so that it is a diopsidic augite, while the other shows a (+) 2V of about 0–10°, so that it is a pigeonite. The extinction angles show a general maximum of 35°, with an occasional 40°. Using the data given by Deer and Wager (1938), this suggests that the compositions of the two pyroxenes are approximately as follows :—

$$\text{Augite} \begin{cases} CaSiO_3 = 35 \\ MgSiO_3 = 55 \\ FeSiO_3 = 10 \end{cases}$$

$$\text{Pigeonite} \begin{cases} CaSiO_3 = 15 \\ MgSiO_3 = 75 \\ FeSiO_3 = 10 \end{cases}$$

* Numbers in brackets [ ] refer to specimens in the collection of the Geological Survey of W.A.

The plagioclase occurs as laths which range up to 1 mm. in length, when they appear to be porphyritic, but they average about 0·3 mm. They show extinction angles as high as 33° in the symmetrical zone, and are optically positive, so that they are labradorite, of a composition about Ab40. Small areas of chlorite, pleochroic from green to pale straw, are of frequent occurrence. They show straight extinction parallel to a single, widely-spaced, but perfect cleavage, so that they appear to represent altered biotite. Sometimes the chlorite is fibrous, with a plumose structure; and sometimes, as in [3750], it appears to be pseudomorphous after small crystals of olivine. The iron ore occurs as sporadic coarse, irregular shaped grains of ilmenite and ilmenite-magnetite intergrowths, moulded on the pyroxene, and ophitic towards the felspar. There is also a certain amount of interstitial felspathic base, which has been altered to sericite; and occasionally, as in [3745], [3768], and [3774], there are intersertal areas which consist of a granophyric intergrowth of quartz and orthoclase. The chemical analyses, Table I., Nos. 1–4, suggest that the specimens showing these micrographic intergrowths are slightly more acid than those in which they are lacking. The possible significance of this is referred to later. The nearest analogue to these rocks in Western Australia is provided by the dolerites and the quartz dolerites which intrude the Nullagine formations in the vicinity of the Upper Ashburton and Upper Gascoyne Rivers, in the North-Western Division (Maitland, 1909; Talbot, 1920). An analysis of one of these dolerites is quoted in Table I., A., for comparison.

In most of the specimens the plagioclase is considerably altered, having been changed to sericite or saussurite, and more rarely to epidote, as in [3753], when the change is reflected in the chemical composition of the rock (Table I., No. 5). The pyroxene has generally resisted alteration, or become slightly chloritized.

In one specimen, however, [3760] from Synnott Creek, the alteration of both felspar and pyroxene is more striking. The original plagioclase has been completely altered to lemon-yellow epidote, which retains to some extent the lath-like form of the felspar, and to albite and quartz. The albite, which is dusted with epidote granules, occurs as allotriomorphic crystals 0·2 to 0·5 mm. in diameter, interlocked with allotriomorphic, and sometimes idiomorphic, crystals of quartz of similar size. The quartz predominates.

Much of the soda set free during the alteration of the labradorite to epidote has attacked the pyroxene, and converted it to a soda-amphibole, presumably glaucophane, which is intensely pleochroic, with X = pale violet, Y = deep violet, Z = deep blue-green. It shows a good cleavage parallel to (110), and extinguishes at 30° on this cleavage. Remnants of the original pyroxene are sometimes enclosed within the glaucophane. Some of the pyroxene, on the other hand, is intimately intergrown with the yellow epidote. The amount of glaucophane present is considerably less than the probable amount of pyroxene present in the original dolerite, and the analysis of the rock (Table I., No. 6) suggests that the glaucophane is rich in iron, and possibly magnesia. It seems probable that the augite of the original rock has altered, in part at least to epidote, while the pigeonite has changed to glaucophane. A little pyrite has been introduced, together with veins and patches of calcite. When the chemical analysis of the rock is compared with the analyses of the less altered rocks of Table I., it is seen that there is a considerable general resemblance, as would be expected, but that K_2O, MgO and TiO_2 have been leached out to a considerable degree during the alteration, while Na_2O has been removed in lesser degree. On the other hand, SiO_2, CaO and CO_2 have been introduced.

Glaucophane is recorded chiefly from metamorphic rocks, and its occurrence as an alteration product of a dolerite is unusual, particularly since the dolerites in this region are for the most part fresh and un-metamorphosed. The presence of pyrite and carbonates in the rock suggests that it has undergone local metasomatism, or possibly autopneumatolysis.

2. *Two-pyroxene andesine-basalts.*

[3749], from 1 mile north-west of Camp F.B. 28, junction of Maurice Creek and Charnley River (analysed).
[3761], from the Calder River, 5 miles west of F.B. 34.
[3763], from the Harding Range, 800 feet below the summit, and 1 mile from F.B. 43.
[3765], from the Harding Range, 1,100 feet below the summit, and 1 mile from F.B. 43.
[3773], from the summit of Mt. Trevor.
[7264], from a dyke in sandstone, Upper Isdell River.

This small group of glassy basalts has a distinctive appearance under the microscope (Plate I., Fig. 2). Both pyroxene and plagioclase occur as elongated laths 0·5 to 1·0 mm. long and 0·02 to 0·05 mm. wide, and show a tendency to form stellate clusters in the dark glassy base. The pyroxene sometimes occurs in radiating sheaves. Two varieties are present. One has (+) 2V = 0°–10°, so that it is a pigeonite. The other has (+) 2V greater than 45°, and is probably augite. In most of the specimens the pyroxene laths were just beginning to crystallize when the rock was chilled, and indistinct trichytes of pyroxene can be made out in the dark glassy base. These trichytes tend to a radial arrangement, suggestive of colourless hornblende fibres, but are proved to be pyroxene by their large extinction angles, which range up to 40°.

The plagioclase laths began to crystallize before the pyroxene, and some of them are of microphenocryst size. They are largely altered to white mica, chlorite, and sometimes epidote, but occasionally they still show broad lamellar twinning, with an extinction angle in the symmetrical zone of about 20°, so that they consist of andesine of a composition about Ab60. In each section there are one or two microphenocrysts of altered olivine, which retain their idiomorphic outline to some extent (Plate I., Fig. 2). The abundant glass is greyish and opaque, but under high magnification it resolves into a network of pyroxene microlites. Iron ores are generally absent.

Texturally these rocks have considerable affinity with tholeiites, but mineralogically they are related to the andesites. A chemical analysis of [3749] (Table II., No. 1) indicates that the rocks are basaltic in composition, but midway, as it were, between the tholeiites proper and the andesites. The Al_2O_3, Na_2O and K_2O contents are too high for tholeiites, just as the andesine felspar is too acid. These features also distinguish this group of basalts from the two-pyroxene dolerites of Group 1.

3. *Andesine-basalts.*

[3766], from the edge of tidal water, 6 miles south-west from F.B. 44.
[3770], from Camp F.B. 53, south side of the Cole River.
[3772], from a hill near Mt. Lyell, and 3 miles north-east of F.B. 57.
[3776], from 3 miles north of F.B. 79, at Napier Broome Bay (analysed).
[3777], an epidositized specimen from the same locality as [3776] (analysed).
[3778], from the same locality as [3776].
[7246], from the Hann River.
[7271], a dyke, from near Mt. Joseph.

The specimens comprising this group are coarser grained than the basalts of Group 2, and contain less glass (Plate 2., Fig. 3). The felspar is a more acid andesine, about Ab_{70}, occurring in laths that lie at all angles to one another, and are often partially micacised. They are associated with laths of clinopyroxene, so altered to chlorite that the composition of the pyroxene cannot be gauged. These laths are set in a base of dark glass with which are associated numerous areas of apple-green chlorite, showing ultra-blue polarization colours. It is this chlorite, presumably, which accounts for the high MgO content in the chemical analysis of [3776] (Table II., No. 2). In some of the specimens, notably [3777], the felspar has been extensively altered to epidote, which occurs in irregular areas through the sections. An analysis of this extensively altered specimen (Table II., No. 3) shows that SiO_2, MgO, Na_2O, K_2O and TiO_2 have been leached out of it, while the FeO has been oxidised, and a large quantity of CaO has been introduced.

In the absence of an analysis, these rocks would be regarded as basic pyroxene-andesites, but their chemistry indicates their basaltic character, and their affinity with the other rocks from this region. Specimen [3772] appears to be intermediate between these andesine-basalts and the two-pyroxene andesine-basalts of Group 2. The pyroxene in it forms colourless microphenocrysts, with (+) 2V greater than 45° so that it approaches augite in composition. The plagioclase is too much altered to secondary mica for its composition to be determined, but it shows a pronounced stellate arrangement, and the interstitial spaces are filled with a dark glass containing trichytic crystals of pyroxene. In [7246] the groundmass consists of a lattice work of chloritized pyroxene microlites in a dark glass. In places this structure is replaced by granular calcite.

Another specimen difficult to classify, but having affinities with this group is [7271], a dyke rock from near Mount Joseph. It consists of small stumpy laths of much altered andesine ophitically intergrown with areas of partially altered pyroxene, which shows a large optic axial angle, and appears to be augite. The glassy base is much altered, and patches of chlorite occur scattered throughout the rock. Associated with the chlorite are small areas of glaucophane, intensely pleochroic from deep-green to pale-brown, pale violet, or nearly colourless.

4. *Microcrystalline andesine-basalts.*

[3759], from the Synnott Tableland, north-east of Camp F.B. 32.
[7230], a dyke at the base of Mt. Brennan, intruding Nullagine sandstone (Fitzgerald). (Farquharson suggests it may be an interbedded lava or a sill.)
[7240], from the Hann River, near its junction with the Barnett River.

As will be seen from Figure 2, two of these rocks come from the south-east portion of the region, away from the main areas of basalt, as mapped by Easton, while the third occurs in the south-central part, associated with other basaltic types.

[7240] consists of minute laths of plagioclase accompanied by small grains of iron ore, in an abundant groundmass of glassy material that has been altered to pale-green chlorite. The felspar laths lie at all angles to one another, with no suggestion of parallelism, and show extinction angles up to 12° in the symmetrical zone when twinned, and almost straight extinction when microlitic, indicating that they consist of acid andesine, of a composition about Ab_{70}. Small patches of calcite occur throughout the rock, in the glass ; and calcite fills a number of small amygdules in the rock, when it is associated with small amounts of radially fibrous chlorite and finely granular quartz. Similar granules of quartz occur through the rock in the vicinity of the amygdules. Occasionally an amygdule is completely filled with chlorite.

In [7230] the plagioclase laths are coarser-grained, though still small, and despite partial kaolinisation, show extinction angles up to 12° in the symmetrical zone, indicating that they consist of acid andesine (Ab_{70}). The amygdules in this rock are filled (i) with chlorite ; or (ii) with quartz and untwinned felspar, stained with iron oxide, and sometimes accompanied by chlorite ; or (iii) with quartz and chlorite. In other respects, however, the rock is identical with [7240].

The same texture is preserved in [3759] from the Synnott Tableland, but in this rock the felspar is so altered to mica and kaolin material that its composition cannot be made out. In addition the rock, which contains numerous amygdules of chlorite, is stained deeply with limonite.

In the absence of a chemical analysis, these rocks might be regarded as basic andesites, but they have been classified as andesine-basalts in view of their general resemblance to the other rocks of the region, which when analysed prove to be basalts.

5. *Hornblende-oligoclase-basalt.*

[7248], from the Hann River, near its junction with the Fitzroy River (analysed).

This variety, which is represented by a single specimen from the south-eastern part of the area, is a micro-crystalline rock consisting of laths of plagioclase and idiomorphic micro-phenocrysts of pyroxene, set in a dark mesostasis of groundmass which has partially crystallized as radiating sheaves of a grey-brown hornblende that shows almost straight extinction. The plagioclase is largely altered to secondary mica, but lamellar twinning can be made out in some crystals, and gives extinction angles up to 10° in the symmetrical zone, so that the felspar appears to be basic oligoclase of a composition Ab_{70}–Ab_{75}. The pyroxene is completely altered to chlorite, so that its composition cannot be determined. In places it is ophitic towards the plagioclase. The hornblende fibres are sometimes interleaved with green chloritic material, representing original glass, and less frequently with fine felspar laths. In view of the acid nature of the plagioclase, and the abundant hornblende, the rock resembles an andesite, but a chemical analysis (Table II, No. 4) indicates that it is a basalt. The fine texture of the rock is shown in Plate 2, Fig. 4.

6. *Volcanic Tuff.*

[3755], from the Synnott Tableland, north-east of Camp F.B. 32.

This specimen is from a much weathered rock consisting of angular fragments, up to 1 cm. across, of highly chloritized material which contains a few small laths of altered felspar, cemented together by material consisting chiefly of limonite, chlorite, and fine mosaics of secondary quartz. The rock is almost certainly a weathered tuff.

DISCUSSION.

The outcrops of basaltic rocks in the North Kimberley region cover an area estimated by Easton (1922) as about 6,250 square miles. The inadequacy of any generalisations concerning these rocks, based on an examination of a collection of only 35 specimens is manifest. However, the specimens display a marked uniformity in their general petrological character, which, coupled with the wide scatter of the localities from which they were obtained, justifies some suggestion as to the probable petrological character of the North Kimberley basalts as a whole With the exception of [3771] (Table 1

No. 4) all the unaltered specimens that have been analysed are either saturated with respect to silica, or nearly so ; and chemically, they have many features in common with the tholeiitic basalts (Kennedy, 1933) or plateau-basalts (Washington, 1922) as distinct from the olivine-basalts (Kennedy, 1933), as is shown by Table III, in which the averaged analyses of the more or less unaltered North Kimberley rocks are compared with averaged analyses of the East Kimberley basalts, the tholeiites of south-western Western Australia, and the theoretical tholeiite magma type. This resemblance is particularly marked with the North Kimberley dolerites. The basalts tend to be rather more andesitic in composition.

Mineralogically, also, the North Kimberley rocks are related to the tholeiites and their derivatives. They tend to form a distinctly calc-alkaline suite, grading towards andesites, rather than towards the more alkaline types which accompany olivine-basalts.

As indicated, the North Kimberley rocks resemble, in their chemical composition, those of East Kimberley (Edwards and Clarke, 1940), but the varieties of basalt known to occur in the two regions cannot be matched. This is not surprising if the North Kimberley rocks are of Nullagine age, while the East Kimberley basalts are Cambrian, or even post-Cambrian in part. The relative abundance of dolerite specimens in the collection suggests that this rock is the most widespread in the region, and, since it is also the most basic found there, it may approximate to the composition of the parent magma. Whether it bears such a relation to the basalts, also, must remain doubtful, for reasons given below.

As pointed out by Farquharson (in his unpublished manuscript), the dolerites from North Kimberley bear considerable resemblance to the dolerites described by Maitland (1909), and by Talbot and Farquharson (1920), from the drainage basin of the Ashburton, Gascoyne, and Oakover Rivers, and the Hammersley-Ophthalmia Plateau, in the North-West Division. The significance of this resemblance is that the latter dolerites occur largely in the form of sills, up to 300 feet thick, intruded into flat-lying beds of Nullagine age (the Carawine Limestones and others). In view of Maitland's observations referred to above (Maitland, 1902), this raised the question as to whether some or all of the dolerites in the North Kimberley may not occur as thin sills, rather than as lava flows. If this should prove to be so, it may be found that the sills have undergone some degree of differentiation in situ, and that the quartz-dolerite facies is a product of this differentiation.

Talbot and Farquharson (1920) showed that the dolerites in the district described by them were younger than the basalts in that region, because dykes of dolerite cut through sedimentary series with which the basalts were interbedded. This raises the further question as to whether the basaltic rocks of the North Kimberley may not also be of two ages—earlier, interbedded basalts, and later intrusive dolerites. This may well be so, but, since there are no details as to the mode of occurrence of the specimens in the collections examined, except an occasional description of a specimen as " from a dyke " (and these occur in four of the five groups established above), and in the case of one dolerite specimen [3771] a note (" laccolith ? "), it is a matter that must be left for future explorers in the North Kimberley to decide.

TABLE I.

	1	2	3	4	5	6	A
SiO_2	51·15	50·70	50·98	46·90	54·44	56·34	49·42
Al_2O_3	15·16	14·02	11·06	14·12	7·72	12·80	14·95
Fe_2O_3	2·00	0·90	5·72	0·07	8·22	4·11	1·38
FeO	11·52	12·70	10·67	12·50	11·20	8·98	10·76
MgO	5·88	3·66	5·88	6·96	4·00	1·16	6·16
CaO	9·70	8·66	8·09	10·92	6·68	12·96	9·85
Na_2O	1·46	3·01	2·75	2·85	3·14	1·11	2·70
K_2O	1·14	1·37	2·11	1·67	1·91	tr	0·72
H_2O+	0·41	0·20	0·28	1·24	0·20	0·06	0·77
H_2O-	0·36	1·35	1·73	0·22	2·01	0·62	0·09
CO_2	tr	...	...	*nil*	*nil*	0·08	*nil*
TiO_2	1·19	1·84	0·70	1·88	1·48	0·34	1·95
P_2O_5	0·01	...	...	...	...	...	0·55
MnO	0·19	0·90	0·65	0·29	0·22	0·36	0·47
FeS_2	n.d.	0·90	0·43	tr	0·16	0·16	0·26
	100·17	99·94	101·06	99·62	101·38	99·08	100·03

Explanation.

1. [3774], two-pyroxene quartz-dolerite, from 4 miles south-west of F.B. 66. *Analyst*—A. B. Edwards.
2. [3768], two-pyroxene quartz-dolerite, from the gorge below F.B. 52, north of Mt. Shadford, Upper Prince Regent River. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
3. [3751], two-pyroxene dolerite, from Camp, F.B. 52, Synnott Creek, Charnley River. *Analyst*—C. C. Wilson. *Bull.* 67, *Geol. Surv. W.A.*
4. [3771], two-pyroxene dolerite, from 3 miles south-east of Mt. Lyell, Glenelg River (laccolith). *Analyst* C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
5. [3753], altered two-pyroxene dolerite, from the Isdell River. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
6. [3760], Epidote-glaucophane rock (altered two-pyroxene dolerite), from Camp, F.B. 32, Synnott Creek, Charnley River. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*

A. [7728], dolerite, sill or flow, Irregully Creek, Upper Ashburton River, North-West Division. *Analyst*—H. Bowley. *Bull.* 33, *Geol. Surv. W.A.*, pp. 1694, 169.

TABLE II.

	1.	2.	3.	4.
SiO_2	51·40	51·04	45·59	49·50
Al_2O_3	16·38	13·60	13·54	17·29
Fe_2O_3	1·26	2·08	9·39	3·95
FeO	12·78	8·40	4·87	7·78
MgO	2·30	7·94	3·01	7·24
CaO	7·32	5·68	20·19	7·75
Na_2O	3·14	4·30	0·57	3·25
K_2O	1·72	1·83	0·06	0·67
H_2O+	0·12	0·36	0·28	0·27
H_2O-	1·99	2·64	0·68	1·11
CO_2	...	*nil*	*nil*	tr.
TiO_2	1·06	1·36	0·68	0·87
P_2O_5	...	...	...	0·01
MnO	tr.	0·34	0·37	0·13
FeS_2	*nil*	...	0·17	n.d.
	99·47	99·57	99·40	99·82

Explanation.

1. [3749], two-pyroxene andesine-basalt, from 1 mile north-west of Camp, F.B. 28, junction of Maurice Creek and Charnley River. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
2. [3776], andesine-basalt, from 3 miles north of F.B. 79, Napier Broome Bay. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
3. [3777], epidositized andesine-basalt, from the same locality as 3776. *Analyst*—C. C. Wilson. *Bull.* 67, *Geol. Surv. W.A.*
4. [7248], hornblende andesine-basalt, from the Hann River, near its junction with the Fitzroy River. *Analyst*—A. B. Edwards.

TABLE III.

	1.	2.	3.	A.	B.	C.
SiO_2	50·3	49·9	50·5	52·2	50·5	50
Al_2O_3	14·5	13·6	15·8	14·5	14·8	13
FeO. Fe_2O_3	13·2	14·0	12·1	11·2	11·5	13
MgO	5·7	5·6	5·8	5·0	6·0	5
CaO	8·3	9·3	6·6	7·3	10·9	10
Na_2O	2·8	2·5	3·6	2·9	2·9	2·8
K_2O	1·5	1·6	1·4	2·0	0·5	1·2

1. Average of North Kimberley basalts and dolerites (7 analyses).
2. Average of North Kimberley dolerite (4 analyses).
3. Average of North Kimberley basalt (3 analyses).

A. Average East Kimberley basalt (7 analyses), A. B. Edwards and E. de C. Clarke, *Jour. Roy. Soc. W.A.*, xxvi, 1939–40, p. 93.

B. Average Tertiary tholeiite from south-western Western Australia (3 analyses). A. B. Edwards, *Jour. Roy. Soc. W.A.*, xxiv, 1937–38, p. 7.

C. Tholeiitic Magma Type. W. Q. Kennedy, *Amer. Jour. Sci.*, Ser. 5, 25, 1933, p. 239.

REFERENCES.

Brockman, F. S., and Crossland, C., 1901: Report on the Exploration of the North-West Kimberley. *Perth: By Authority.*

Deer, W. A., and Wager, L. R., 1938: Two new Pyroxenes included in the system clinoenstatite, clinoferrosillite, diopside, and hedenbergite. *Mineral Mag.*, xxv, p. 22.

Easton, W. R., 1922: Report on the North Kimberley District of Western Australia. *Publication No. 3, Department of the North-West.*

Edwards, A. B., and Clarke, E. de C., 1940: Some Cambrian basalts from the East Kimberley, Western Australia. *Jour. Roy. Soc. West. Aust.*, xxvi, pp. 77–94.

Farquharson, R. A.: Petrological notes on rock specimens from the Kimberley Division. Unpublished manuscript report to Geol. Surv. West. Aust.

Fitzgerald, W. V., 1907: Reports on Portions of the Kimberleys, 1905–6. *Parliamentary Paper*, West. Aust., No. 19.

Hardman, E. T., 1885: Report on the Geology of the Kimberley District, Western Australia. *Perth: By Authority.*

Jutson, J. T., 1934: The Physiography of Western Australia, 2nd edit. *Bull.* 95, *Geol. Surv. West. Aust.*, pp. 34–46.

Kennedy, W. Q., 1933: Trends of differentiation in basaltic magmas. *Amer. Jour. Sci.*, 25, pp. 239–256.

Maitland, A. Gibb, 1902: *Ann. Prog. Rept. Geol. Surv. West. Aust.* for 1901, p. 9.

Maitland, A. Gibb, and Thomson, J. A., 1909: The Gascoyne, Ashburton, and West Pilbara Goldfield. *Bull.* 33, *Geol. Surv. West. Aust.*, pp. 163–9.

Talbot, H. W. E., and Farquharson, R. A., 1920: The Geology and Mineral Resources of the North-West, Central, and Eastern Divisions. *Bull.* 83, *Geol. Surv. West. Aust.*, pp. 142–5, 190–2, 195–214.

Washington, H. S., 1922: The Deccan Traps and other Plateau Basalts. *Bull. Geol. Soc. Amer.*, 33, pp. 765–804.

PLATE I.

Fig. 1. Microphotograph of typical two-pyroxene dolerite. In ordinary light. ×15.

Fig. 2. Two-pyroxene andesine-basalt, in ordinary light, showing the pyroxene laths in the glassy base, and an olivine microphenocryst. ×15.

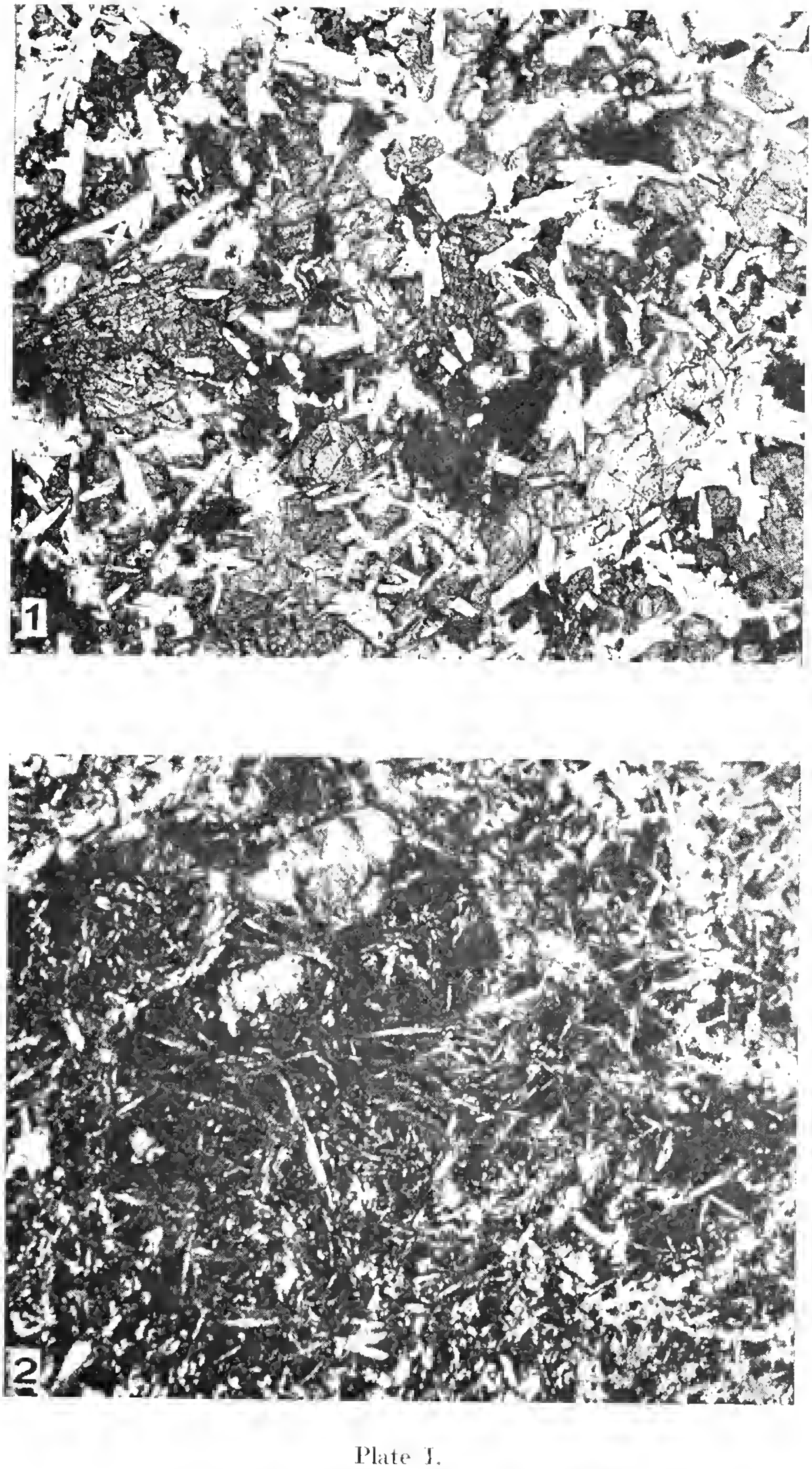

Plate I.

Plate II.

Fig. 3. Andesine-basalt, in ordinary light, showing patches of chlorite. ×15.

Fig. 4. Hornblende-oligoclase-basalt, in ordinary light, showing its extremely fine-grained texture. ×15.

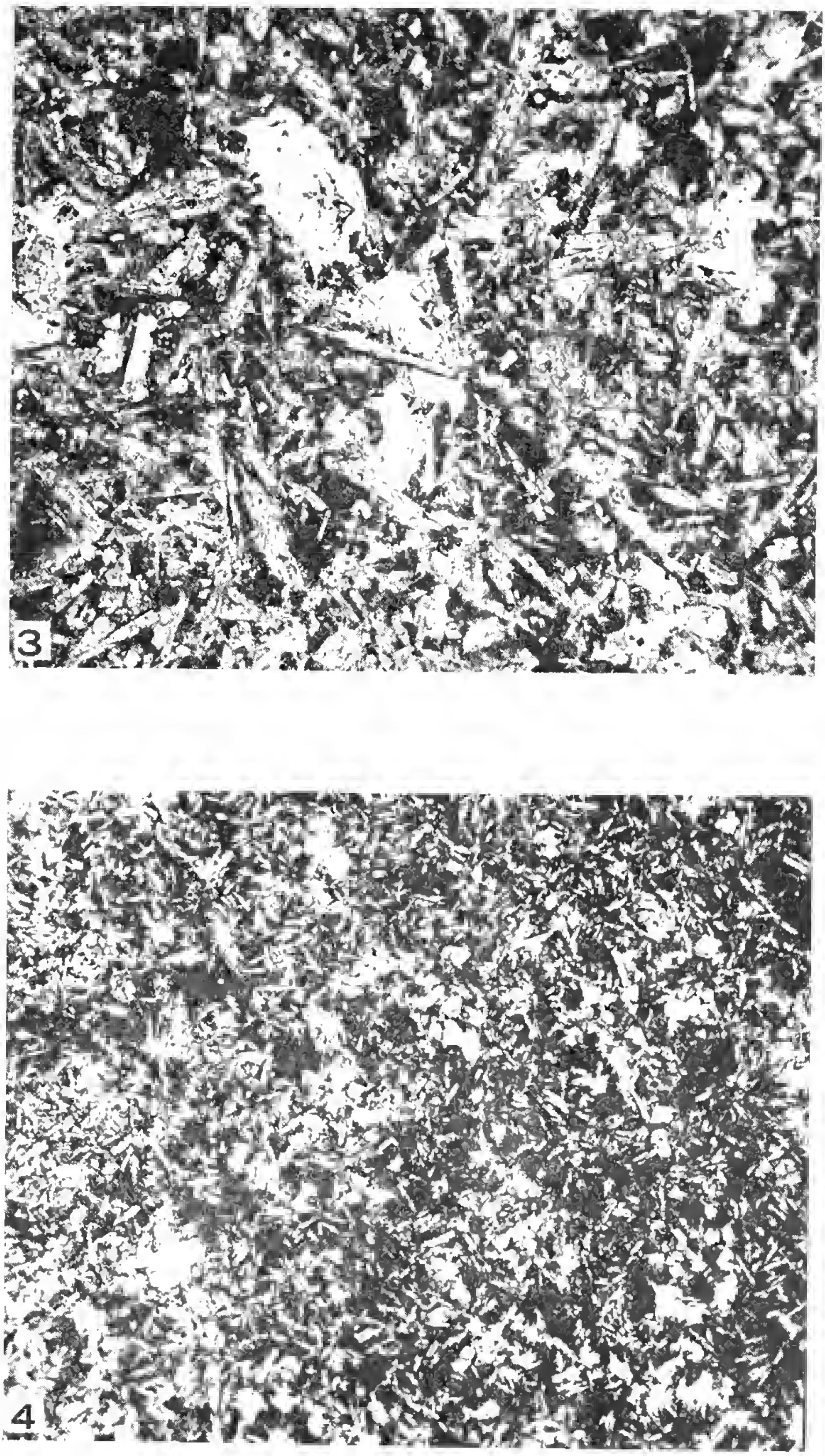

Plate II.

7.—NOTE ON FOSSIL CORALS FROM LANGLEY PARK BORE, PERTH.

By JOHN W. WELLS,
Ohio State University, Columbus, U.S.A.

Communicated by DOROTHY CARROLL.

Read: 12th November, 1940; Published: 15th May, 1942.

INTRODUCTORY NOTE.

Through the kindness of Dr. Dorothy Carroll of the Department of Geology, University of Western Australia, I have been enabled to examine the specimens of stony hexacorals obtained from the Langley Park Bore at Perth. All the specimens came from a depth between 428 and 440 feet and occurred in a "soft sandstone or unconsolidated grey sand, medium grained, with a little clay." Two species are represented in the collection, one belonging to *Trematotrochus lateroplenus* Dennant, the other probably a new species of oculinid but not specifically named at this time. The fact that the first species previously has been found in Balcombian strata at Shelford, Muddy Creek (lower), "Fishing Point," and "Lower Moorabool," and in Janjukian strata at Spring Creek, Cape Otway, and Lake Alexandrina (Janjukian ?), Victoria (Dennant and Kitson,* p. 135), might be taken to indicate Balcombian or Janjukian age for some of the beds in the Langley Park Bore, but the known long range of some of the corals of the Australian Tertiary deposits (a few species even ranging from Balcombian to Recent) makes any such assumption based upon the corals unwarranted at this time. Very careful studies of the Australian Tertiary coral species and their stratigraphic distribution are desiderata, practically nothing having been done since Dennant's work at the turn of the last century.

DESCRIPTIONS.

Family CARYOPHYLLIIDAE.

Subfamily TURBINOLIINAE.

Genus TREMATOTROCHUS Tenison Woods 1877.

Trematotrochus lateroplenus Dennant 1899. *Trans. Proc. Roy. Soc. South Australia*, xxiii, 282, pl. 9, figs 2a, b.

The single, slightly worn specimen identified with this species agrees closely with Dennant's excellent description of the types, except for its size, which is smaller. Typical specimens, according to Dennant, measure 5 mm. in height, and 2 x 3 mm. across the compressed calice. The present specimen, probably immature, is 2·5 mm. in height, the calice 1 x 2 mm. In all other respects there are no differences. The septal arrangement of the specimen is peculiar to this and one other species of the genus, that is, there are three complete cycles of septa (24) with the fourth cycle developed only in those systems on either side of the ends of the longer axis of the calice, giving a total of 32 septa.

* J. Dennant and A. E. Kitson, Catalogue of the Described Species of Fossils (except Bryozoa and Foraminifera) in the Cainozoic Fauna of Victoria, South Australia, and Tasmania. *Rec. Geol. Survey Victoria*, Vol. 1, Pt. 2, p. 89, 1902–6.

Occurrence: Type locality, Balcombian at Shelford, Victoria; and at Muddy Creek, Victoria. Langley Park Bore, Perth, Western Australia, between 428 and 440 feet. (No. 19,999, University of Western Australia, Dept. of Geology).

Family **OCULINIDAE.**

Subfamily **OCULININAE.**

Genus **OCULINA** Lamarck 1816.

Oculina ? sp.

Several small fragments may pertain to this genus, ranging from Upper Cretaceous to Recent especially in Europe and North America, but all are badly worn and certain essential structural details lacking, so that it is undesirable to make them the types of a new species. There are, however, no species now known from the Australian Tertiaries that remotely resemble these pieces, and there is no point in comparing them with forms occurring elsewhere until a more precise generic assignment is possible.

The corallum appears to have been small and dendroid, the corallites about 1·5 to 1·75 mm. in diameter, rather short and branching mostly in one plane simultaneously on either side of the parent nearly at right angles. Septa strongly spinose laterally, in three complete cycles (24), the first two equal and extending to the columella, the third little more than rudimentary. Columella small, composed of 4 to 6 twisted trabecular strands. Dissepiments feeble. Externally the corallites are covered with small faint costal granulations, arranged more or less in rows corresponding to the septa.

The principal obstacles to generic identification lie in the absence of well-preserved calices showing the disposition of the pali, traces of which are present, and the lack of information concerning the mode of colony-formation. If pali are present in one irregular crown before the first two cycles, and this is quite likely, the genus may be either *Oculina* or *Archohelia*, depending on the presence or absence of a persistent axial corallite: if there is but one crown before the second cycle it may be *Sclerhelia*, a genus known only from two Recent species.

(No. 20,000, University of Western Australia, Dept. of Geology).

8.—FORAMINIFERA AND A TUBICOLOUS WORM FROM THE PERMIAN OF THE NORTH-WEST DIVISION OF WESTERN AUSTRALIA.

By WALTER J. PARR.

Read : 10th December, 1940 ; Published : 15th May, 1942.

INTRODUCTION.

This paper presents the results of the examination of a number of rock samples and other material containing foraminifera from the Permian of the North-West Division of Western Australia. The specimens were collected by Mr. Henry Coley and Dr. C. Teichert and, with two exceptions which will be noted later, are all from beds forming part of the Wandagee Stage of Dr. H. G. Raggatt (1936) and later authors.

Foraminifera have not been previously recorded from beds of the Wandagee Stage and, at first glance, the hard, brownish, impure limestones and calcareous, fine-grained sandstones, in places highly ferruginous, from these beds appear unfavourable to their occurrence. Fortunately a collection of the larger fossils, presented to the Museum of the Victorian Mines Department in 1938 by Mr. Henry Coley, included a specimen on the weathered surface of which examples of a large foraminifer, now identified as *Hyperammina coleyi*, sp. nov., were recognised. Mr. Coley and Dr. Teichert afterwards forwarded many samples from which the foraminifera now described were obtained. The calcareous nature of the rock in most cases enables the sandy-shelled foraminifera, which constitute almost the whole of the fauna, to be freed from the surrounding matrix by immersing the sample in weak hydrochloric acid. The results of this treatment have been surprisingly successful, for, although the number of species is not large, the number, size and preservation of the specimens is remarkable. Other specimens were identified on the surface of those samples which could not be treated with acid and a number were obtained from weathered sandy shale. Twelve genera and fifteen species of foraminifera are recorded, of which twelve species are described as new. There is also what is believed to be a new tubicolous worm.

DESCRIPTION OF THE SAMPLES.

In a recent paper, Dr. Teichert (1939) has dealt with the stratigraphy of the Permo-Carboniferous sequence of the North-West Division of Western Australia. The sequence has been divided by Raggatt (1936) and others into the following stages, which are given in descending order :—

Wandagee Stage
Kennedy Stage.
Byro Stage.
Wooramel Stage.
Callytharra Stage.
Lyons Stage.

As a result of his work with Messrs. H. G. Higgins and E. Utting on the Wandagee beds, Dr. Teichert subdivides the Wandagee Stage as follows (from above) :—

Fenestella-Helicoprion beds.
Lamellibranch beds.
Calceolispongia-Strophalosia beds.
Calceolispongia-Aulosteges beds.
Lingula beds.

On the presence of the shark *Helicoprion* and the crinoid *Calceolispongia*, he suggests an Artinskian rather than a Uralian age for the beds.

In a later personal communication, dated 18th May, 1940, Dr. Teichert states that, on a visit to Wandagee Station in 1940, he found an horizon higher than any previously met with, with the result that the total thickness of the Wandagee beds is increased from the 2,000 feet given in his paper to approximately 2,500 feet. With the exceptions noted later, the samples examined by the writer were from the new horizon and from the *Calceolispongia* (the *C.-Strophalosia* and the *C.-Aulosteges* beds have not been differentiated) and the *Lingula* beds.

As a result of the study of a large quantity of material, it was found that each of these beds was characterised by the presence of certain species which occurred in practically every sample from that horizon. It is therefore not necessary to give particulars of more than some representative samples from each of the beds. Before dealing with these in detail, it may be stated that the residues left from the samples after treatment with hydrochloric acid consist almost wholly of foraminifera, ferruginous mud, fine angular quartz grains, and frequently numerous flakes of mica. Evidence that silicification of some of the calcareous fossils has occurred is provided by the presence of siliceous replacements of molluscan shells in the residues.

Uppermost beds (unnamed)—about 200 feet above *Fenestella* beds:—

(1) Highly ferruginous fine-grained sandstone from Nalbia Paddock, about 110 chains due east of Trig. Station, Wandagee Hill. (Coll. C. Teichert.)

Foraminifera—

Ammodiscus wandageeensis, sp. nov. common, exposed on weathered surface of rock.

(2) Highly ferruginous fine-grained sandstone from Coolkilyia Flat, approximately 1 mile south of Homestead-Garden Road and 1 mile east of Shed-Outcamp telephone line. (Coll. H. Coley.)

Foraminifera—

Ammodiscus wandageeensis, sp. nov. common, exposed on weathered surface of rock.

Calceolispongia beds.

(3) South of Minilya River. Light brown impure limestone, near top of *Calceolispongia-Aulosteges* beds. (Coll. C. Teichert.)

The residues after treatment with HCl consist principally of countless fragments of *Hyperammina coleyi*, sp. nov.

Foraminifera—

Hyperammina coleyi, sp. nov. abundant.
Hyperamminoides acicula, sp. nov. frequent.

(4) Minilya Road, Coolkilyia Flat, east limb of syncline north of Wandagee Hill. Light brown impure limestone. (Coll. C. Teichert.)

Foraminifera

Tolypammina undulata, sp. nov. very common.
Hyperammina coleyi, sp. nov. frequent.
Hyperamminoides acicula, sp. nov. very common.

(5) Burna Burna Paddock, Wandagee Station, on Wandagee-Mia Mia Road, about 3 miles in 231° 5′ from Burna Burna Hill. (Coll. C. Teichert.)

Dr. Teichert states that the rock (a light brown, dense, impure limestone) contains fragments of a species of *Calcolispongia* and remains of *Cleiothyridina* ?, from which he concludes an approximately Middle Wandagee age of the beds. He adds that the outcrop is quite isolated by major faults and is situated more than 10 miles north-east of the type area of the Wandagee beds (Wandagee Hill). The foraminifera include two species which have otherwise occurred only in the *Lingula* beds.

Foraminifera

Ammodiscus nitidus, sp. nov. frequent.
Tolypammina sp. rare.
Hyperammina coleyi, sp. nov. one broken example.
Hyperamminoides sp. a fragment.
Thurammina papillata H. B. Brady. rare.

Lingula beds.

(6) South side of Minilya River, near Coolkilyia Pool, Wandagee Station. Brown impure limestone. (Coll. H. Coley.)

This material is very rich in foraminifera and included a worm tube constructed of broken sponge spicules.

Foraminifera

Ammodiscus wandageeensis, sp. nov. very common.
Ammodiscus nitidus, sp. nov. frequent.
Glomospira adhaerens, sp. nov. frequent.
Tolypammina undulata, sp. nov. rare.
Hyperammina coleyi, sp. nov. common.
Hyperamminoides acicula, sp. nov. common.
Psammosphaera pusilla, sp. nov. rare.
Thurammina papillata H. B. Brady. rare.
Crithionina teicherti, sp. nov. rare.
Calcitornella stephensi (Howchin). rare.
Ammobaculites woolnoughi Crespin and Parr. rare.
Reophax subasper, sp. nov. rare.
Reophax tricameratus, sp. nov. rare.
Trochammina subobtusa, sp. nov. rare.

(7) Same locality as No. 6. Brown impure limestone. (Coll. C. Teichert.) Foraminifera are very common and include numerous perfectly-preserved examples of a new species of *Crithionina*.

Foraminifera—

Ammodiscus wandageeensis, sp. nov. common.
Ammodiscus nitidus, sp. nov. frequent.
Glomospira adhaerens, sp. nov. frequent.
Hyperammina coleyi, sp. nov. frequent.
Hyperamminoides acicula, sp. nov. frequent.
Crithionina teicherti, sp. nov. common.

(8) East of Coolkilyia Paddock, 865 links east of Teichert, Higgins and Utting's Station LII, traverse of 20th May, 1939. Brown impure limestone. (Coll. C. Teichert.) The foraminifera in this sample are nearly all large and very well preserved.

Foraminifera—

Ammodiscus nitidus, sp. nov. rare
Tolypammina sp. frequent.
Hyperammina coleyi, sp. nov. common.
Hyperammina (?) rudis, sp. nov. rare.
Hyperamminoides acicula, sp. nov. common.
Reophax subasper, sp. nov. rare

Probably from *Lingula* beds.

(9) Extreme south-east corner of Coolkilyia Paddock. (Coll. H. Coley.) These specimens differ from any of the others recorded in having naturally weathered out of sandy shales. They are generally fragmentary and distorted, as is so frequently the case when foraminifera are found in shales. The weathered material in which they occur is a cinnamon-coloured fine sand.

Foraminifera—

Ammodiscus wandageeensis, sp. nov. rare.
Tolypammina undulata, sp. nov. rare.
Hyperammina coleyi, sp. nov. frequent.
Hyperamminoides acicula, sp. nov. common (specimens usually flattened, or transversely ribbed through pressure).
Crithionina teicherti, sp. nov. frequent (specimens generally collapsed).
Reophax tricameratus, sp. nov. rare.

In view of their interest, the following specimens are also included, although they are from beds below the Wandagee Stage:—

(10) Brownish-green thin-bedded micaceous sandstone from sandstone outcrops in the Gascoyne River at Jimba Jimba Homestead. (Coll. C. Teichert.) Dr. Teichert states that this is older than the Wandagee series of the Minilya district and is placed by Raggatt (1936, p. 135) in the Byro.

Foraminifera—

Hyperamminoides acicula, sp. nov. 6 selected specimens.

(11) Ferruginous, finely-sandy shale from Gastropod horizon of Cundlego Series, about 1 mile west of Cundlego Well, Minilya River. (Coll. C. Teichert.)

Foraminifera—

Hyperamminoides, sp. cf. **acicula**, sp. nov. very rare fragments.

TABLE SHOWING SPECIES OF FORAMINIFERA OCCURRING IN BEDS OF THE WANDAGEE STAGE AND THEIR DISTRIBUTION.

(This is based on Samples Nos. 1–4 and 6–8.)

Species.	Uppermost (unnamed) horizon.	*Calceolispongia* beds.	*Lingula* beds.
Ammodiscus wandageeensis, sp. nov. ...	×	—	×
Ammodiscus nitidus, sp. nov.	—	—	×
Glomospira adhaerens, sp. nov.	—	—	×
Tolypammina undulata, sp. nov.	—	×	×
Hyperammina coleyi, sp. nov.	—	×	×
Hyperammina (?) rudis, sp. nov. ...	—	—	×
Hyperamminoides acicula, sp. nov. ...	—	×	×
Psammosphaera pusilla, sp. nov.	—	—	×
Thurammina papillata H. B. Brady ...	—	—	×
Crithionina teicherti, sp. nov.	—	—	×
Calcitornella stephensi (Howchin)	—	—	×
Ammobaculites woolnoughi Crespin and Parr	—	—	×
Reophax subasper, sp. nov.	—	—	×
Reophax tricameratus, sp. nov.	—	—	×
Trochammina subobtusa, sp. nov. ...	—	—	×

The foraminifera, with the exception of *Calcitornella stephensi*, are all species constructing their shells of extraneous matorial, usually quartz grains, cemented together by the animal. As the species are nearly all new, a close com arison with faunas elsewhere is not possible. Two of the species, *Calcitornella stephensi* and *Ammobaculites woolnoughi*, have been described from the Permian of Eastern Australia. The genera, with the exception of *Hyperamminoides* and *Calcitornella*, all occur living at the present day. Cushman (1933, pp. 161, 81) states that *Calcitornella* occurs in the Pennsylvanian and the Permian, but that *Hyperamminoides* is known only from the Pennsylvanian. Cushman and Waters, however, described at least one species of *Hyperamminoides*, *H. glabra*, from the upper part of the Graham formation of Texas, U.S.A. Raggatt and Fletcher (1937, p. 179) state that, while this was originally placed in the Pennsylvanian, it is now, they understand, considered to be Lower Permian.

Arenaceous foraminiferal faunas of the type occurring in the Wandagee beds are in present day seas characteristic of cold water. The genus *Hyperammina*, which is so common at Wandagee, is as a Recent genus widely distributed, but is most abundantly represented in cool waters, the temperature of the water having more control than the depth. The related, but now extinct *Hyperamminoides* probably occurred under similar conditions. *Crithionina* is also particularly characteristic of cold water.

The impure limestones and calcareous fine-grained sandstones in which these and the other foraminifera occur in the Wandagee beds indicate seas of no great depth, so it can be assumed that they represent a cool, moderately-shallow water facies.

The types of the new species described and other figured specimens have been deposited in the collection of the Geology Department, University of Western Australia. Examples of most of the species will also be lodged in the

Commonwealth Palaeontological Collection, Canberra, the Western Australian Museum, Perth, the Heron-Allen and Earland Collection in the British Museum, the Cushman Collection, the New Zealand Geological Survey Museum, and in the writer's own collection.

ACKNOWLEDGMENTS.

The writer gratefully acknowledges his indebtedness to Mr. Henry Coley and to Dr. Curt Teichert for the material examined. He also thanks Dr. Teichert for his continued assistance in the preparation of the paper. Miss Irene Crespin, B.A., the Commonwealth Palaeontologist, has kindly furnished copies of literature which were not available in Melbourne and also supplied specimens from the Commonwealth Collection for comparison. The photographs illustrating several of the species have, through the courtesy of Professor E. W. Skeats, been taken by Mr. J. S. Mann in the Geology Department of the University of Melbourne.

DESCRIPTION OF THE SPECIES.

Phylum PROTOZOA.

Order FORAMINIFERA.

FAMILY **AMMODISCIDAE.**

SUB-FAMILY **AMMODISCINAE.**

Genus **AMMODISCUS** Reuss, 1861.

Ammodiscus wandageeensis, sp. nov.

Plate II., fig. 1.

Test large, free, planospiral, composed of a small globular proloculus, followed by a long undivided tubular chamber closely coiled in a single plane, the tube fairly thick-walled, almost circular in section and slowly increasing in diameter as it lengthens ; number of whorls usually 6 or 7 ; spiral suture strongly depressed ; wall coarsely arenaceous with a rough surface and little visible cement ; aperture formed by the rounded open end of the chamber.

Diameter of test usually about 6 mm. ; thickness, 0.6 mm.

Holotype from Sample 6 (*Lingula* beds).

The exceptionally large size of this species (6 mm.) makes it a conspicuous object wherever it occurs. Palaeozoic species of *Ammodiscus* are usually small and the writer is not acquainted with any other with a diameter of more than 1 mm. *A. wandageeensis* may be compared with *A. semiconstrictus*, var. *regularis* Waters, from the Pennsylvanian of Oklahoma and Texas, U.S.A. The American form is less than one-sixth of the size of the Western Australian species, which also differs in its use of broken sponge spicules with quartz sand to form its test, and in its proportionately smaller proloculus. It is seldom that species of *Ammodiscus* incorporate spicules in the shell wall, but in *A. wandageeensis* they form a large part of the material used. A peculiar feature of many of the specimens is that the spicules have been leached out leaving numbers of short cylindrical cavities in varying planes in the shell wall. The occurrence of siliceous replacements of molluscan shells has already been mentioned ; possibly the silicia was derived from these spicules.

Ammodiscus nitidus, sp. nov.

Plate I., figs. 1*a*, *b*.

Test small, free, planospiral, composed of a minute proloculus and an elongate tubular chamber, almost semi-circular in section and slowly increasing in diameter, often transversely ridged, number of whorls usually 7 or 8, each whorl overlapping to a considerable extent its precedessor ; spiral suture only slightly depressed ; wall thin for the genus, composed of very small quartz grains with little visible cement ; shell surface comparatively smooth ; aperture semicircular, formed by the open end of the tube.

Diameter of holotype, 0·6 mm. ; thickness, 0·1 mm.

Holotype from Sample 8 (*Lingula* beds).

There are over 50 specimens. The smoothly-finished, thin shell wall and constrictions in the tubular chamber have led to the suspicion that the specimens are siliceous replacements of a species of *Cornuspira* or *Spirillina*. The surface of the test, however, absorbs water readily when it is moistened and, in thin section, the shell wall is seen to include quartz grains of different sizes. Both of these characters indicate that the specimens are referable to the genus *Ammodiscus*.

The central portion of the shell of *A. nitidus* is very thin and is often broken away. In many specimens the tube is regularly constricted at close intervals, but the constrictions are so slight as to be only faintly visible. These features and the smoothly-finished surface of the test will enable the species to be distinguished from any other. *A. bradynus* (Spandel), as described and figured by Paalzow (1935, p. 29, pl. iii., figs. 5, 6) from the Upper Permian (Zechstein) of Germany is perhaps nearest to *A. nitidus*, but the whorls do not overlap as in the Western Australian species.

Genus **GLOMOSPIRA** Rzehak, 1888.

Glomospira adhaerens, sp. nov.

Plate I., fig. 2.

Test usually attached, early portion coiled planospirally after which the tubular chamber increases in diameter and winds rather irregularly over the early portion to form a subglobular heap, finally in some specimens extending as a straight or curved tube adherent to the object of attachment ; wall composed of fine quartz grains firmly cemented to form a comparatively smooth surface ; aperture formed by the open end of the tube.

Diameter of closely coiled specimens up to 1·25 mm., with tube diameter of 0·25 mm. at end of tube.

Holotype from Sample 6 (*Lingula* beds).

Examples of this species are common in the material from the *Lingula* beds. They usually occur attached to the tests of *Hyperamminoides acicula*, but there are a few small free specimens. I have referred this species to the genus *Glomospira* as the plan of growth, except for the attached character of most of the specimens, is similar to that found in this genus. It may be added that the Recent *G. gordialis* (Jones and Parker), although typically a free form, occurs in the attached condition.

SUB-FAMILY **TOLYPAMMININAE**.

Genus **TOLYPAMMINA** Rhumbler, 1895.

Tolypammina undulata, sp. nov.

Plate II., fig. 2.

Test adherent, tubular, earliest portion apparently a small planospiral coil of about one whorl after which the tube winds from one side to the other or irregularly meanders over the object of attachment, the tube and the undulations meanwhile gradually increasing in size ; tube flattened on the under side ; wall formed of sand grains set in abundant cement ; surface comparatively smooth ; aperture formed by the open end of the tube.

Length up to 5 mm. or more ; diameter of tube at apertural end up to 0·4 mm.

Holotype from Sample 6 (*Lingula* beds).

Adherent tubular arenaceous foraminifera are very common in the middle and lower parts of the Wandagee Stage and the usual difficulty experienced in discriminating between these irregular-growing forms has been encountered. The present species may, however, be distinguished from the other tubular form described, *Glomospira adhaerens*, by the regular increase in the diameter of the tube as it lengthens and by the thicker tube wall, which is also more smoothly finished because of the much larger amount of cement used in its construction. Paalzow's *Adhaerentina permiana* (Paalzow, 1935, p. 29, pl. iii, fig. 3), from the Permian (Zechstein) of Germany, resembles the Wandagee species in form, but appears to differ in having the wall composed mainly of cement in which sand grains are embedded. *A. permiana*, according to Paalzow, was represented in his material by broken specimens only, the largest of which was over 2 mm. in length with a tube-diameter of 0·1 mm. It is therefore smaller and more slender than the present species.

FAMILY **HYPERAMMINIDAE**.

SUB-FAMILY **HYPERAMMININAE**.

Genus **HYPERAMMINA** H. B. Brady, 1878.

Hyperammina coleyi, sp. nov.

Plate II., fig. 3.

Test elongate cylindrical, consisting of a sub-globular proloculus and long slender tubular chamber of lesser diameter than the proloculus, widest in the middle portion, occasionally slightly constricted at irregular intervals ; wall thick, composed of medium-sized sand grains firmly cemented, surface rough, interior not smoothly finished ; aperture circular, formed by the open end of the tube.

Length up to 9 mm.; diameter of proloculus variable, ranging from 0·5 mm. to 1 mm.; diameter of tubular chamber usually about 0·5 mm.

Holotype from Sample 6 (*Lingula* beds).

This species is named in honor of Mr. Henry Coley, to whom the writer is indebted for so much interesting material from Wandagee Station.

Perfect examples of *H. coleyi* are common in the samples from the *Lingula* beds. Broken specimens, many of which are densely covered with *Tolypamminae*, occur in the *Calceolispongia* beds. The species may be compared with the Recent *H. elongata* H. B. Brady, from which it differs in the tapering apertural end, much thicker wall and rough interior. *H. bulbosa* Cushman and Waters (1927, p. 109, pl. xxii, figs. 7*a*, *b*), from the Pennsylvanian of Michigan, U.S.A., is also somewhat similar but has the proloculus flattened on one side and is much smaller.

Hyperammina (?) **rudis**, sp. nov.

Plate I., fig. 3.

Test elongate cylindrical, consisting of a tubular chamber closed at one end and of almost the same diameter throughout ; wall thick, composed of large angular to subangular sand grains firmly cemented ; surface very rough; aperture formed by the open end of the tube.

Length of holotype (probably incomplete), 1·4 mm.; breadth, 0·3 mm. Other specimens attain a slightly greater length.

Holotype from Sample 8 (*Lingula* beds).

There are fifteen examples, all from Sample 8. While one end of the tube of this species is closed, there is not a distinct proloculus and it is accordingly doubtful whether it is properly referable to *Hyperammina*. The very coarsely built test is unlike that found in typical *Hyperamminae* and strongly resembles that of *Rhabdammina*, in which genus, however, the end of the tube is not closed. It seems likely that a new genus of the Astrorhizidae is represented but the material available is not sufficiently well preserved to enable this to be decided.

Genus **HYPERAMMINOIDES** Cushman and Waters, 1928.

Hyperamminoides acicula, sp. nov.

Plate I., figs. 4, 5 ; Plate II., fig. 4.

Test elongate, tapering, sometimes at first slightly curved, very narrow at the initial end and from there gradually widening ; tube constricted at irregular intervals but not septate, the constrictions strongest in the early part of the shell ; wall thick, composed of comparatively small quartz grains set in abundant siliceous cement ; exterior smooth ; apertural end not constricted ; aperture circular, formed by the open end of the tube.

Length of holotype, 11 mm.; greatest diameter, 1·3 mm. Other broken specimens attain a diameter of 1·4 mm. or more and when complete were probably 18 to 20 mm. in length.

Holotype from Sample 7—brown, impure limestone, *Lingula* beds, south side of Minilya River, near Coolkilyia Pool, Wandagee Station (coll. C. Teichert).

The best examples of this fine species are from the *Lingula* beds in which it is common. The initial end of the larger specimens is in every case broken off. With these specimens, however, there are others of similar form, but very small and delicate, and it appears that these represent the early stages of the larger examples. Sometimes they are slightly curved in the earliest portion, but, with one exception, they are also incomplete. The exception, which is figured, shows a minute ovoid proloculus and is possibly the megalospheric form of the species. Another of these specimens, which is also figured with the same magnification, is extremely slender and apparently represents the microspheric form.

Several species of *Hyperamminoides* have been described from the Pennsylvanian of U.S.A. Of these, *H. proteus* (Cushman and Waters) described (Cushman and Waters, 1928, p. 36, pl. iv, figs. 5, 6) from Texas, most nearly resembles *H. acicula*, but has a different outline, particularly in the early stages, and attains a length of only 2·25 mm.

Prior to the receipt of the Wandagee material by the writer, Miss Irene Crespin, B.A., the Commonwealth Palaeontologist, had identified the genus *Hyperamminoides* in beds, probably of the same age as the Wandagee beds, in the Permian of New South Wales, and also in material collected by Dr. Arthur Wade and now in the collection of the Geology Department of the University of Western Australia, from the West Kimberley District, Grant Range, south section, just north of Hill 6. The Grant Range specimen has been kindly loaned to me and the species proves to be *H. acicula*. The examples of *Hyperamminoides* from New South Wales are from shales and are not sufficiently well preserved to enable a satisfactory specific determination. They have been recorded and figured, in a recent paper by Miss Crespin and the present writer (1941, p. 301, pl. xii, figs. 4, 5), as *H.* cf. *proteus* (Cushman and Waters). Better specimens may prove them to belong to the present species.

Dr. Teichert has forwarded six selected specimens of a species of *Hyperamminoides* in thin-bedded micaceous sandstone from beds of the Byro Stage on the Gascoyne River, at Jimba Jimba Homestead. These are referred to *H. acicula*. They are all broken and must have been of unusual size when complete, as one specimen in its present state is 16 mm. in length.

FAMILY **SACCAMMINIDAE**.

SUB-FAMILY **PSAMMOSPHAERINAE**.

Genus **PSAMMOSPHAERA** F. E. Schulze, 1875.

Psammosphaera pusilla, sp. nov.

Plate I., figs. 6, 7.

Test very small, spherical, consisting of a single chamber ; wall comparatively thick, formed of fine quartz grains, very firmly cemented, the cement apparently siliceous ; surface smoothly finished.

Diameter of holotype (an average specimen), 0·45 mm.

Holotype from Sample 6 (*Lingula* beds).

There are twelve examples of this species. The strength of the shell wall is, for such a small organism, remarkable. Considerable pressure with the point of a needle is necessary before the test can be broken.

P. cava, described by Moreman (1930, p. 48, pl. vi., fig. 12) from the Lower Palaeozoic of U.S.A., resembles the present species in external characters but has a thin wall ; its diameter is 0·5 mm. Moreman states that *P. cava* was very abundant in the Chimney Hill limestone. He remarks that it is very close to *P. papyracea* (Cushman), but that the latter has a thinner wall and is about twice as large.

SUB-FAMILY **SACCAMMININAE**.

Genus **THURAMMINA** H. B. Brady, 1879.

Thurammina papillata H. B. Brady.

Plate I., fig. 8.

Thurammina papillata H. B. Brady, 1879, p. 45, pl. v., figs. 4 8 ; 1884, p. 321, pl. xxxvi., figs. 7–18. Chapman and Howchin, 1905, p. 9, pl. ii., fig. 13. Heron-Allen and Earland, 1917, pp. 530 537. Moreman, 1930, p. 51, pl. v., fig. 13.

Test spherical, consisting of a single undivided chamber ; wall thin, composed of sand grains firmly cemented ; apertures numerous and irregularly scattered over the surface, situated at the end of nipple-like projections.

Diameter of Permian specimens up to 0·6 mm. ; Recent, up to 1·5 mm.

The specimens are very well preserved, the internal cavity being unfilled and the apertures at the end of the surface papillae are still open. Palaeozoic examples of *Thurammina* seem to be more coarsely built generally than Recent specimens and also vary more in form than do the specimens found in any single Recent dredging. Heron-Allen and Earland (*loc. cit.*) have, however, shown that *T. papillata* varies considerably both in shape and in the size of the material used in the construction of the shell wall. The Wandagee specimens appear to fall within the limits of these variations and are accordingly referred to Brady's species.

One Wandagee specimen has the surface projections extended in the form of comparatively long tubes, at the end of which the apertures are situated. Brady has figured a similar Recent specimen in the Challenger Report (pl. xxxvi., fig. 14).

While *T. papillata* is best known as a Recent form, it has been recorded by Chapman and Howchin from the Permian of New South Wales and by Moreman from the Silurian of U.S.A.

FAMILY **ASTRORHIZIDAE**.

Genus **CRITHIONINA** Goës, 1894.

Crithionina teicherti, sp. nov.

Plate I., figs. 9, 10.

Test free, comparatively large, spherical, thick-walled, but variable in this respect, central cavity large, connected with the outside surface by numerous moderately-sized pits which extend irregularly through the thickness of the shell wall and reach the exterior surface through minute openings ; wall composed of fine sandy material fairly well cemented, with a thin compact surface layer.

Diameter of holotype, 2·2 mm., other specimens are slightly larger.

Holotype from Sample 7 (*Lingula* beds).

As far as I am aware, there is only one previous record, that of Moreman from the Silurian of U.S.A., of this genus as a fossil. It is therefore specially interesting to meet with it in such numbers in the Permian of Australia. The specimens are exquisitely preserved and every detail of structure can be studied as readily as in the best Recent material.

In the living condition, *Crithionina* is best developed in cold waters, particularly in the North Atlantic, where it occurs in immense numbers.

FAMILY OPHTHALMIDIIDAE.

SUB-FAMILY CORNUSPIRINAE.

Genus CALCITORNELLA Cushman and Waters, 1928.

Calcitornella stephensi (Howchin).

Cornuspira, sp. nov. Jones, 1882, p. 6.

Nubecularia lucifuga Defrance, var. *stephensi* Howchin, 1894, p. 345, pl. x*a*, xi*a*.

N. stephensi Howchin: Chapman and Howchin, 1905, p. 5, pl. i., figs. 1, 2; pl. iii., figs. 13, 14; pl. iv., figs. 1, 4. Etheridge, Junr., 1907, p. 26, pl. x., figs. 4–9; 1907a, p. 13, pl. xii., fig. 11.

Calcitornella stephensi (Howchin): Chapman, Howchin, and Parr, 1934, p. 187.

No weathered-out examples of this species were found, the record being based on several internal casts found adherent to the tests of sandy species after the calcareous material in the rock had been dissolved by treatment with hydrochloric acid. The casts show the arrangement of the tubular chamber found in *C. stephensi*.

C. stephensi was described from the Permian of Tasmania and has since been recorded from beds of this epoch in New South Wales, Western Australia, and Northern Territory.

FAMILY LITUOLIDAE.

SUB-FAMILY HAPLOPHRAGMIINAE.

Genus AMMOBACULITES Cushman, 1910.

Ammobaculites woolnoughi Crespin and Parr.

Plate I., fig. 11.

Ammobaculites woolnoughi Crespin and Parr, 1941, p. 304, pl. xii., figs. 2, 3.

There are two specimens which appear to be referable to this species. The types are from the Permian, Farley Road, 300 yards north-east of Farley Railway Station, New South Wales. The Wandagee specimens, from the *Lingula* beds, are smaller (0·5 mm.) and built of coarser material than those from New South Wales, but are of similar form. The latter are from shales and this probably accounts for the finer-grained, more smoothly finished test.

FAMILY REOPHACIDAE.

SUB-FAMILY REOPHACINAE.

Genus REOPHAX Montfort, 1808.

Reophax subasper, sp. nov.

Plate I., fig. 12.

Test consisting of up to 7 chambers, rapidly increasing in size as added, early chambers indistinct, usually arranged in a curved series, later chambers larger and more distinct, in nearly a straight line; wall built of coarse quartz grains, firmly cemented, surface rough; aperture a small opening between three or more sand grains at the end of the final chamber.

Length of holotype, 1 mm.; breadth, 0·4 mm.

Holotype from Sample 8 (*Lingula* beds).

There are nineteen examples of this species. The most closely related Palaeozoic species is probably *R. asper* (Cushman and Waters, 1928, p. 37, pl. iv., fig. 7), from the Pennsylvanian of Texas, U.S.A. This is much like *R. subasper*, particularly when the specimens of the latter have lost the early arcuate series of chambers. The two may, however, be distinguished by the final chamber which in the Australian species is always wider than any other, while that in *R. asper* is narrower than the penultimate chamber.

Reophax tricameratus, sp. nov.

Plate I., fig. 13.

Test composed of a few (typically three) chambers, increasing rapidly in size as added, the last-formed chamber making up about half the length of the test ; axis of test straight or slightly curved ; wall composed of medium-sized sand grains, firmly cemented ; surface rough ; apertural end slightly produced ; aperture terminal.

Length of holotype, 1·7 mm. ; breadth, 1 mm.

Holotype from Sample 6 (*Lingula* beds).

This species is represented by the holotype from Sample 6 and six crushed specimens from the weathered shale sample (No. 9). It appears to be different from any previously-described form.

FAMILY TROCHAMMINIDAE.

SUB-FAMILY TROCHAMMININAE.

Genus **TROCHAMMINA** Parker and Jones, 1859.

Trochammina subobtusa, sp. nov.

Plate I., figs. 14*a*–*c*.

Test subglobose, trochoid, spire low, under side umbilicate, composed of three whorls ; chambers strongly inflated, with four in the last-formed whorl, the chambers of which are so much larger than those in the preceding whorls that they form the greater part of the test ; sutures distinct and depressed ; wall finely arenaceous, with the surface smoothly finished but not polished ; aperture an arched slit at the base of the last-formed chamber, opening into the umbilical depression.

Diameter of holotype, 0·45 mm. ; height, 0·24 mm.

Holotype from Sample 6 (*Lingula* beds).

This species is represented by six specimens, all of which are very well preserved. *Trochammina arenosa* Cushman and Waters (1927a, p. 152, pl. xxvii., figs. 4*a*–c), described from the Pennsylvanian of Texas, U.S.A., shows a similar arrangement of the chambers, but is much flattened and spreading and the wall is rather coarsely arenaceous.

Phylum ANNELIDA.
Class CHAETOPODA.
Sub-Class POLYCHAETA.

ORDER CRYPTOCEPHALA (SEDENTARIA OR TUBICOLA).

Amphictene (?) **permiana**, sp. nov.

Plate II., fig. 5.

Tube thin, circular in section, tapering slightly, formed of fragments of siliceous sponge spicules arranged concentrically in a single layer.

Length of holotype (incomplete specimen), 3·5 mm. ; diameter, 1·1 mm.

Holotype from Sample 6 (*Lingula* beds).

This species is represented by a single specimen. Its identification has been a matter of some difficulty, but after an examination of the available literature, it appears that it is a tubicolous worm, forming a tube like the Recent *Amphictene auricoma* (O. F. Müller). No foraminifer known constructs a similar test.

A. auricoma occurs in the North Atlantic and normally constructs its long, thin-walled, tapering, slightly curved tube of sand grains. On muddy bottoms (McIntosh, 1894 and 1922), broken sponge spicules are used instead of the sand grains, the spicule fragments being so arranged that those in one row alternate with those in the next, like the bonding of bricks in a wall, to form the strongest tube possible. A minimum of cement is used to hold the spicules together and the resultant tube is thin-walled and most neatly constructed and finished.

Nothing showing a wall structure like that found in the spicular tubes of *A. auricoma* appears to have been recorded as a fossil and the present specimen from the Permian is therefore of unusual interest. While it also consists of a similar layer of spicular fragments, comparison with the figures of *A. auricoma* given by McIntosh (*loc. cit.*) and by Heron-Allen and Earland (1909, pl. xxxv., fig. 14) and with examples of the Recent species for which I am indebted to my friend, Mr. Arthur Earland, F.R.M.S., shows the fossil form to be distinct, being less neatly built and also smaller than *A. auricoma*. It should be added that, while this comparison with *A. auricoma* has been made, the two forms may be unrelated although apparently similar; the Permian species has accordingly been doubtfully referred to the genus *Amphictene*.

REFERENCES.

Brady, H. B.:

1879: Notes on some of the Reticularian Rhizopoda of the "Challenger" Expedition. *Quart. Journ. Micr. Sci.* (London), XIX., pp. 20–63, pls. iii–v.

1884: Report on the Foraminifera dredged by H.M.S. "Challenger" during the years 1873–1876. Rep. Voy. *Challenger*, Zoology, vol. ix.

Chapman, F., and Howchin, W., 1905: A Monograph of the Foraminifera of the Permo-carboniferous Limestone of New South Wales. *Mem. Geol. Surv. N.S.W.*, Pal. No. 14, pp. 1–22, pls. i–iv.

Chapman, F., Howchin, W., and Parr, W. J., 1934: A Revision of the Nomenclature of the Permian Foraminifera of New South Wales. *Proc. Roy. Soc. Vic.*, XLVII. (N.S.), pt. 1, pp. 175–189.

Crespin, I., and Parr, W. J., 1941: Arenaceous Foraminifera from the Permian Rocks of New South Wales. *Jour. Proc. Roy. Soc. N.S.W.*, LXXIV., pp. 300–311, pls. xii, xiii.

Cushman, J. A., 1933: Foraminifera. Their Classification and Economic Use. Second Edition.

Cushman, J. A., and Waters, J. A.:

1927: Pennsylvanian Foraminifera from Michigan. *Contr. Cushman Lab.*, III., pp. 107–110, pl. xxii.

1927a: Arenaceous Palaeozoic Foraminifera from Texas. *Ibid.*, III., pp. 146–153, pls. xxvi, xxvii.

1928: Some Foraminifera from the Pennsylvanian and Permian of Texas. *Ibid.*, IV., pp. 31–55, pls. iv–vii.

Etheridge, R. (Jun.):

1907: Descriptions of Carboniferous Fossils from the Irwin River, collected by Mr. C. F. V. Jackson, late Assistant Government Geologist. *West. Aust. Geol. Survey Bull.* No. 27, pp. 26–37, pls. (Foraminifera on pl. x.)

1907a: Official Contributions to the Palaeontology of South Australia. *Supplement to Parlty. Paper* No. 55 of 1906, pp. 1–21, pls. i–xii. (Foraminifera on p. 13 and pl. xii.)

Heron-Allen, E. and Earland, A.:

1909: On a New Species of *Technitella* from the North Sea, etc. *Jour. Quekett Micr. Club* [2], X., pp. 403–412, pls. xxxi–xxxv.

1917: On some Foraminifera from the North Sea, dredged by the Fisheries Cruiser "Goldseeker"—V. On *Thurammina papillata* Brady: A Study in Variation. *J.R.M.S.*, 1917, pp. 530–557, pls. xxvi–xxx.

Howchin, W., 1894: On the Occurrence of Foraminifera in the Permocarboniferous Rocks of Tasmania. *Rept. Aust. Assocn. Adv. Sci.*, Adelaide Meeting (1893), pp. 344–348, pls. x, xi.

Jones, T. R., 1882: Catalogue of the Fossil Foraminifera in the British Museum (Natural History). London, 1882.

McIntosh, W. C.:

1894: On certain Homes or Tubes formed by Annelids. *Ann. Mag. Nat. Hist.* [6], xiii, pp. 1–18, text-figs.

1922: A Monograph of the British Marine Annelids, vol. IV., pt. 1. London, Ray Society.

Moreman, W. L., 1930: Arenaceous Foraminifera from Ordovician and Silurian Limestones of Oklahoma. *Jour. Pal.*, IV., pp. 42–59, pls. v–vii.

Paalzow, R., 1935: Die Foraminiferen im Zechstein des östlichen Thüringen. *Jahrb. Preuss. Geol. Landesanstalt*, LVI., pp. 26–45, pls. iii–v.

Raggatt, H. G., 1936: Geology of the North-west Basin, Western Australia, with Particular Reference to the Stratigraphy of the Permo-Carboniferous. *Jour. and Proc. Roy. Soc. N.S.W.*, LXX., pp. 100–174.

Raggatt, H. G., and Fletcher, H. O., 1937: A Contribution to the Permian-Upper Carboniferous Problem and an Analysis of the Fauna of the Upper Palaeozoic (Permian) of North-West Basin, Western Australia. *Records Aust. Mus.*, XX., pp. 150–184.

Teichert, C., 1939: Recent Research Work in the Permian of Western Australia. *Aust. Jour. Sci.*, II., No. 1, pp. 5–7.

EXPLANATION OF PLATES.

PLATE I.

Figs. 1*a*, 1*b*. **Ammodiscus nitidus,** sp. nov. Holotype. ×50. No. 20670.

Fig. 2. **Glomospira adhaerens,** sp. nov. Holotype. ×25. No. 20675.

Fig. 3. **Hyperammina** (?) **rudis,** sp. nov. Holotype. ×37. No. 20677.

Figs. 4, 5. **Hyperamminoides acicula,** sp. nov. Early stages, apparently of microspheric form (Fig. 4) and megalospheric form (Fig. 5). Both ×37. No. 20679.

Figs. 6, 7. **Psammosphaera pusilla,** sp. nov. 6, holotype external view; 7, internal aspect of another specimen. Both ×37. No. 20680.

Fig. 8. *Thurammina papillata* H. B. Brady. ×43. No. 20681.

Figs. 9, 10. **Crithionina teicherti,** sp. nov. 9, holotype, ×13; 10, internal aspect of broken specimen, showing wall structure, ×13. No. 20674.

Fig. 11. *Ammobaculites woolnoughi* Crespin and Parr. ×50. No. 20669.

Fig. 12. **Reophax subasper,** sp. nov. Holotype. ×37. No. 20685.

Fig. 13. **Reophax tricameratus,** sp. nov. Holotype. ×20. No. 20684.

Figs. 14*a*-14*c*. **Trochammina subobtusa,** sp. nov. Holotype. a, dorsal view; b, ventral view; c, edge view. All ×75. No. 20683.

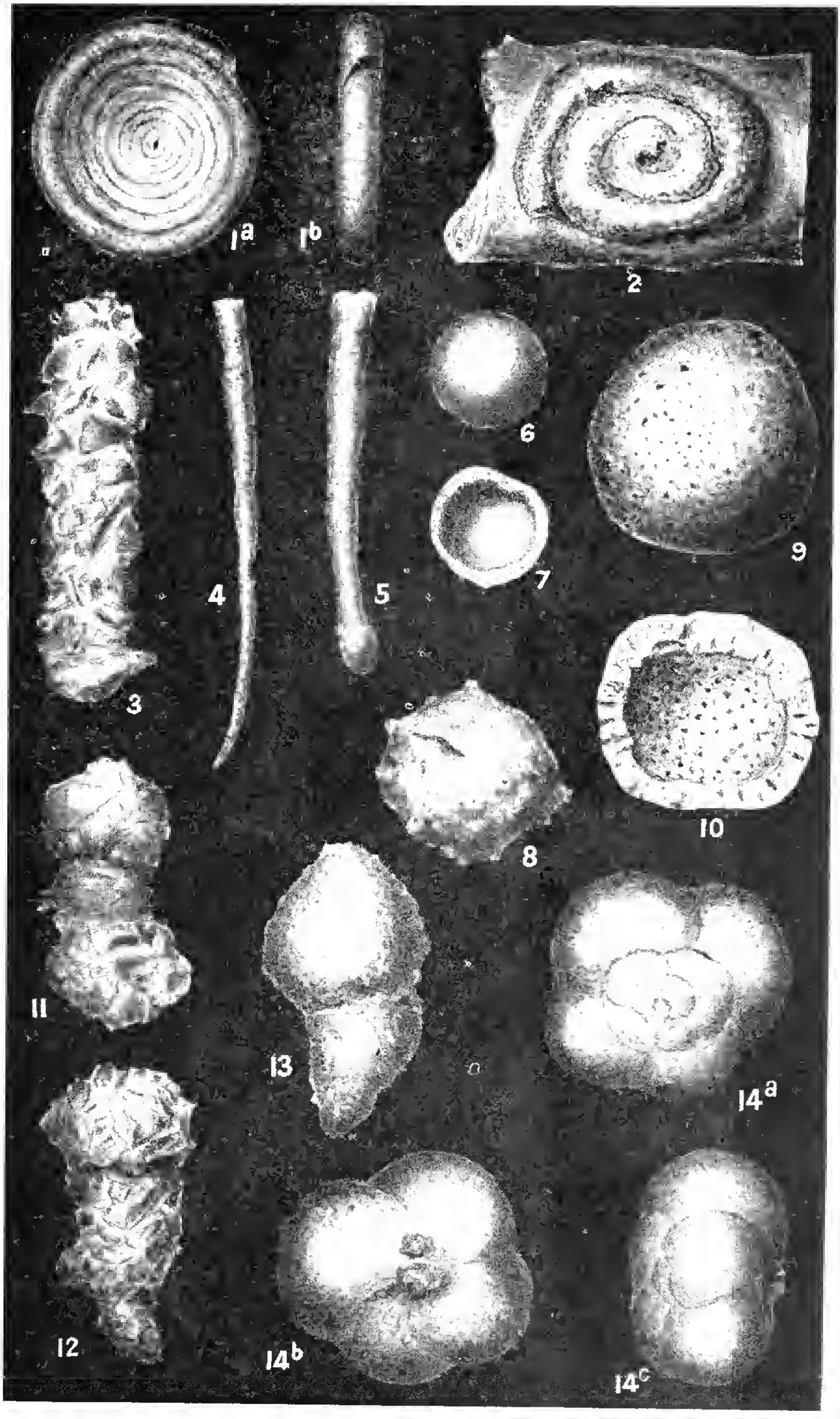

PLATE I.

PLATE II.

Fig. 1. **Ammodiscus wandageeensis,** sp. nov. Holotype. ×12. No. 20671.

Fig. 2. **Tolypammina undulata,** sp. nov. Three specimens adherent to a test of **Ammodiscus wandageeensis.** The holotype is the specimen just to the right of the extreme left hand specimen. ×12. No. 20682.

Fig. 3. **Hyperammina coleyi,** sp. nov. Holotype. ×11. No. 20676.

Fig. 4. **Hyperamminoides acicula,** sp. nov. Holotype. ×9½. No. 20678.

Fig. 5. **Amphictene** (?) **permiana,** sp. nov. Holotype. ×19. No. 20672.

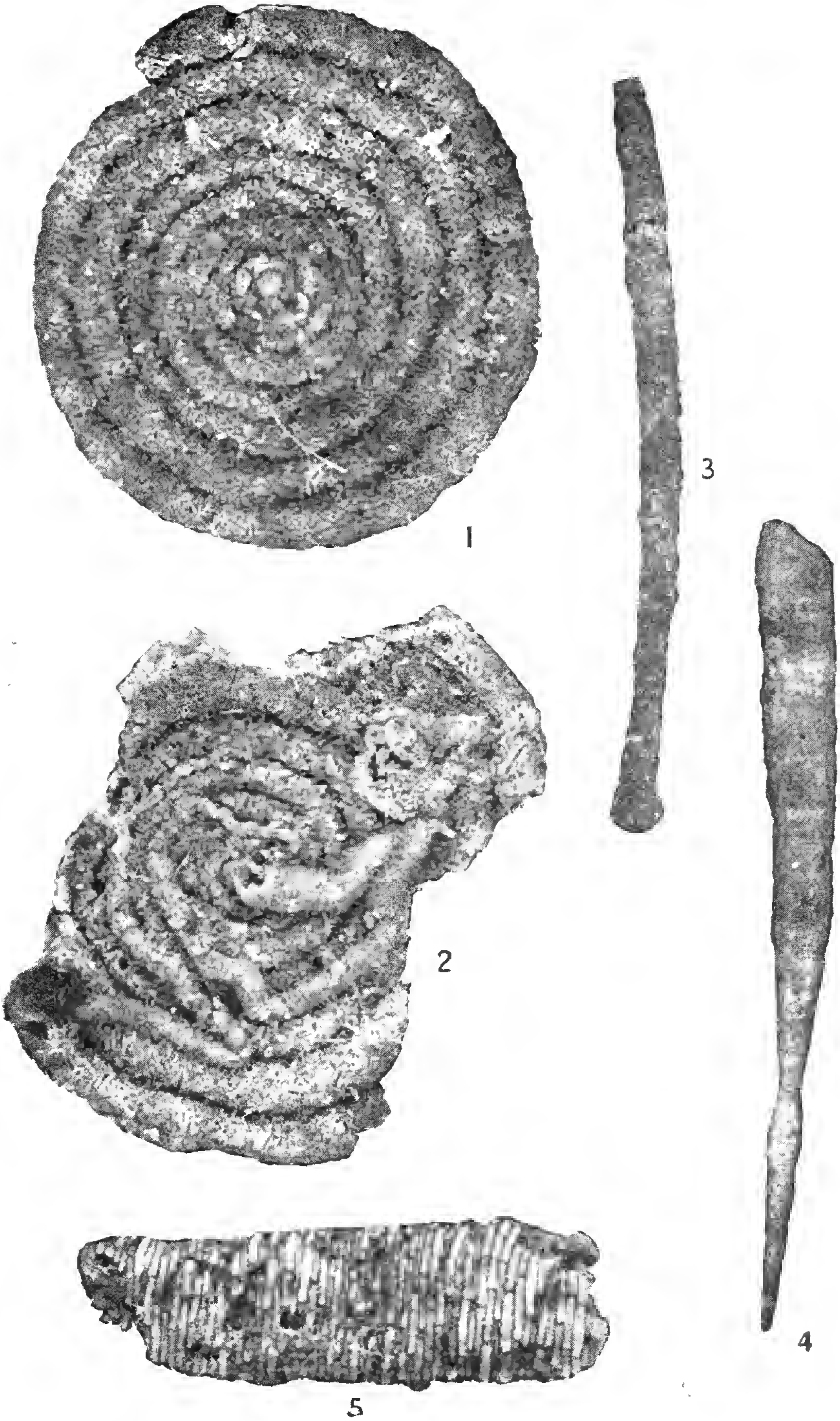

PLATE II.

9.—THE SEEDS OF *STRYCHNOS LUCIDA*, R.Br., AND THEIR ALKALOID CONTENT.

By E. M. WATSON.

Read: 11th March, 1941; Published: 15th May, 1942.

Strychnos lúcida, R. Br., which is the only representative of the genus recorded in Western Australia, is recorded by Gardner (1) as being common in Central Kimberley. The author is indebted to Rev. J. R. B. Love, formerly of Kunmunya Mission, for collecting the fruits used in this investigation.

It is an erect shrub, 6 to 15 feet in height. It bears orange-yellow fruits which are globular or ovoid-globular in shape, up to about 25 mms. in diameter and containing one or more seeds. Those available for this work were 12 to 15 mms. in diameter and were single seeded. The pericarp is brittle, hard and polished and is very slightly wrinkled and pitted; it is about 0·5 mm. thick and is easily cracked. The pulp, which is milky-white in fresh fruits, dries to a dark tacky semi-solid which adheres to the seed. It is readily removed by soaking the seeds in cold water and then rubbing between the fingers. The pulp has an intensely bitter taste and colour tests indicate that it contains an appreciable amount of brucine and a much smaller amount of strychnine.

The seeds are typically grey or greenish-grey in colour, disc or button-shaped, 10 to 13 mms. in diameter and about 3 mms. thick. They are generally flat and regular in shape but are occasionally irregularly bent or oval in shape. The edge of the seed is rounded (or very occasionally acute) and shows a distinct raised micropyle which is often connected by a ridge to the hilum. The testa is covered with radially arranged, closely adpressed, silky, lignified hairs. The endosperm, which makes up practically the whole of the seed, is horny and translucent, and is yellow, greenish-yellow or greyish-yellow in colour. It consists of large thick walled cells and, when sectioned and treated with nitric acid, shows the characteristic red colour given by brucine. When similarly treated with sodium vanadate in sulphuric acid solution, it gives the violet colour characteristic of strychnine. The intensity of this colour is appreciably less than that given by the seeds of *Strychnos nux vomica*, indicating a lower strychnine content, a fact borne out by subsequent analysis. The embryo is small and consists of two cordate, leaf-like cotyledons about 3 mms. long, with a cylindrical radicle about 2 mms. long, directed towards the micropyle. The seeds are odourless when dry and have an intensely bitter taste.

Macroscopically the seeds differ from those of *S. nux vomica* in size only, whilst microscopically no obvious differences are apparent.

On analysis, the seeds showed a strychnine content of 0·84 per cent. and a brucine content of 1·55 per cent. The former figure is much lower than the average strychnine content of nux vomica seeds (1·23 per cent.) or of St. Ignatius' beans (1·5 per cent.), so that commercial exploitation of *S. lucida* appears unlikely as long as nux vomica is available.

EXPERIMENTAL.

The method of estimation of the alkaloids was based on the methods of assay of nux vomica of the British Pharmacopoeia, 1932, and the United States Pharmacopoeia X.

The seeds were very finely shredded and the alkaloids completely extracted with alcohol-chloroform mixture (3 : 1) containing 6 per cent. of 10 per cent. ammonia solution. The solvent was removed from the extract, the alkaloids dissolved in chloroform containing a little alcohol, and the alkaloids extracted as their sulphates, the usual precautions being taken to avoid loss. The solution of the alkaloid sulphates was thoroughly washed with chloroform, the alkaloids then liberated with ammonia and extracted with chloroform. From this extract the solvent was removed, 5 ml. of alcohol added, again evaporated and the alkaloids dried at 100°C. for 30 mins. The total alkaloids were estimated by dissolving in 10 ml. of standard sulphuric acid solution and titrating the excess acid with standard sodium hydroxide solution, using methyl red as indicator.

The titration liquid was made alkaline with ammonia and the alkaloids again extracted with chloroform and recovered as before. The brucine was then oxidised with nitric acid in dilute sulphuric acid solution under the conditions of the British Pharmacopoeia, 1932, and the strychnine recovered and estimated volumetrically as before. The strychnine content, allowing the usual 2 per cent. loss associated with the method of estimation, was 0·84 per cent., and the difference between the strychnine and total alkaloids was equivalent to 1·55 per cent. of brucine.

REFERENCE.

(1) Botanical Notes, Kimberley Division of Western Australia (Forests Dept. Bulletin No. 32).

Perth Technical College.

10.—NOTES ON THE VEGETATION OF THE NORTH EASTERN GOLDFIELDS.

By NANCY T. BURBIDGE.

Read: 11th March, 1941; Published: 20th May, 1942.

INTRODUCTION.

The ecology of the pastoral region commonly referred to as the North Eastern Goldfields has been discussed by Melville in a paper as yet unpublished. The present paper includes information obtained during two short visits to Glenorn Station, Malcolm (about 120 miles north of Kalgoorlie). The first visit was from 16th April to 9th May and the second was for a fortnight in August. During the first visit fourteen ecological transects—all except one being of the strip type—were surveyed. In this manner representative sample cross-sections of the perennial vegetation were obtained. It is not possible to publish the resultant ecological maps but notes on them and lists of the plants encountered are given herein.

Since the summer rains had been disappointing, there was little growth of summer annuals, including the grasses. A few perennials flowered as a result of rains during February and March, though the falls were light. In August there was a certain amount of herbage available as a result of the June-July rains though these, again, were not heavy.

Owing to the poorness of the seasons and to the shortness of the visits, the remarks made in this paper are not intended to give a complete analysis of the vegetation of the area, but rather, to make available information concerning an area about which very little has been previously published. Reference is made in various parts of the paper to different varieties of *Acacia aneura*. It is proposed to discuss these more fully in a forthcoming paper.

Ecologically speaking the area is in the southern portion of the Acacia Semi-desert Scrub as defined by Teakle (1936). *Acacia aneura*, its varieties and allied species, constitute the most important tree and shrub forms. The Malcolm area was surveyed geologically by Clarke (1925). Most of the country studied during the two trips lay in the greenstone areas, all the transects being worked in this type except those across quartz "blows." According to the geological map (Clarke, 1925) the area of spinifex sandplain seen on Glenorn lies over greenstone. Talbot (1920) considered that sandplain development could be correlated with the occurrence of granite. It is possible that the sand in this instance has been transported from granite areas to the north and north-east.

ECOLOGY.

Melville recognises the following types of country:—(1) Flood Plain, (2) Hills Scrub, (3) Shrub Steppe, (4) Sandplain. With the exception of the third section these hold for the Glenorn area.

(1) *Flood Plain.*

"Flooded" country is the local term used in referring to the wide flats across which drains the run off from the low hills. Drainage is of two types.

(a) Occasional well defined, but short, creeks which are shallow and narrow. These soon lose their identity in (b). The course of the creeks can be followed, from some distance away, owing to the bright green foliage of the creek gums (*Eucalyptus camaldulensis*), which are almost invariably associated with them. Other characteristic plants are jamwood (*Acacia Burkitti*) and creek cassia (*Cassia artemisioides*). The botanical differences between (a) and (b) are quite marked and are probably related to the water supply factor.

(b) Wide flats where the water flows, as a sheet, across the almost level surface. These flats include most of the mulga country that is pastorally valuable, all the better types of mulga (*Acacia aneura*) being found in this habitat. These include the "Silver Leaved" mulga and medium leaved forms. Curara bush (*Acacia genistoides*) is characteristic of this country though, where the creeks merge into the flood plain proper, curara may mingle with jamwood for a short distance. *Eremophila Latrobei*, *E. Margarethae* and *E. maculata* occur in the better watered patches. All are generally referred to as fuchsia bushes though this name is most commonly attached to *E. maculata*. This species, though regarded with suspicion by some as a poison bush, is considered quite useful feed on Glenorn. The first named of the three species is the most widespread. Other shrubs include *Cassia eremophila* and, amongst the smaller forms, *Enchylaena tomentosa*, *Rhagodia* sp. *Abutilon cryptopetalum* and *A. otocarpum*. (See Transects III., IV., XII.)

After the winter rains the flats carry an abundant crop of ephemerals, though at other times the ground between the trees and occasional shrubs is completely bare. The area covered by, and the individual size of, these plants is strikingly related to the amount of water available. By far the best development takes place on the lower levels except where claypan formation, with consequent water-logging of the soil, has prevented any growth whatever. Members of the Compositae, Cruciferae, Chenopodiaceae and Amarantaceae are the most important constituents.

The growth resulting from summer rains includes a number of annual grasses of which *Aristida arenaria*, *Neurachne Mitchelliana* and *Enneapogon caerulescens* are the most abundant.

The chief soil of the flood plain is a sandy-clay loam (Teakle, 1936) overlying a siliceous hardpan which rests on the country rock. The surface of the hardpan, which is characteristic of the whole pastoral region, is variable so that soil depth may change from a few inches to two or three feet within a few yards.

Throughout the flood plain low ridges of variable extent and importance have developed. Here sand overlies the hardpan to a considerable depth. These are referred to as "Wandarrie" country and the vegetation differs markedly from that of the lower flats. The mulga remains more or less the same though, so far as could be judged in the time available, it was in a poorer condition. Curara is completely absent and is replaced by bogada bush *Acacia brachystachya*. It may be noted here that this common name is used in the Murchison area to refer to *Acacia linophylla*, while *Acacia brachystachya* is known as sugar brother. *A. linophylla* was not collected at Glenorn. Amongst the smaller shrubs poverty bush (*Eremophila leucophylla*) is, both numerically and pastorally, important as sheep will feed on it when more palatable species disappear during dry seasons. Another species, *E. compacta* also occurs but is not so important on either point. Both these shrubs are capable of standing dormant for long periods. After rain they respond with fresh growth within a short time. Also the conditions favouring germination do not seem to be as exacting as in the case of *Acacia aneura*. In good seasons with satisfactory summer rains the soil carries an abundant growth of Wandarrie grasses which give the type of country its name. The most important of these are *Eragrostis eriopoda*, *E. setifolia* and *Eriachne Helmsii*. During dry periods these die back to their woolly rhizomes and become dormant so that the ground is bare between the shrubs. Less important grasses are *Danthonia bipartita*, *Neuraclne Mitchelliana*, *Aristida arenaria* and *Enneapogon caerulescens*. None of these latter grasses is restricted to any particular association but they all prefer the deeper soils. (See Transects II., VIII., XI.)

During the August visit the poverty bushes had formed new growth and there was a number of young seedlings. The bogada had freshened up and some was in flower. The ephemeral growth was very poor compared with that on the loamy flats. The following annuals were collected however :—*Stenopetalum pedicellare*, *S. robustum*, *Parietaria debilis*, *Halorrhagis odontocarpa*, *Velleia rosea*, *V. cycnopotamica*, *Podolepis pallida*, *Calotis multicaulis* and *C. hispidula*. There was also a fair amount of *Erodium cygnorum*.

If the Wandarrie country be excepted, the flood plain formation may be regarded as lying between the Hills Scrub and the Shrub Steppe.

(2) *Hills Scrub.*

On Glenorn the vegetation of the higher ground is closely related to the soil and country rock and may be subdivided as follows :—

(a) On greenstone outcrops and the residual hills from the pre-existing plateau there is a poor Acacia scrub (*Acacia Burkitti* var.) which, especially on the higher ground is mixed with *Cassia Sturtii*, *Cassia desolata* and *Brachychiton Gregorii* (kurrajong). The surface consists of boulders of varying size from small pebbles to rounded stones weighing several pounds. The ephemeral growth is poor and most of the species are the same as those on the flats.

(b) Quartz outcrops, i.e. quartz " blows," carry various species of *Cassia*, *C. eremophila* being the most important. *Eremophila scoparia*, *E. Pantonii*, *E. oppositifolia* and *E. Oldfieldii* var. *angustifolia* also occur. These are all tall species 4–7 feet high. Trees are rare, *Acacia aneura* being absent, but there are occasional specimens of myall (*Acacia* sp.) and needle bush (*Hakea* ? *recurva*). Low shrubs include bluebush (*Kochia sedifolia*), sagobush (*K. pyramidata*) and sage (*Cratystylis conocephala*). (See Transects XII., XIV.)

(c) Ironstone ridges carry a poor growth of mulga and practically nothing else. The mulga trees, though about normal in height, carry a very low proportion of leaves to twigs. Hence there is little " top feed " available for the sheep. Other trees, of which occasional specimens were seen, are kurrajong and sheoak (*Casuarina* sp.). There are few shrubs though poverty bush, bluebush and sagobush were seen. There was practically no ephemeral growth in this country in August.

(3) *Shrub Steppe.*

This country is locally known as " lake " country. Providing the rain has been sufficiently heavy the water draining from the higher ridges across the flats ultimately reaches the so-called lakes. A portion of Lake Raeside extends across the south-western corner of the Glenorn property. The lake consists of loamy flats which may, after good rains, hold shallow pools of water from a few inches to a couple of feet in depth. More frequently the water is insufficient to form surface pools. The soil from a dry flat was found to contain 1·33% NaCl. Loose sand, which sparkles with salt crystals, covers the surface in some places and carries a sparse population of samphire. Outside this central area is a zone of very thick samphire (*Arthrocnemum* sp.) 1–2 feet high. All the samphire is valueless from a pastoral point of view. It was not in flower during either visit and was not studied. On its outer fringe the samphire association merges into the edible shrub association. This outer zone includes low shrubs, up to three and a half feet high, the most important being saltbush (*Atriplex hymenotheca*), sagobush (*Kochia pyramidata*), sage (*Cratystylis conocephala*) and waterbush (*Lycium australe*). Except for waterbush these are all useful fodder plants. Waterbush presents an attractive appearance after rain owing to its abundant succulent leaves. In a dry season however, when they might be of value, these leaves fall, leaving only bare thorny branches. Bluebush (*Kochia sedifolia*) is present in the association but plays a minor role. (See Transects VI. and IX.)

The term "steppe," so far as this Lake Raeside area is concerned is a misnomer, since all the lake zones are broken by low sand ridges bearing small trees. These include needlebush, sheoak, willow (*Pittosporum phillyraeoides*) and one without a common name (*Eremophila miniata*). There is a small amount of a narrow-leaved form of *Acacia aneura*. *Cassia eremphila* and *Acacia brachystachya* also occur.

In overgrazed edible shrub country the saltbush and bluebush appeared to be less capable of regrowth than the sagobush. In time of drought the saltbush seems the least resistant. It is also the most palatable of the shrubs judging by observations. In one place where the vegetative cover had been almost completely lost the plants present were *Bassia divaricata*, annual saltbush (*Atriplex halimoides* and *Atriplex spongiosum*), *Rhagodia* sp. and a relatively large number of plants of *Frankenia fecunda* and *Frankenia setosa*. *Bassia divaricata* and these *Frankenia* spp. were rare in normal edible shrub country. (See Transect VII.)

When seen in August the perennial shrubs were in good condition with plenty of fresh growth and a heavy crop of flowers.

The perennial shrub country is better developed on the north-eastern side of the lake than on the south-western, where low ridges carry wandarrie plants and the flats are normal flood plain. This supports the theory regarding the tendency of these lakes to migrate in a south-westerly direction. Of special interest in regard to this theory was the discovery of an irregular zone of mixed country carrying the plants of the flood plain association interpersed with the edible shrubs. If the lake has migrated, this zone may well represent the intrusion of mulga and curara into the shrub steppe. The peculiar balanced association of the two types cannot be explained by soil character or a difference in water supply. (See Transects V. and X.)

Currant bush (*Scaevola spinescens*) was fairly common in this mixed country. This shrub, though reported as being able to survive heavy stocking (McTaggart, 1936), is not regarded locally as a useful plant.

(4) *Sandplain.*

This type of country is not well developed on Glenorn. There are some small areas of spinifex in the section of the station north of Mount Morgans. There does not seem to be any well defined zone of spinifex. The area seen covered about a square mile, and was surrounded by flood plain and hills scrub formations. The soil of the sandplain is lighter in colour than that that of the wandarrie areas. No information was obtained concerning the existence of hardpan in this country.

The spinifex association is very distinct botanically. *Triodia Basedowii* is dominant. No other grass, annual or perennial, was seen. A low shrub form of *Acacia brachystachya* -smaller than the bogada of the wandarrie country—and an occasional specimen of a myrtaceous plant, which was not found in flower but is probably a species of *Melaleuca*, occur fairly commonly amongst the spinifex plants. The only tree form is an occasional group of mallee of which two species are present. One of these is *Eucalyptus pyriformis*, but the other could not be found in either flower or fruit and was not identified. (See Transect I.)

When seen in August the acacia carried a few flowers, and the spinifex a few seed-heads, though there was practically no new growth. The ephemerals were almost completely absent.

Where the pure spinifex merges into the mulga (flood plain association), the *Acacia* and mallee stop abruptly, but the spinifex mingles with the mulga formation for some distance. The plants of this transition zone, both the mulga and the spinifex, appear to be in better general condition than those in the purer associations.

ECOLOGICAL TRANSECTS.

Method.—The first transect was of the line type and ran for 200 yards. The remainder were strips 200 yards long by 24 feet wide, and were worked in squares of 24 feet sides. Soil depth was, in most cases, tested every 24 yards, *i.e.*, every third square. The distance from the surface to the siliceous hardpan was measured by a post hole auger. It was necessary to use water to soften the sunbaked loam so no deep samples could be taken. Surface samples were obtained, however, and these have already been published (Teakle, 1938).

Transect I.

On spinifex sandplain north of Mount Morgans. This transect was of the line type. The following plants were encountered in 200 yards:—

Triodia Basedowii (spinifex)	163
Acacia brachystachya	54
Melaleuca sp.	2
Eucalyptus pyriformis (mallee)	2

Transect II.

The transect ran from a sandy wandarrie ridge across the edge of a claypan. The first hundred yards was marked by the number of saltbush plants. The rest of the transect was strongly influenced by the claypan.

	1st 100 yards.	2nd 100 yards.
Acacia aneura (Mulga):		
Medium-leaved tree	5	1
Short-leaved pine type	0	6
Dead trees	1	17
Atriplex hymenotheca (saltbush)	30	4
Wandarrie grass (dormant)	31	6
Eremophila leucophylla (poverty bush)	3	0
Rhagodia sp.	2	1
Kochia sedifolia (bluebush)	0	3
Kochia villosa (glabrous type)	0	1
Dead shrubs	3	30

Transects III. and IV.

Transect III. was in line with but in the opposite direction to Transect IV., so that they give a strip 400 yards in length. All but 48 yards of this distance was in typical flood plain country, the mulga and curara bush when considered together averaging about one and a half plants per 64 square yards. The ground was completely bare. According to Melville the mulga association is a closed one.

In the last 48 yards sand covered the loam of the flood plain and there was an abrupt change into wandarrie conditions. The wandarrie grass in the list below refers to the dormant stumps only. It was impossible to tell how many of these were capable of regrowth, so all were counted. This principle was adhered to in all transects.

	1st 352 yds.	last 48 yds.
Acacia aneura:		
Medium-leaved tree	38	3
Narrow-leaved tree with pine habit	5	0
Broad-leaved inedible shrub	1	0
Dead	42	1
Acacia genistoides (curara)	17	0
Acacia brachystachya (bogada)	1	6
Eremophila leucophylla (poverty)	4	3
Eremophila longifolia	1	0
Eremophila sp.	4	0
Abutilon otocarpum	2	0
Wandarrie grasses	0	113

The following soil depths were recorded:—

III.-IV. 12″, 15″, 11″, 17″, 28″, 30″, 11″, 19″, 10″, 12″, 17″, 21″, 19″, 39″, 15″, 18″, 14″, 18″. (The last three on wandarrie ridge.)

Transects V. and X.

These transects were worked parallel to one another and within a hundred yards. The quantity of edible shrubs, mixed with flood plain plants, is in marked contrast to the two previous transects. Wandarrie grass appeared wherever the surface became sandy. Elsewhere the soil was a sunbaked clay-loam.

	V.	X.
Acacia aneura:		
Medium-leaved tree	10	10
Broad-leaved tree	1	1
Broad-leaved shrub	2	7
Dead	20	11
Acacia genistoides	5	8
Kochia sedifolia (bluebush)	11	15
Kochia pyramidata (sagobush)	2	9
Kochia villosa (glabrous type)	5	5
Atriplex hymenotheca (saltbush)	16	19
Rhagodia sp.	16	6
Lycium australe (waterbush)	2	9
Scaevola spinescens (currantbush)	8	8
Solanum orbiculatum	8	0
Cassia eremophila	6	4
Eremophila leucophylla (poverty)	1	0
Wandarrie grasses	123	57
Dead shrubs	29	30

The following soil depths were recorded along the two transects :—

V. 13″, 8″, 8″, 18″, 21″, 25″, 27″, 15″, 20″.

X. 9″, 9″, 12″, 14″, 11″, 12″, 11″, 11″, 12″.

Transects VI. and IX.

Both these were worked in "lake" country and were within half a mile of each other. The transects lines were roughly parallel to the long axis of Lake Raeside so that both dealt with plants of the edible shrub zone only. The area chosen lay to the north of the lake.

	VI.	IX.
Kochia pyramidata (sagobush)	3	95
Kochia sedifolia (bluebush)	1	4
Atriplex hymenotheca (saltbush)	79	97
Rhagodia sp. I.	14	15
,, sp. II.	29	30
Cratystylis conocephala (sage)	69	17
Lycium australe (waterbush)	13	88
Eremophila miniata	0	3
Acacia aneura	0	2

The following soil depths were recorded :—

VI. 28″, 28″, 31″, <52″, < 52″, 22″, 14″, 17″, 18″.

IX. 10″, 28″, 21″, 9″, 13″, 10″, 9″, 4″, 4″.

Transect VII.

This transect area was reported to have formerly carried edible shrubs. Most of the few shrubs left were dead, owing to drought or overstocking or possibly both.

Atriplex hymenotheca	1	
Atriplex halimoides	6	
Rhagodia sp.	27	(all very small)
Bassia divaricata	6	
Frankenia fecunda	70	
Frankenia setosa	12	
Cratystylis conocephala	6	
Dead shrubs	104	

No soil depth tests were made in this area.

Transects VIII. and XI.

The wandarrie country was in poor condition, most of the perennials looking shrivelled and browned. Many of the poverty bushes lacked leaves when seen in April but shewed fresh growth in August. It is often difficult to state with certainty which plants are dead and which still capable of recovering. The two transects were mapped within a hundred yards of each other and parallel.

	VIII.	XI.
Acacia aneura :		
Medium leaved tree	15	4
Narrow leaved with pine habit	7	9
Dead	5	5
Acacia brachystachya	26	17
Eremophila leucophylla	56	63
Cassia eremophila	0	4
Rhagodia sp.	2	11
Solanum orbiculatum	1	0
Wandarrie grass	328	380
Dead shrubs	10	15

The following soil depths were recorded :—

VIII. 37″, 37½″, 27″, 28″, 28″, 36″, 43″, 42″, 28″.

XI. $<$52″, $<$52″, $<$52″, $<$52″, 39″, 50″, 18″, 15″, 26½″.

Transect XII.

This was mapped in country carrying mulga of a broader leaved form. This type is known locally as Silver Leaved mulga. It retains in the adult leaf the remains of the bladdery hairs found on the young leaves of all varieties. The character is most marked in new growth and on the leaves of trees growing near water.

The presence of a number of poverty bushes—a species which in general prefers sandy situations—was the most interesting feature of the transect.

Acacia aneura :	
Silver leaved tree	47
Medium leaved tree	1
Dead	12
Acacia genistoides	5
Eremophila leucophylla	21
Eremophila sp.	2
Dead shrubs	7

The following soil depths were recorded :—

XII. 26″, 17″, 7½″, 20″, 8″, 16″, 12″, 13″, 9½″.

Transect XIII.

The transect line ran down a low slope below a quartz blow. The soil was littered with fragments of quartz. The slope ultimately became a samphire flat. Similar country nearby had formerly carried sage, sagobush and bluebush but it had suffered badly in the bad seasons and practically all the plants were dead. The area selected did not represent the worst, though a very high proportion of the shrubs were dead.

Kochia sedifolia	70
Kochia pyramidata	17
Cratystylis conocephala	4
Frankenia fecunda	18
Dead shrubs	128
Eremophila scoparia (alive)	8
,, ,, (dead)	4
Hakea recurva	1

Soil depths were tested at distances of 48 yards along the transect. The quartz fragments in the soil of this transect and the following one made the work with the auger difficult. As a result full reliance cannot, unfortunately, be placed in the figures recorded.

XIII. 35″, 35″, 9″, 6″, 21″.

Transect XIV.

The area chosen was the side of a stony myall ridge formed by a quartz "blow." On the lower levels the ridge became a loamy flat which carried all the sagobush plants counted during this survey. As in the previous transect the great majority of the shrubs were dead.

Acacia aneura (medium leaved tree)	3
Acacia sp. (myall)	10
Cassia eremophila	4
Kochia sedifolia	6
Kochia pyramidata	32
Dead shrubs	137

The soil depth tests resulted as follows :—

XIV. 13″, 9″, 9″, 9″, 35″, 12″, 7″, 10″, 12″.

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REFERENCES.

Clarke, E. de C., 1925: The Field Geology and Broader Mining Features of the Leonora-Duketon District. *Geol. Surv. West. Aust. Bull* 84.

McTaggart, A., 1936: A Survey of the Pastures of Australia. *C.S.I.R. (Aust.) Bull.* 99.

Talbot, H. W. B., 1920: The Geology and Mineral Resources of the North-West, Central and Eastern Divisions. *Geol. Surv. West. Aust. Bull.* 83.

Teakle, L. J. H.:

1936: The red and brown hardpan soils of the acacia semi-desert scrub of Western Australia. *Jour. Agric. West. Aust.* Vol. XIII.

1938: A Regional Classification of the Soils of Western Australia. *Jour. Roy. Wes. Aust.* Vol. XXII.

PLANTS COLLECTED AT GLENORN STATION, MALCOLM.

Owing to the poor seasons during 1937 and 1938 and, also, to the shortness of the visits made to the station the following list cannot be regarded as in any way complete. The month given in the list refers to the period when the species was found in flower :—

A = Creeks, B = Flood Plain, C = Wandarrie, D = greenstone outcrops, E = quartz outcrops, F = ironstone outcrops, G = lake country. H = mixed lake and flood plain, I = Spinifex sandplain.

Marsileaceae:			
Marsilea hirsuta R. Br.	Nardoo	Aug.	B
Gramineae:			
Neurachne Mitchelliana Nees	...	Ap. Aug.	B, C
Paspalidium basicladum Hughes	...	Ap. Aug.	B. C. H
Aristida arenaria Gaud.	Wind Grass	Ap. Aug.	B, C, D, H
Stipa Tuckeri F. v. M.	Spear Grass	Aug.	B, D
Stipa trichophylla Benth.	,, ,,	Aug.	B, D
Stipa Drummondii Steud.	,, ,,	Aug.	B, D
Alopecurus australis Nees	...	Aug.	B
Eriachne pulchella Domin.	...	Aug.	B
Eriachne Helmsii Domin	Broad-leaved Wandarrie	Ap. Aug.	C
Danthonia bipartita F. v. M.	...	Aug.	B, C
Enneapogon caerulescens (Gaud.) N.T.B.	...	Ap. Aug.	B, C, D
Triodia Basedowii Pritzel	Spinifex	Aug.	I
Eragrostis eriopoda Benth.	Narrow-leaved Wandarrie	Ap. Aug.	C
Eragrostis setifolia Nees	,, ,,	Ap. Aug.	C
Eragrostis leptocarpa Benth.	...	Ap. Aug.	B
Eragrostis Dielsii Pilger	...	Ap. Aug.	B, D, G, H
Cyperaceae :			
Cyperus Iria L.	...	Ap. ...	A
Scirpus multiculmis F. v. M.	...	Ap. Aug.	A
Casuarinaceae :			
Casuarina sp. I.	Sheoak	...	F
,, sp. II.	,,	...	G
Urticaceae :			
Parietaria debilis Forst	...	Aug.	C
Proteaceae :			
Hakea recurva Meissn.	Needle bush	...	D, E
Hakea lorea R. Br.	Corkwood	Aug.	B
Grevillea sp. (flowers only)	...	Aug.	A
Grevillea sp (follicles only)	Water tree	Ap. ...	B
Santalaceae :			
Exocarpus aphylla R. Br.	...	Ap. ...	C, H
Santalum spicatum (R. Br.) D. C.	Sandalwood	Ap. Aug.	A, B, H
Santalum lanceolatum R. Br.	,,	Ap. Aug.	B, D

Loranthaceae :			
Loranthus gibberulus Tate ...	Mistletoe on *Acacia aneura*	Ap. Aug. ...	B
Loranthus Murrayi F. v. M. et. Tate	Mistletoe on curara	Ap. Aug. ...	B
Loranthus Mitchellianus	Mistletoe on curara and mulga	Ap. Aug. ...	B
Loranthus pendulus Sieb	Mistletoe on willow	Ap. Aug. ...	B, G
Loranthus Quandong Lindl. ...	Mistletoe on Silver-leaved mulga	Ap. Aug. ...	B
Polygonaceae :			
Muehlenbeckia Cunninghamii F. v. M.	Lignum	Ap. Aug. ...	B
Chenopodiaceae :			
Rhagodia spp.	... ...	... ...	G, H
Chenopodium Blackianum Aellen.	... ...	Aug. ...	B
Chenopodium myriocephalum Aellen	... ...	Aug. ...	B
Chenopodium cristatum F. v. M. ...	... ...	Aug. ...	B
Chenopodium melanocarpum Aellen.	... ...	Aug. ...	B
Atriplex hymenotheca Moq. ...	Saltbush	Aug. ...	G, H
Atriplex semilunaris Aellen. ...	Annual Saltbush ...	Aug. ...	B, G
Atriplex halimoides Lindl. ...	" " ...	Ap. Aug. ...	B, G, H
Atriplex spongiosum F. v. M. ...	" " ...	Ap. Aug. ...	B, G, H
Atriplex nummularia Lindl. ...	Old Man Saltbush ...	Ap.	G, H
Bassia sclerolaenoides F. v. M. ...	... ...	Aug. ...	B
Bassia paradoxa (R. Br.) F. v. M.	... ...	Aug. ...	B
Bassia divaricata (R. Br.) F. v. M.	... ...	Ap. Aug. ...	B, G, H
Bassia eriacantha (F. v. M.) Anderson	... ...	Aug. ...	B
Bassia uniflora F. v. M. ...	... ...	Ap. Aug. ...	B
Bassia densiflora Fitz.	... ...	Aug. ...	B
Kochia Georgei Diels.	... ...	Aug. ...	B, C, H
Kochia triptera Benth.	... ...	Aug. ...	B, C
Kochia amoena Diels	... ...	Aug. ...	B
Kochia pyramidata Benth. ...	Sagobush	Aug. ...	B, E, G, H
Kochia villosa var.	... ...	Ap. Aug. ...	B, C, H
Kochia sedifolia F. v. M. ...	Bluebush	Ap. Aug. ...	E, G, H
Kochia glomerifolia F. v. M. et. Tate	... ...	Aug. ...	E
Kochia carnosa (Moq.) Anderson	... ...	Aug. ...	B
Enchylaena tomentosa R. Br. ...	... ...	Ap. Aug. ...	B, C, G, H
Arthrocnemum sp.	Samphire	... ...	G
Salsola Kali. L.	Roly poly	Aug. ...	B, G
Amarantaceae :			
Trichinium obovatum Gaud ...	Cotton bush ...	Aug. ...	B, C
Trichinium alopecuroideum Lindl.	... ...	Aug. ...	B
Trichinium helipteroides F. v. M.	... ...	Aug. ...	B, C
Trichinium corymbosum F. v. M.	... ...	Aug. ...	B
Ptilotus villosiflorus F. v. M. ...	... ...	Aug. ...	B
Alternanthera denticulata R. Br. ...	... ...	Ap. Aug. ...	B, C
Aizoaceae :			
Trianthema crystallina Vahl. ...	... ...	Ap. Aug. ...	B, G
Tetragonia expansa Murr. ...	Spinach	Aug. ...	B
Mesembryanthemum australe Soland	Pigface	Aug. ...	G
Portulacaceae :			
Calandrinia balonensis Lindl ...	Parakeelya ...	Aug. ...	B, C, G, H
Ranunculaceae :			
Ranunculus pentandrus J. M. Black	... ...	Aug. ...	B

Cruciferae :			
Lepidium Drummondii Thell.	...	Aug.	B
Lepidium rotundum (Desv.) D. C.	...	Aug.	B
Lepidium oxytrichum Sprague	...	Aug.	B
Stenopetalum pedicellare Benth.	...	Aug.	B, C
Stenopetalum robustum Endl.	...	Aug.	B, C
Menkea sphaerocarpa F. v. M.	...	Aug.	B
Menkea australis Lehm.	...	Aug.	B, G, H
Menkea villosula J. M. Black	...	Aug.	B
Capsella Andraeana F. v. M.	...	Aug.	B
Crassulaceae :			
Crassula colorata Ostf.	...	Aug.	B
Pittosporaceae :			
Pittosporum phillyraeoides D. C.	Willow	Ap. Aug.	B, G
Leguminoseae :			
Acacia genistoides Benth.	Curara	Ap. Aug.	B, H
Acacia Burkittii Benth.	Jamwood	Aug.	A
Acacia aneura F. v. M.	Mulga	Ap. Aug.	A, B, C, F, G, H
Acacia brachystachya	Bogada	Aug.	G, I
Acacia Burkittii var.	...	Aug.	D
Cassia Chatelainiana Gaud.	...	Aug.	D, E, F
Cassia eremophila A. Cunn.	...	Aug.	B, C, D, H
Cassia artemisioides Gaud.	Creek Cassia	Aug.	A
Cassia Sturtii R. Br.	...	Aug.	D, E
Cassia desolata F. v. M.	...	Aug.	D
Cassia cardiosperma F. v. M.	...	Aug.	D
Brachysema Chambersii Benth.	...	Aug.	I
Daviesia aphylla Benth	...	Aug.	B, C
Indigofera Georgei Pritzel	...	Aug.	A, B, C
Swainsonia microphylla A. Gray	...	Aug.	B
Swainsonia occidentalis F. v. M.	...	Aug.	B
Geraniaceae :			
Erodium cygnorum Nees.	Crowfoot	Aug.	A, B, C, D
Zygophyllaceae :			
Zygophyllum iodocarpum F. v. M.	...	Aug.	B, D, H
Zygophyllum fruticolosum D. C.	...	Aug.	B, D, H
Tribulus astrocarpus F. v. M.	...	Aug.	B
Euphorbiaceae :			
Euphorbia australis Boiss	Hairy Balsam	Aug.	B
Euphorbia Drummondii Boiss	Balsam	Aug.	B
Euphorbia eremophila A. Cunn.	Rock Balsam	Aug.	D
Stackhousiaceae :			
Stackhousia viminea Sm.	...	Aug.	D
Sapindaceae :			
Dodonaea lobulata F. v. M.	Hopbush	Aug.	D
Dodonaea filifolia Hook	,,	Aug.	D
Rhamnaceae :			
Blackallia connata C. A. Gardn.	...	Aug.	In mulga-spinifex zone
Malvaceae :			
Abutilon cryptopetalum F. v. M.	...	Aug.	B
Abutilon otocarpum F. v. M.	...	Aug.	B
Plagianthus Gardneri Bak. M. S.	...	Aug.	B
Sida corrugata var. *ovata*	...	Aug.	B
Sida calyxhymenia J. Gay.	...	Aug.	B, H
Sida ciliata N. T. Burbidge ms.	...	Aug.	B, H

Sterculiaceae :			
Brachychiton Gregorii F. v. M.	Kurrajong	Aug.	D, F
Frankeniaceae :			
Frankenia fecunda Summerhayes	...	Ap. Aug.	G
Frankenia setosa Fitz.	...	Ap. Aug.	G
Thymelaeaceae :			
Pimelea microcephala R. Br.	...	Aug.	B, G, H
Pimelea thesoids S. Moore	...	Aug.	B, G, H
Myrtaceae :			
Eucalyptus pyriformis Turcz.	Mallee	Aug.	I
Eucalyptus sp.	"	...	I
Eucalyptus camaldulensis	Creek Gum	Ap.	A
Halorrhagaceae :			
Halorrhagis odontocarpa F. v. M.	...	Aug.	C
Myriophyllum rhomboideum N. T. Burbidge ms.	...	Aug.	In claypan
Umbelliferae :			
Didiscus eriocarpa Benth.	...	Aug.	B, D
Daucus brachiatus Sieb.	...	Aug.	B, D
Asclepiadaceae :			
Pentatropis Kempeana	Cogala Creeper	Ap.	B
Labiatae :			
Teucrium racemosum R. Br.	...	Ap.	B
Solanaceae :			
Solanum orbiculatum Dun.	...	Aug.	B
Solanum Oldfieldii var. *plicatile* Sp. Moore	...	Aug.	E
Solanum amblymerum Dun.	...	Aug.	E
Solanum lasiophyllum Dun.	...	Aug.	B, C, H
Nicotiana Gossei	...	Aug.	D
Nicotiana Murrayi F. v. M. et Tate	...	Aug.	D
Scrophulariaceae :			
Peplidium Muelleri Benth.	...	Aug.	B
Myoporaceae :			
Eremophila compacta Sp. Moore	Poverty bush	Aug.	C
Eremophila leucophylla Benth.	" "	Aug.	B, C
Eremophila Margarethae Sp. Moore	...	Aug.	B, D
Eremophila oppositifolia R. Br.	...	Aug.	D, E, F
Eremophila metallicorum Sp. Moore	...	Aug.	B
Eremophila Latrobei F. v. M.	Fuchsia bush	Aug.	B
Eremophila Latrobei var. *tuberculata*	" "	Aug.	B
Eremophila Pantoni F. v. M.	...	Aug.	D, E
Eremophila scoparia F. v. M.	...	Aug.	D, E
Eremophila Fraseri F. v. M.	Fuchsia bush	Aug.	E
Eremophila longifolia F. v. M.	...	Aug.	B, D
Eremophila Youngii F. v. M.	...	Aug.	D, E, F
Eremophila Oldfieldii var. *angustifolia* Sp. Moore	...	Aug.	E
Eremophila maculata F. v. M.	Fuchsia bush	Aug.	B
Rubiaceae :			
Plectronia latifolia Benth. et Hook	...	Aug.	B

Goodeniaceae :			
Velleia rosea sp. Moore ...	... ...	... Aug.	... C
Velleia cycnopotamica F. v. M. ...	... ...	... Aug.	... C
Scaevola spinescens R. Br. ...	Currant bush	... Aug.	... H
Compositae :			
Minuria leptophylla D. C. ...	... ...	... Aug.	... B
Calotis multicaulis Druce ...	... ...	... Aug.	... C
Calotis hispidula F. v. M. ...	... ...	... Aug.	... C
Cratystylis conocephala (F. v. M.) Sp. Moore	Sage ...	... Aug.	... G
Pterigeron cylindriceps J. M. Black	... ...	... Aug.	... B
Helipterum splendidum Hemsl. ...	Everlasting	... Aug.	... B, C, I
Helipterum Battii F. v. M. ...	... ...	... Aug.	... B
Helipterum craspedioides Fitz. ...	... ...	... Aug.	... B
Helipterum Charsleyae F. v. M. ...	... ...	... Aug.	... B
Helipterum corymbosum Benth. ...	... ...	... Aug.	... B
Helichrysum roseum var. *Davenportii*	... ...	... Aug.	... B, C
Schoenia cassiniana Steetz. ...	... ...	... Aug.	... B
Myriocephalus sp.	... ...	... Aug.	... B
Myriocephalus Guerinae F. v. M.	... ...	... Aug.	... B
Angianthus Drummondii Benth. ...	... ...	... Aug.	... B
Calocephalus Francisii Benth. ...	... ...	... Aug.	... B
Gnaphalodes uliginosum A. Gray	... ...	... Aug.	... B
Cephalipterum Drummondii Benth.	... ...	... Aug.	... B, C
Podolepis pallida Turcz.	... ...	... Aug.	... B, C
Erodiophyllum acanthocephalum Stapf.	... ...	... Aug.	... B

11.—BERAUNITE—FROM DANDARAGAN, WESTERN AUSTRALIA.

By C. R. Le Mesurier, A.A.C.I.

Read 8th April, 1941 : Published 20th May, 1942.

The occurrence of phosphate minerals at Dandaragan was first officially reported by W. D. Campbell in 1906 (1). They comprised the iron phosphates Dufrenite and Vivianite and the aluminium phosphate Wavellite, besides beds rich in coprolites and apatised wood.

In 1932 the late Dr. E. S. Simpson visited the area and collected specimens of a new mineral, a hydrous basic phosphate of potassium and aluminium, which was named Minyulite, after Minyulo Well near which it was found (2).

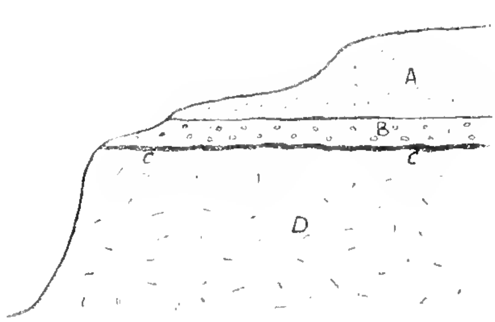
The subject of the present paper, Beraunite, a hydrous ferric phosphate with the formula $2Fe_3(OH)_3(PO_4)_2.5H_2O$ was collected by Mr. F. Forman from a locality known as "The Caves," about 2½ miles N.E. of Yandan Hill, during a recent inspection of this area.

The township of Dandaragan lies 22 miles by road west of Moora, which is 106 miles north of Perth on the Midland Railway.

For the following description of the mode of occurrence of the Dandaragan Beraunite the author is indebted to Mr. Forman, Government Geologist.

The mineral is exposed on the face of a bluff about 50–60 ft. high, composed in the lower 30–40 ft. of ferruginous sandstone overlaid by coprolite bearing sandstone 3–5 ft. thick which is in turn capped by what is probably greensand (glauconite bearing sand).

The ferruginous sandstone is impregnated to a depth of from 2–3 ft. below the coprolite bed with dark green dufrenite while the beraunite is confined to a narrow zone, not more than 3 inches in width in the upper surface immediately underlying the coprolite beds. See section.



A. Probable Greensand B. Coprolite
C. C Beraunite D Ferruginous Sandstone

The mineral occurs as radiating fibres with a silky lustre enclosed between walls of lustrous black limonite in irregular veins varying in width from 2 to 5 mm.

The colour in mass varies from Ridgways 13'k, Russet to 21'''m, dark olive. Hardness, 4–5. Specific gravity, 2·95.

Under the microscope the fibres are transparent, with opaque blotches due to adhering limonite, which has penetrated between the finest fibres.

Extinction is difficult to ascertain owing to the sheaf-like form and extreme fineness of the fibres, but appears to be straight or of small amount. N in all directions is greater than that of methylene iodide (1·74), and birefringence moderate.

Pleochroism is strong from honey yellow to deep amber.

The material is readily soluble in acids and is decomposed by 5 % NaOH solution, in the latter case about 90 % of the P_2O_5 is soluble.

An analysis of the crushed material separated by floating in methylene iodide Sp. gr. 3·005, and sinking in bromoform Sp. gr. 2·85, then air dried and dried to constant weight over H_2SO_4 and barium perchlorate gave the following results :—

——			Mols.	Mol. ratio.
Insol. in HCl	SiO_2	1·88		
	Not SiO_2	·03		
Sol. in HCl	Al_2O_3	·43		
	Fe_2O_3	54·11	338^{8}	3·4
	MnO	*Nil*		
	CaO	*Nil*		
	MgO	*Nil*		
	Na_2O	·58		
	K_2O	·12		
	P_2O_5	27·24	191^{9}	2
	H_2O +	15·60	865^{9}	8·6
	SO_3	*Nil*		
	Cl	*Nil*		
		99·99		

The excess mols. of Fe_2O_3 and H_2O over the ratio 3 : 2 : 8 may be accounted for by intergrown limonite which it was impossible to eliminate.

SUMMARY.

A physical and chemical description is given of the mineral beraunite, a hydrous phosphate not previously reported from this State.

(1) *Geol. Surv. W.A. Bull.* 26, pp. 14–23.
(2) *Jour. Roy. Soc. W.A.*, 1932, XIX, pp. 13–16.

12.—MARINE COPEPODA FROM WESTERN AUSTRALIA.

I. LITTORAL HARPACTICOIDS FROM ROTTNEST ISLAND.

By A. G. NICHOLLS, Ph.D., University of Western Australia.

Read 8th April, 1941 ; Published 20th May, 1942.

The species dealt with in the following pages were collected from weed, attached to rocks on the shore at Bathurst Point, Rottnest Island. This island is a coastal limestone formation (actually a calcareous sandstone) lying some 12 miles west of Fremantle, with its long axis running approximately east and west. A description of the island is given by Glauert (1929). Bathurst Point lies at the north-east point of the island (Lighthouse Point in Glauert's map). The material was collected during April, 1939.

Fam. **PELTIDIIDAE.**

Parapeltidium cristatum.

P. cristatum Nicholls, 1941, p. 399, fig. 9.

One specimen, an adult male, was taken and has been described in a recent paper dealing with copepods from South Australia.

Fam. **THALESTRIDAE.**

Eudactylopus australis.

E. australis Nicholls, 1941, p. 410, fig. 15.

This species, of which the female has already been described, is amongst those which are common to the coasts of South and Western Australia. Two specimens were taken here, one of each sex. The female (length, 1·68 mm.) shows a few minor points of difference in the second antenna, first and fifth legs. The basal segment of the exopod of the second antenna bears only one seta whereas there were two in the specimens from South Australia. In the first leg the endopod is somewhat more robust and relatively shorter, when compared with the exopod, than in the original material. The fifth leg bears an extra seta on the distal segment (fig. 1).

Male : Length, 1·35 mm. Differs from the female in the usual features and in the first leg which is rather more slender than in the female, resembling that of the female described from South Australia. The first antenna is 9-segmented, with a long sensory filament attached to the 4th segment ; there is the usual hinge between the 5th and 6th segments. The other head appendages resemble those of the female. The seta formula for legs 2–4 agrees with that of the female, except for the modified endopod of the second leg (fig. 1). The segments of the fifth leg are partially fused, the basal segment bearing three unequal spines and the distal segment one large spine, four small spines, and two setae (fig. 1).

Phyllothalestrls lata sp. nov.

This species, of which only one female has been found, was at first (Nicholls, 1941, p. 411) identified as *P. mysis* (Claus). There can, however, be little doubt that it is distinct owing to the greatly enlarged genital segment, described for no other species of this genus.

Female: Length, 1·71 mm. Body less slender than is usual in the genus and with a wide genital segment, the remaining segments of the urosome being much narrower (fig. 2). Rostrum small, downwardly projecting, not visible from above. First antenna 9-segmented, with sensory filament on the fourth; second antenna with 2-segmented exopod; mandible palp biramous: maxillule, maxilla, and maxilliped well developed (fig. 2), similar to those of the type species. First legs slender, rami subequal, exopod with very long middle segment. Seta formula for legs 2–4:

	endopod			exopod		
p. 2	1	2	221	1	1	223
p. 3	1	1	321	1	1	323
p. 4	1	1	221	1	1	323

Fifth legs of the usual type for the genus but with small differences in armature. The basal segment lacks the inner seta found in *mysis*, *paramysis* Monard (1928, p. 345) and *royi* (Monard, 1928, p. 354), and the distal segment shows two of the terminal setae transformed into spines, instead of the usual one. Caudal rami about three times as wide as long.

Male: Unknown.

This species is distinguished from all other known species in the great width of the genital segment. In other respects it is not unlike *mysis*, but differs in the exopod of the second antenna and in the fifth legs. It resembles Willey's variety *mysis harringtoni* (1935, p. 93) in the seta formula, the end segment of the second endopod having only two inner setae, whereas in *mysis* and *paramysis* there are three. In the shape and proportions of the segments of the fifth legs it resembles *paramysis* but differs in the armature.

Fam. **DIOSACCIDAE.**

Amphiascopsis hirsutus.

Dactylop(h)usia hirsuta Thompson and Scott, 1903, p. 269, Pl. IX., figs. 19–24.

This species has been recorded from Ceylon (Thompson and Scott); "Siboga" Station 273 (A. Scott, 1909, p. 221); Banyuls (Monard, 1928, p. 373); Bermuda (Willey, 1931, p. 611; 1935, p. 57); and Algeria (Monard, 1937, p. 32).

The occurrence of this species on the coast of Western Australia forms yet another link between the fauna of Bermuda, the Mediterranean, Ceylon and Australia. The specimens taken here (27 females, 1 male) were all somewhat larger than those previously recorded: females 1·25–1·40 mm., male 1·17 mm.

There can be no doubt of its identity, the peculiar structure of the basipod of the male first leg and second endopod, described by Willey (1931) are characteristic, and were well shown in the specimen found here. As with the Mediterranean and Bermudan specimens the first leg shows the endopod considerably longer than was described by Thompson and Scott.

Fam. **CANTHOCAMPTIDAE.**

Orthopsyllus littoralis sp. nov.

Female: Length 0·9 mm. Body of usual shape, each segment except the first and last having the hinder margin fringed with denticles as shown in the figure of the urosome (fig. 3); this fringe completely encircles the body in the urosome. Rostrum well defined and articulated with the head. First antenna

4-segmented, with a large spur on the second segment and with a sensory filament on the third segment ; second antenna with 1-segmented exopod, bearing 2 terminal and 1 lateral setae ; mouth parts of usual structure (fig. 3). First legs with basal segment of endopod longer than distal and without inner seta, end segment with 2 long terminal setae, plumose terminally ; seta formula for legs 2–4 :

	endopod		exopod		
p. 2	0	120	0	1	022
p. 3	0	020	1	1	022
p. 4	0	010	1	1	022

Fifth legs like those of *linearis* but distal segment somewhat wider. Caudal rami half as long again as wide, with large terminal seta, nearly as long as urosome, and a few inner spines. Anal operculum with a few coarse spines.

Male : Length 0·78 mm. Differs from the female in the first antenna, endopod of 3rd leg, 5th and 6th legs. First antenna 6-segmented, *subchirocerate*, (fig. 3). Endopod of third leg 3-segmented, bearing a long barbed spine on the second segment, similar to that found in *wallini* Lang (1934), and a single terminal seta on the end segment ; fifth and sixth legs reduced (fig. 3). The seta formula of legs 2–4 is like that of the female.

This species, of which 2 females and 1 male were found, resembles *wallini* in having only two outer spines on the end segments of the exopods of the swimming legs, but differs from that species in lacking an inner seta on the basal segment of the first endopod, in the seta formula, and in the shape of the fifth legs in the female. The male, which resembles *wallini* in the third endopod, differs from it in the fourth endopod.

Orthopsyllus similis sp. nov.

Female : Length 0·96 mm. Body similar to that of the preceding species but the fringe of denticles on the hinder margins of the segments is confined to the dorsal surface ; rostrum well defined and articulated with the head ; first antenna 4-segmented, with a small spur on the second segment ; exopod of the second antenna with two terminal and two lateral setae ; mouth parts as in *O. littoralis*. First leg similar to that of the preceding species but having the distal segment of the endopod longer and more slender ; distal segments of endopods 2–4 also longer than in *littoralis* (cf. figs. 3 and 4), and seta formula for these legs as follows :

	endopod		exopod		
p. 2	0	110	0	0	013
p. 3	0	110	0	0	013
p. 4	0	121	0	0	013

Fifth legs very like those of *littoralis* ; caudal rami nearly twice as long as wide, with a well developed inner denticulate ridge ; anal operculum unarmed.

Male : Length 0·96 mm. Differs from the female in the usual sexual characters and a few minor points. First antenna 6-segmented, *subchirocerate* ; coxa of first legs with outer projection ; endopod of second leg having the distal segment considerably longer than in the female ; third endopod 3-segmented, the modified spine on the middle segment considerably larger and more strongly modified than in other species, distal segment with an inner seta in addition to the terminal seta ; distal segment of fifth legs comparatively short. The seta formula for legs 2–4 differs somewhat from that of the female :

		endopod		exopod	
p. 2	....	0	120	0 0	023
p. 3	....	....		0 0	023
p. 4	....	0	110	0 0	023

This species resembles *linearis* ((Claus) Sars 1911) and *rugosus* Nicholls (1941) in having three outer spines on the end segment of the exopods of legs 2–4, and *wallini*, *propinquus* Monard (1926) and *rugosus* in the armature of the caudal rami. It differs from *linearis*, *wallini* and *rugosus* in the seta formula and from *propinquus* in the first and fifth legs. The male third leg is characteristic of the species.

Fam. METIDAE.

Metis jousseaumei.

Ilyopsyllus jousseaumei Richard, 1892.

Reference has already been made (1941, p. 425) to the presence in Western Australia of this widely distributed species.

REFERENCES.

Claus, C., 1863.—Die freilebenden Copepoden. Leipzig.

Glauert, L., 1929.—Contributions to the Fauna of Rottnest Island. I. Introduction and Vertebrates. *Jour. Roy. Soc. West Austr.*, xv, 37–46.

Lang, K., 1934.—Marine Harpacticiden von der Campbell-Insel und einigen anderen südlichen Inseln. *Kungl. Fysiogr. Sällsk. Handl.*, N.F., xlv, No. 14.

Monard, A., 1926.—Note sur la faune des Harpacticoides marins de Cette. *Arch. Zool. Exp. Gen.*, lxv, 39–54.

———— 1928.—Les Harpacticoides marins de Banyuls. *Ibid.*, lxvii, 259–443.

———— 1937.—Les Harpacticoides marins de la région d'Alger et de Castiglione. *Bull. Trav. Stat. Aquic., Castiglione.*

Nicholls, A. G., 1941.—Littoral Copepoda from South Australia. I. Harpacticoida. *Rec. South Austr. Mus.*, vi., 381–427.

Richard, J., 1892.—Sur l'identité des genres *Ilyopsyllus* Brady et Robertson et *Abacola* Edwards ; description de *I. jousseaumei* n. sp. *Bull. Soc. Zool. France*, xvii.

Sars, G. O., 1911.—An Account of the Crustacea of Norway. Vol. V., Harpacticoida. Bergen.

Scott, A., 1909.—The Copepoda of the Siboga Expedition. Siboga-Expeditie., xxixa, Leyden.

Thompson, I. C. and Scott, A., 1903.—Report on the Copepoda. Ceylon Pearl Oyster Fisheries. Supp. Rep., Pt. I. No. 7, 227–307, Royal Society, London.

Willey, A., 1931.—Copepod Phenology. Observations based on new material from Canada and Bermuda. *Arch. Zool. Ital.*, xvi, 601–617.

———— 1935.—Harpacticoid Copepoda from Bermuda. II. *Ann. Mag. Nat. Hist.*, (10) xv, 50–100.

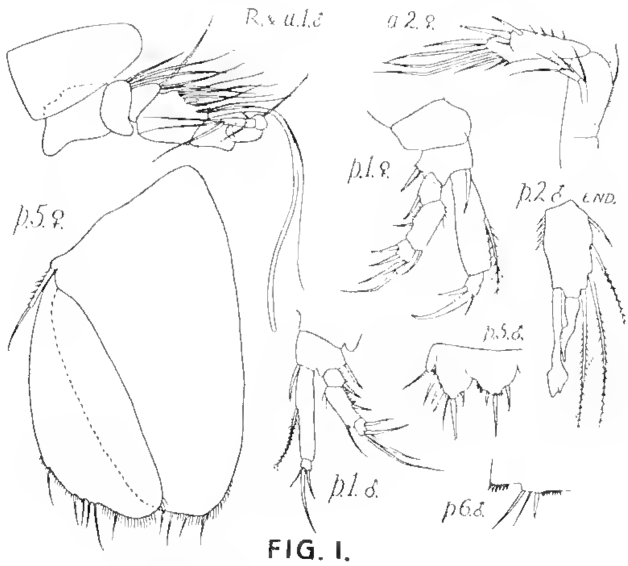


FIG. I.

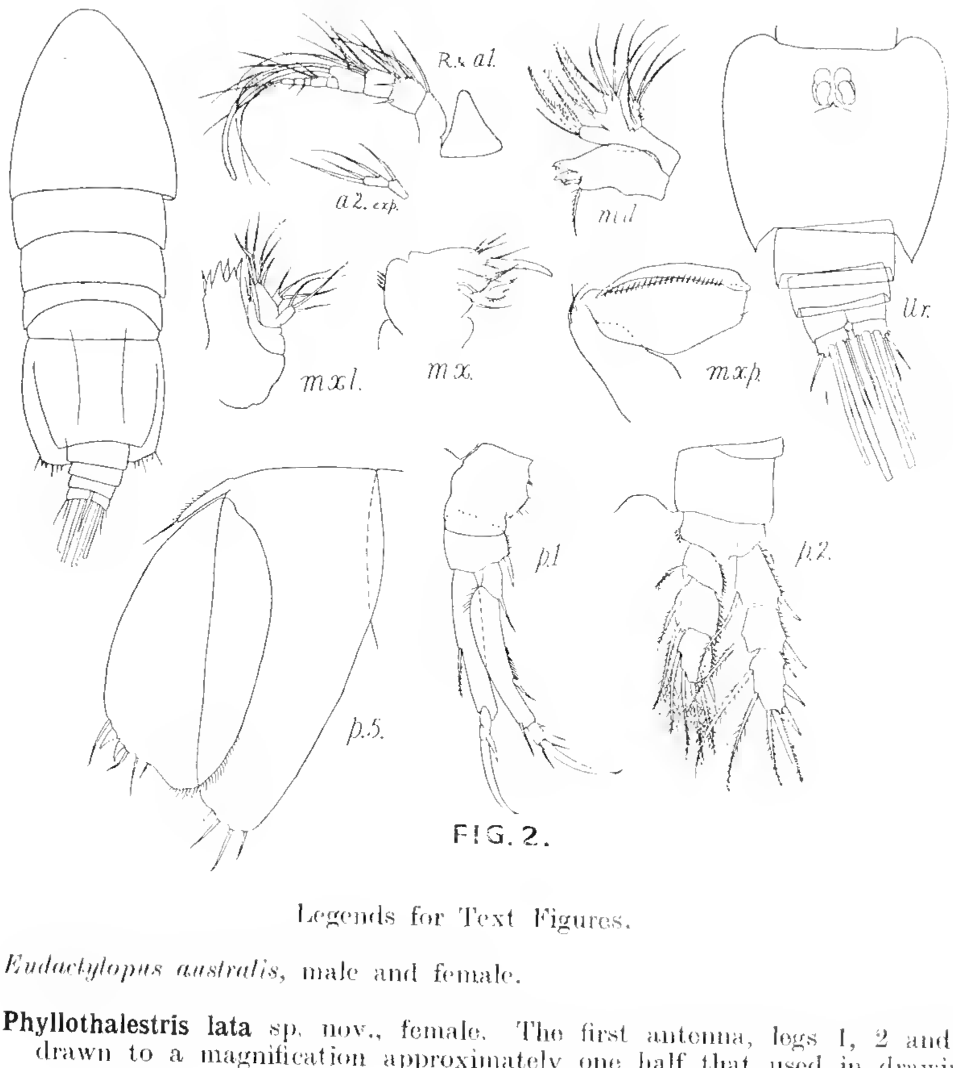


FIG. 2.

Legends for Text Figures.

Fig. 1. *Eudactylopus australis*, male and female.

Fig. 2. **Phyllothalestris lata** sp. nov., female. The first antenna, legs 1, 2 and 5 are drawn to a magnification approximately one half that used in drawing the mouth parts.

Fig. 3. **Orthopsyllus littoralis** sp. nov., male and female. All the appendages are drawn to the same scale.

Fig. 4. **Orthopsyllus similis** sp. nov., male and female. All the appendages are drawn to the same scale.

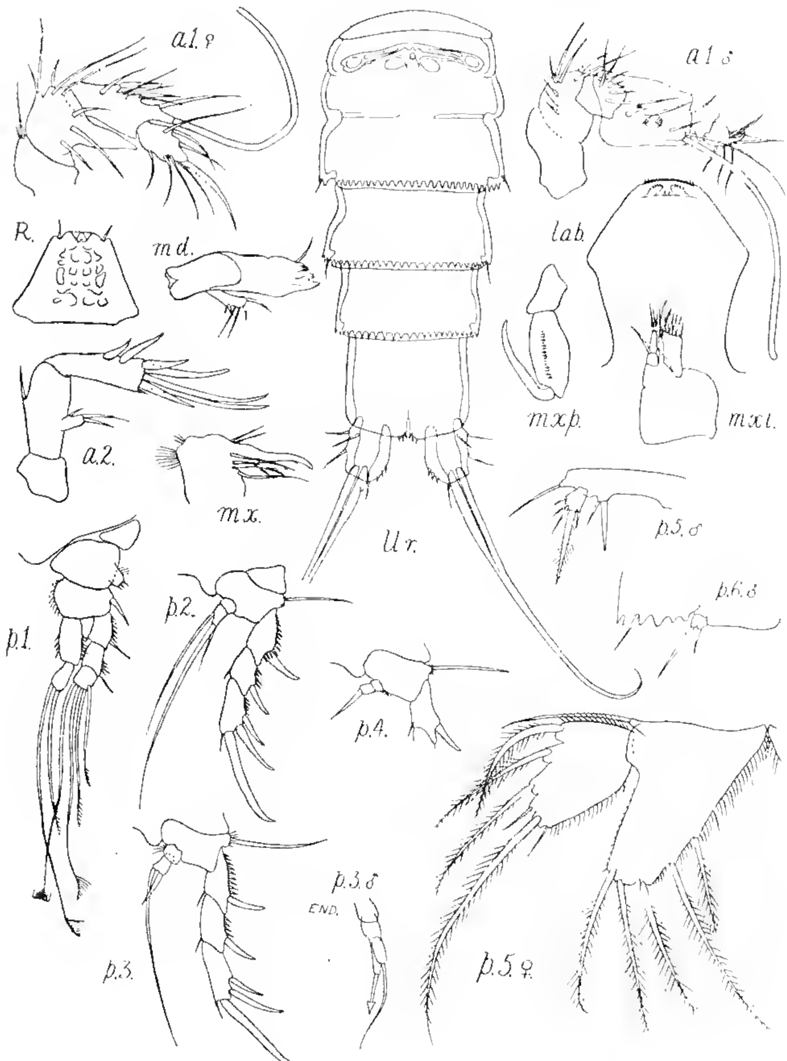

a.1.♀
a.1.♂
R.
md.
lab.
a.2.
mx.
mxp.
mxi.
Ur.
p.5.♂
p.6.♂
p.1.
p.2.
p.4.
p.3.♂
END.
p.3.
p.5.♀

FIG. 3.

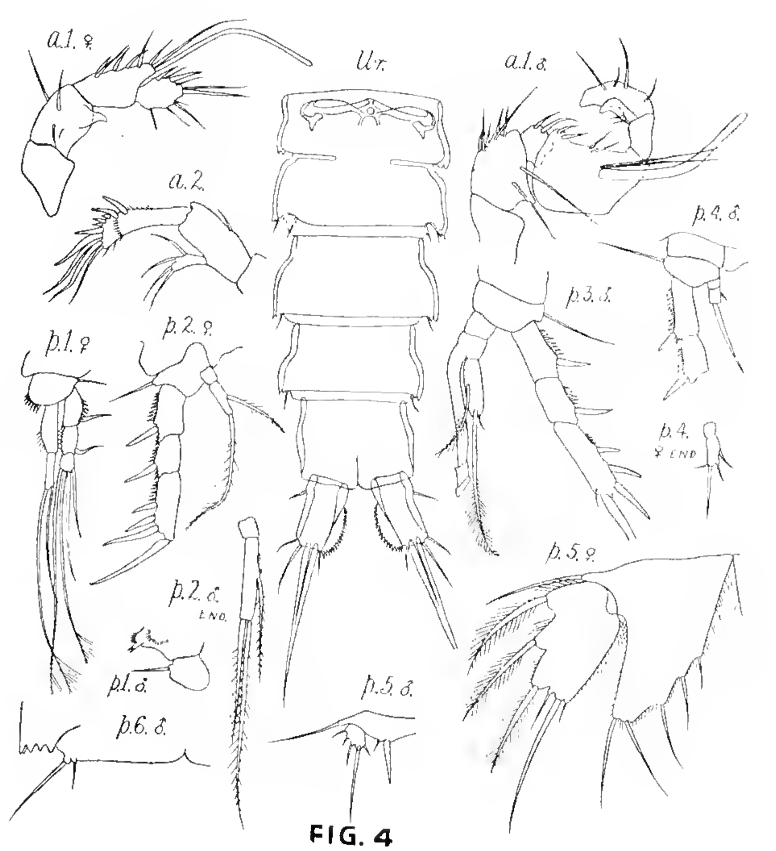

a.1.♀
Ur.
a.1.♂.
a.2.
p.4.♂.
p.3.♂.
p.1.♀
p.2.♀
p.4.
♀ END
p.5.♀
p.2.♂.
END.
p.1.♂.
p.5.♂.
p.6.♂.

FIG. 4

13.—NEW LEAF-HOPPERS (HOMOPTERA, JASSOIDEA) FROM WESTERN AUSTRALIA.

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Communicated by C. F. H. Jenkins.

Although the leaf-hoppers of Western Australia are not well known, sufficient material has been described from this region to arouse great interest. It is probable that the Eurymelidae, which is the dominant group of Australian leaf-hoppers, originated in Western Australia in Cretaceous times and to-day one sub-family, the Pogonoscopinae, which is myrmecophilous, is almost entirely confined to it. The most interesting genera of the Ipoinae, *Cornutipoides* Ev. and *Bakeriola* Ev. are Western Australian, as is also the most handsome representative of the whole family, *Eurymelops generosa* (Stål).

On this account it has been a privilege to have had an opportunity to examine the large collection of Western Australian Jassoids collected by Mr R. E. Turner in 1935 and 1936, and I am grateful to the Trustees of the British Museum and to Mr. W. E. China for having afforded me this opportunity. Eight new genera and fifty-one new species are described, and lists given of species that have previously been recorded from Western Australia or that occur in the present collection. The arrangement into families is based on the system proposed in an earlier publication (Evans, 1939, b).

The sole new species described that was not collected by Mr. Turner is one which is represented by a specimen collected by Charles Darwin at King George's Sound in 1836. All the types will eventually be returned to the British Museum.

EURYMELIDAE.

The following species of Eurymelidae have previously been recorded from Western Australia. Those marked with a * are believed to be confined to the State. Sub-family Eurymelinae: *Eurymelops generosa** (Stål), *Eurymelops latifascia* (Walk.), *Eurmeloides walkeri** Dist., *Eurymeloides punctata* (Sign.), *Eurymelita terminalis* (Walk.). Sub-family Ipoinae: *Ipo torpens** Jac., *Ipoella norrisi** Ev., *Stenipo swani** Ev., *Ipoides casurinae* Ev., *Anacornutipo lignosa* (Walk.), *Cornutipoides tricornis** Ev., *Bakeriola procurrens** (Jac.). Sub-family Pogonoscopinae: *Pogonoscopus lenis** (Jac.), *P. myrmex** China, *P. clarki** China, *P. fuscus** China, *Lasioscopus acmaeops** (Jac.), *Australoscopus whitei*† China. Descriptions and figures of the Eurymelinae listed above are given in Evans, 1933, of the Ipoinae in Evans, 1934 and 1939, c, and of the Pogonoscopinae in China, 1926.

IPOINAE.

Anipo fusca sp. nov.

(Plate I., fig. 14.)

Length 3·5 mm. *Head*, ventral surface, ante-clypeus, lora and maxillary plates, pale yellowish-brown with a median chestnut-brown longitudinal stripe; vertex anteriorly dark brown, posteriorly pale brown. Crown of even width throughout. *Pronotum* and *Scutellum* pale brown. *Tegmen* colour

† This species also occurs in Victoria.

less-hyaline, clavus pale hyaline-brown, veins with brown and white markings. *Thorax*, ventral surface black. Hind tibia with a few spines in addition to a single spur, thus differing from the genotype, *A. porriginosa* (Sign.) in this characteristic. *Abdomen*, ventral surface pale brown. *Male Genitalia*, aedeagus as in Plate I., fig. 14. *Type* ♂ from Perth.

Anipo darwini sp. nov.

(Plate I., fig. 15.)

Length 4·5 mm. *Head*, ventral surface, lora and maxillary plates, pale whitish-brown ; ante-clypeus reddish-brown, fronto-clypeus and vertex pale brown mottled with dark brown. *Pronotum* and *Scutellum* dark brown mottled with yellow. *Tegmen* colourless-hyaline with pale brown and whitish markings, clavus pale hyaline-brown with white markings ; veins pink. *Thorax*, ventral surface dark brown, margins of epimera and episterna pale brown. *Abdomen*, ventral surface pale brown. *Male Genitalia*, aedeagus as in Plate I., fig. 15. *Type* ♂ from King George's Sound (C. Darwin, 2/1836).

Anipo flavens sp. nov.

(Plate I., fig. 12.)

Length 5 mm. General coloration apricot, eyes grey. *Tegmen* hyaline, pale apricot. *Male Genitalia*, aedeagus as in Plate I., fig. 12. *Type* ♂ from Dedari, 1/36.

Ipoella fulva sp. nov.

(Plate I., fig. 13.)

Length 5 mm. *Head*, ventral surface pale brownish-yellow with a large dark brown T-shaped marking ; eyes reddish-brown. *Pronotum* grey mottled with dark brown. *Scutellum* brown. *Tegmen* pale colourless-hyaline mottled with brown. *Thorax*, ventral surface dark brown. *Abdomen*, ventral surface pale brown. *Male Genitalia*, aedeagus as in Plate I, fig. 13. *Type* ♂ from Dedari, 11/35.

Ipoides fasciata sp. nov.

(Plate I., fig. 16.)

Length 5 mm. *Head*, ventral surface, ante-clypeus, lora and maxillary plates whitish, fronto-clypeus pale brownish-white ; vertex, including the crown, mottled with black and pale brown and with three longitudinal white stripes. *Pronotum* grey, mottled with light and dark brown. *Scutellum* chestnut-brown. *Tegmen* proximally hyaline-brown, distally colourless-hyaline, veins dark brown. A white fascia extends transversely from the costal border almost as far as the hind margin of the clavus, thence it bends towards the anal margin. *Thorax* and *abdomen*, ventral surface pale brown. *Male Genitalia*, aedeagus as in Plate I., fig. 16. *Type* ♂ from Spargoville, 1/36.

Ipo speciosa sp. nov.

(Plate I., figs. 10, 11.)

Length 6 mm. *Head*, ventral surface white with pale brown markings on the ante-clypeus, lora, maxillary plates and fronto-clypeus anteriorly, and black markings on the vertex ; eyes bright red. *Pronotum* grey, mottled with very dark brown and with a broad median longitudinal white stripe. *Scutellum* chestnut-brown with pale brown markings, laterally pale brown. *Tegmen* whitish-hyaline with dark brown markings and a broad white fascia extending from the costal to the claval border. *Thorax*, ventral surface with white and brown markings. Legs, tibiae very dark brown with white and dark brown markings. *Abdomen*, ventral surface pale brown. *Male Genitalia*, sub-genital plate, paramere and aedeagus as in Plate I., figs. 10 and 11. *Type* ♂ from Dedari, 1/36.

Stenipo grisea sp. nov.

(Plate I., fig. 17.)

Length 4 mm. *Head*, ventral surface grey anteriorly ; fronto-clypeus and vertex anteriorly, pinkish ; eyes black. Crown grey with brown markings. *Pronotum* pale greyish-brown. *Scutellum* pale reddish-brown. *Tegmen* hyaline-grey, veins pink. *Thorax*, ventral surface black, laterally pale brown. *Abdomen*, ventral surface and legs pale brown. *Male Genitalia*, aedeagus curved, narrowly cylindrical, paramere and sub-genital plate as in Plate I., fig. 17. *Type* ♂ from Dongarra, 10/35.

BYTHOSCOPIDAE.

The following species belonging to this family have been recorded from Western Australia: *Eurinoscopus viridis* Ev., *Chinaella cudmorei** Ev., *Hecalus basedowi** Ev. and *H. elongatus** Ev. The two former are described and illustrated in Evans, 1936, the two latter in Evans, 1939, a. Of the three new species described below one belongs to a genus closely related to *Bythoscopus* Germ., whilst two not only are not bythoscopoid in appearance but have dorsal ocelli and ledrid-like heads. They are placed in the Bythoscopidae because of their close affinity with *Thaumatoscopus* Kirk. The reason for placing the last named genus in this family has been discussed previously (Evans, 1939, b).

BYTHOSCOPINAE.

Eurinoscopus transulcidus sp. nov.

(Plate I., fig. 28.)

Length 4 mm. *Head* yellow, eyes black, frontal and epicranial sutures indistinct. Crown yellow, slightly wider in the centre than against the eyes. *Pronotum* and *Scutellum* concolorous with the crown. *Tegmen* opaque, pale green with ill-defined yellow and brown areas ; veins green, apex of tegmen pale hyaline-brown. *Thorax* and *Abdomen*, ventral surface and legs yellow. *Type* ♀ from Dedari, 1/36.

PENTHIMIINAE, THAUMATOSCOPINI.

PLATYSCOPUS gen. nov.

The head is produced and spatulate, the ventral surface concave, the dorsal convex. The antennae are short and posterior to the eyes. There is a median longitudinal carina on the crown, and the ocelli which are on the crown lie midway between the carina and the sides of the head. The pronotum is parallel-sided and collar-like and the tegmina overlap apically and have wide appendices. The hind tibiae have four rows of spines ; a row of alternate long and short spines, a row of short strong spines separated by minute spines, a row of short spines and a row of hair-like spines.

Note.—It is possible that in spite of the differences in coloration and the shape of the head that exists between the two insects described below, they are not distinct species but the two sexes of a single species.

Platyscopus badius sp. nov. (Genotype).

(Plate I., figs. 24, 25.)

Length 7 mm. *Head* chestnut-brown, eyes red. *Pronotum* chestnut-brown partially suffused with dark brown. *Scutellum* chestnut-brown. *Tegmen* pale hyaline-brown, apically smoky-grey, veins pale brown. *Thorax* and *Abdomen*, ventral surface and legs, brown. Last abdominal segment narrowly produced medially, emarginate laterally. Ovipositor sheath spinose. *Type* ♀ from Dedari, 1/36.

Platyscopus coloratus sp. nov.

(Plate I., figs. 26, 27.)

Length 5·5 mm. *Head*, ventral surface dark brown. Crown chestnut-brown with a medium black stripe extending from the base to within one-third of the apex and two small brown markings close to the eyes on each side; eyes red. *Pronotum* chestnut-brown. *Scutellum* black. *Tegmen* hyaline-brown, the costal border colourless ; apex and veins dark brown. *Thorax* and *Abdomen*, ventral surface black. *Type* ♂ from Dedari, 1/36.

EUSCELIDAE.

*Eutettix norrisi** Ev. and *Thamnotettix argentata* Ev. are the only previously described representatives of this family recorded from Western Australia. Both are described and figured in Evans, 1939, a. In an earlier paper (Evans, 1937, a) the genera *Paradorydium* Kirk. and *Deltodorydium* Kirk. were placed in the Euscelidae, in the tribe Paradorydiini of the sub-family Eupelicinae. Later (Evans, 1939, b) the Eupelicinae were transferred to the Ledridae. Further study has led to the conclusion that the Paradorydiini were misplaced and that they are a Euscelid tribe. *Deltodorydium viridis* Ev. is the only known Western Australian representative of this tribe.

OCCIPLANOCEPHALUS gen. nov.

The head is considerably wider than long, ventrally it is almost flat, the antennal pits are shallow and the eyes large. The frontal sutures are almost parallel to each other and to the internal margins of the eyes. They appear to extend posteriorly beyond the ocelli and the apices are directed towards the eyes on each side. The crown is wide and consists almost entirely of the vertex, the coronal suture is short and the ocelli though marginal are visible from above. The pronotum narrows laterally. The tegmina are short and do not nearly reach to the apex of the abdomen ; their appendices continue round their apices to the costal margins. The hind tibiae have a strong armature of spines. Each spine of the row of strongest spines is mounted on an enlarged base and separated from its neighbour by three or four minute spines. The male genitalia have wide flat sub-genital plates that narrow apically and narrowly produced pygophores.

Occiplanocephalus ravus sp. nov. (Genotype).

(Plate II., fig. 18.)

Length 6·8 mm. *Head*, ventral surface pale greyish-brown with transverse brown muscle impressions on the fronto-clypeus, eyes dark brown, crown grey. *Pronotum* grey mottled with brown. *Scutellum* grey with brown and black markings. *Tegmen* whitish-hyaline, veins brown; venation partially reticulate. *Thorax*, ventral surface grey with brown markings. Hind tibia pale brown, the bases of the spines dark brown. *Abdomen*, ventral surface pale brown. *Type* ♂ from Dedari, 1/36.

EUSCELOSCOPUS gen. nov.

The head is as wide as long and slightly convex. The antennal pits are deep and the antennal ridges distinct. The eyes are small and the ocelli which are large are on the crown, close to but not touching the eyes. The crown may be of even width throughout or medially produced and the head including the eyes is the same width as the pronotum at the base. The pronotum laterally separates the head from the bases of the tegmina. The hind tibiae have three rows of long strong spines. The internal row decrease in size from the apex to the base and the bases of the two external rows are arranged in pairs adjacent to each other, the spines of one of these row are slightly larger than those of the other and are separated from each other by short spines. *Euscelosсopus* is close to *Cicadula* Zett.

Euscelosсopus yanchepensis sp. nov. (Genotype).

(Plate II., figs. 15–17.)

Length 4 mm. *Head* reddish-brown, eyes black, ocelli red. Crown of even width throughout. *Pronotum* and *Scutellum* reddish-brown. *Tegmen* hyaline-brown but for the two cells adjoining the appendix which are smoky-hyaline; veins pink. *Thorax* and *Abdomen*, ventral surface and legs, yellowish-brown. *Type* ♂ from Yanchep, 11/35.

Euscelosсopus pallidus sp. nov.

(Plate II., fig. 19.)

Length 4·2 mm. *Head* buff-coloured, eyes and ocelli black. Crown apically acute, much wider medially than laterally, buff. *Pronotum* and *Scutellum* concolorous with the head. *Tegmen*, including the veins, pale hyaline-brown. *Thorax* and *Abdomen*, ventral surface yellow. *Type* ♂ from Yanchep, 12/35.

Deltocephalus dedarensis sp. nov.

(Plate II., figs. 21, 22.)

Length 3·6 mm. *Head*, ventral surface orange-yellow, fronto-clypeus darker in colour than the rest of the head. Eyes and antennae dark brown. Crown orange-buff, wider in the centre than against the eyes, rounded apically; coronal suture absent. *Pronotum* and *Scutellum* concolorous with the crown. *Tegmen*, pale hyaline-brown. *Thorax* and *Abdomen*, ventral surface and legs, pale orange yellow. *Type* ♂ from Dedari, 1/36.

Deltocephalus decoloratus sp. nov.

(Plate II., fig. 20.)

Length 3·8 mm. *Head*, ventral surface pale buff with faint brown transverse muscle impressions on the fronto-clypeus. Crown wider in the centre than against the eyes rounded apically, pale buff with a pattern of narrow brown markings ; eyes pale brown. *Pronotum* and *Scutellum*, yellowish-white with a few transverse narrow brown markings. *Tegmen* whitish-hyaline partially suffused with brown ; veins white. *Thorax* and *Abdomen*, ventral surface whitish-yellow. *Type* ♂ from Dedari, 1/36.

Deltocephalus pullatus sp. nov.

(Plate II., fig. 23.)

Length 4 mm. *Head*, ventral surface pale brown with a pattern of regular bold black markings ; eyes black, ocelli red. Crown wider in the centre than against the eyes, pale brown with transverse and curved black stripes : coronal suture distinct, terminating in front of the eyes. *Pronotum* yellowish-brown anteriorly, grey posteriorly with a regular pattern of brown markings. *Scutellum* pale brownish-yellow with black markings ; muscle impressions apricot. *Tegmen* whitish-hyaline, the borders of each cell suffused with brown. *Thorax*, ventral surface black, the edges of certain sclerites edged with yellow. Hind tibia pale brown, spines brown. *Abdomen* proximally black, distally yellow. *Type* ♀ from Yanchep, 12/35.

EUPTERYGIDAE.

It is almost certain that this family is well represented in Western Australia, although not previously recorded from there. The species described below is placed in the genus *Aneono* Kirk. on account of its resemblance to the genotype *A. pulcherrima* Kirk. The venation of the two species is similar though not identical. Myers (1928) stated that *Aneono* was "apparently not a Typhlocybine genus." Nevertheless it would appear to have closer relationships with the Eupterygidae than with other jassoid families. A nymph of an un-described species belonging to the same genus is illustrated in Pl. 3, fig. 20. It is extremely flattened and has a series of projecting flaps on the head, legs and abdomen. The nymph was taken at Hobart, Tasmania.

Aneono venusta sp. nov.

(Plate III., figs. 18, 19.)

Length 4 mm. *Head* pinkish, partially suffused wuth white *Pronotum*, antero-laterally white, medially grey. *Scutellum* very dark brown, apically brownish-yellow. *Tegmen*, apical third pale brownish-hyaline ; proximal two-thirds brown, but for the costal area distally which is pink, and for irregular white areas. *Thorax*, ventral surface dark brown. *Abdomen*, ventral surface pale brown. *Type* ♀ from Dedari, 1/36.

IDIOCERIDAE.

Only two species belonging to this family have been described previously from Western Australia. They are *Idiocerus divisus** Ev. and *I. lesmurdensis** Ev. Both are described in Evans, 1936.

TUMOCERUS gen. nov.

The maxillary plates are narrow, and the lora and ante-clypeus are flat and depressed below the swollen fronto-clypeus; the eyes are large. The crown is wide and more or less at right-angles to the face though forming part of one curved surface with it. The sutures that limit the fronto-clypeus posteriorly may be distinct or indistinct. The pronotum narrows laterally and the bases of the tegmina lie close behind the eyes. The tegmina have wide appendices and the cross-vein that represents M_{1+2} is considerably longer than is usual. The hind tibiae are short and have two strong spines set on enlarged bases in addition to several weak spines. The sub-genital plates in the male are wide apically, the parameres are short and the pygophores are not produced.

Tumocerus varius sp. nov. (Genotype).

(Plate III, figs 4–7.)

Length 4 mm. *Head*, ventral surface yellow, eyes dark brown, ocelli red, hind margin of the fronto-clypeus brown. Crown wider in the centre than against the eyes, yellow suffused with brown medially and with two round black markings. *Pronotum* brownish-grey. *Scutellum* yellow, with two triangular brown markings close to the centre; muscle inpressions black. *Tegmen* hyaline, partially suffused with brown; veins dark brown. *Thorax* and *Abdomen*, ventral surface yellow, legs brown. *Type* ♂ from Dedari, 1/36. *Note*.—A variety occurs in which extensive black markings occur on the head, and the thorax may be largely brown.

Tumocerus merredinensis sp. nov.

(Plate III., figs. 2, 3.)

Length 4 mm. *Head* pale buff, eyes dark brown. Crown of even width throughout with two brown spots. *Pronotum* and *Scutellum* concolorous with the head. *Tegmen* pale hyaline-brown, veins pale brown. *Thorax* and *Abdomen*, ventral surface apricot yellow. *Type* ♀ from Merredin 12/35.

Tumocerus grandis sp. nov.

(Plate III., fig. 1.)

Length 5·5 mm. *Head* pale buff, eyes dark brown. Head wider in the centre than against the eyes with two round black markings. *Pronotum* concolorous wuth the crown. *Scutellum* with two small brown spots lying on each side of the centre, muscle impressions dark brown. *Tegmen*, pale hyaline-brown, veins brown. *Thorax* and *Abdomen*, ventral surface pale buff. *Type* ♀ from Dedari, 1/36.

Tumocerus glaucus sp. nov.

(Plate III., fig. 15.)

Length 5 mm. *Head*, ventral surface pale yellowish green. Crown of even width throughout, narrowly pale yellowish-green against the eyes, medially pink, with two marginal large black spots; eyes red. *Pronotum*, antero-laterally pale yellowish-green, medially pink. *Scutellum*, apricot. *Tegmen*, proximally, membrane and veins pale yellowish-green, distally hyaline-brown, veins dark brown. *Thorax* and *Abdomen*, ventral surface and legs, pale yellowish-green. *Type* ♂ from Dedari, 1/36.

GNATIA gen. nov.

The ante-clypeus is angularly swollen, the hind margin of the fronto-clypeus is distinct and the ocelli lie well away from the apices of the frontal sutures. The crown is of even width throughout and the tegmina are long and narrow and have wide appendices. The hind tibiae are short and have two spines mounted on enlarged bases in addition to several weak spines.

Gnatia angustata sp nov. (Genotype)

(Plate III., figs. 13, 14.)

Length 5 mm. *Head*, ventral surface, ante-clypeus pale brown, lora, maxillary plates and the vertex anteriorly whitish. Fronto-clypeus chestnut-brown mottled with dark brown. Crown medially dark grey, laterally pinkish ; eyes dark brown. *Pronotum* antero-laterally pinkish-yellow, otherwise grey. *Scutellum* pinkish-brown, muscle impressions brown. *Tegmen* hyaline-grey with a dark brown fascia ; veins pale brown bordered with a double row of fine hairs. *Thorax*, ventral surface black. *Abdomen*, ventral surface yellow. *Type* ♀ from Dedari, 1/36.

Idiocerus luteus sp. nov.

Length 4 mm. *Head* slightly convex, yellow ; eyes black. *Pronotum* concolorous with the head. *Scutellum* apricot. *Tegmen*, proximally bronze-hyaline-yellow, distally hyaline-brown ; veins yellow. *Thorax* and *Abdomen*, ventral surface yellow. Hind tibia pale green with two rows of dark brown spines. *Type* ♀ from Dedari, 1/36.

Idiocerus coloratus sp. nov.

Length 4 mm. *Head* whitish, convex, eyes dark red ; ocelli yellow. Muscle impressions on fronto-clypeus pale apricot. Crown wide, of even width throughout. *Pronotum* grey. *Scutellum*, bright orange-red. *Tegmen* proximally, and veins, whitish-hyaline ; distally and veins smoky-grey. *Thorax* and *Abdomen*, ventral surface, buff. *Type* ♀ from Dedari, 1/36.

Idiocerus fucatus sp. nov.

(Plate III., figs. 9, 10.)

Length 3·5 mm. *Head*, ventral surface apricot, eyes red. Crown narrow, of even width throughout, the width of each eye equal to half the breadth of the crown. *Pronotum* and *Scutellum* apricot. *Tegmen* including the veins, golden-hyaline. *Thorax* and *Abdomen*, ventral surface and legs, pale yellow. *Type* ♀ from Dedari, 1/36.

Idiocerus rubens sp. nov.

(Plate III., fig. 12.)

Length 3·2 mm. *Head* bright red sparsely mottled with pale brownish-yellow ; eyes black. Crown slightly wider in the centre than against the eyes. *Pronotum* and *Scutellum* concolorous with the head. *Tegmen* proximally hyaline-red with irregular whitish markings, distally hyaline-colourless ; veins pink. Coastal area, proximally white. *Thorax* and *Abdomen*, ventral surface and legs, pinkish-yellow. *Type* ♀ from Southern Cross, 1/36.

Idiocerus viridiceps sp. nov.

(Plate III., fig. 11.)

Length 2·8 mm. *Head* greenish-yellow, eyes brown. *Pronotum* and *Scutellum* concolorous with the head. *Tegmen* hyaline-green the veins indistinctly bordered by fine hairs. *Thorax* and *Abdomen*, ventral surface, pale greenish-yellow. *Type* ♀ from Dongarra, 11/35.

Idiocerus candidus sp. nov.

(Plate III., fig. 8.)

Length 2·2 mm. *Head*, ante-clypeus, maxillary plates and lora white; fronto-clypeus white with dark brown markings; vertex pale brown mottled with brown; eyes brown. *Pronotum* grey mottled with brown. *Scutellum* yellowish-white, muscle impressions brown. *Tegmen*, claval and costal areas white, the rest of the tegmen hyaline-grey irregularly suffused with brown. *Thorax* ventral surface brown. *Abdomen*, ventral surface and legs, yellow. *Type* ♀ from Dongarra, 9/35.

AUSTROAGALLOIDIDAE.

Only a single species, *Austroagalloides flavus** Ev. has been described previously from Western Australia. (Evans, 1939, c)

Austroagalloides maculata sp. nov.

(Plate III., fig. 17.)

Length 5 mm. *Head* orange-yellow, eyes red. Crown slightly wider against the eyes than in the centre. *Pronotum* deep orange yellow flecked with small raised transverse black markings. *Scutellum* orange, with a few small raised black spots. *Tegmen* pale hyaline-orange-yellow with numerous raised dark brown spots lying especially along the veins; apically black. *Thorax* and *Abdomen*, ventral surface orange yellow. *Type* ♂ from Dedari, 1/36.

THYMBRIDAE.

Three species of Thymbridae have been recorded from Western Australia. They are *Euprora mullensis** Ev., *Ledraprora compressa** Ev., and *Rhotidoides montana* Ev. *E. mullensis* was described in Evans, 1939, a, *L. compressa* in Evans, 1939, c, and *R. montana* in Evans, 1937, b. *Euprora mullensis* was provisionally placed in the Eupelicinae, but it was stated, preceding its description, that its affinities were doubtful. The genus *Euprora* is now transferred to the Thymbridae close to *Hackeriana* Ev. The type, a female from Mullewa, was yellowish-brown in colour. Several specimens of this species occur in the British Museum material; they are all pale yellowish-green and display considerable variation in regard to the shape and length of the head. The head, which is always narrowly produced, ranges from 2–4 mm. in length. The aedeagus is illustrated in Plate I., fig. 2.

Putoniessa nota sp. nov.

(Plate I., figs. 1, 4.)

Length 7 mm. *Head*, ventral surface black mottled with dull yellow anterior to the transverse ridge that lies between the ocelli and the antennal ridges, posterior to the ridge pale pinkish-white sparsely mottled with dark brown. Crown narrow, wider against the eyes than in the centre. *Pronotum* grey mottled with dark brown and grey. *Scutellum* reddish-brown mottled with black. *Tegmen* greyish-hyaline mottled with brown ; veins pink with white and brown bars and a series of evenly spaced white spots against the costal border. *Thorax*, ventral surface marked with a pattern of light and dark brown. *Male Genitalia*, pygophore more or less rectangular with an upturned apical process. Aedeagus as in Plate I., fig. 4. *Type* ♂ from Dedari.

Hackeriana translucens sp. nov.

(Plate I., fig. 3.)

Length 7 mm. *Head*, ventral surface greenish-yellow, eyes red. Ocelli marginal, closer to the narrow apex of the head than to the eyes on each side. Crown pale greenish-yellow with faint oval white markings, a central triangular area, flat, laterally declivous. *Pronotum* and *Scutellum* concolorous with the crown. *Tegmen*, colourless-hyaline, veins green. *Thorax* and *Abdomen*, ventral surface yellow. *Male Genitalia*, parameres spanner-shaped, pygophores long and narrow, aedeagus as in Plate I., fig. 3. *Type* ♂ from Burracoppin. 1/36.

Rhotidoides dongarrensis sp. nov.

(Plate I., figs. 5, 6.)

Length 7 mm. *Head*, ventral surface, ante-clypeus, lora and maxillary plates marked with a pattern of pale brown, dark brown, and black ; fronto-clypeus and vertex, yellowish-white ; eyes concolorous with the maxillary plates. Crown slightly wider against the eyes than in the centre, marked with a pattern of pale and dark brown. *Pronotum*, anterior margin in front of the eyes, flat, followed by a narrow declivous area, the remainder and greater part, flat, brownish-grey with dark brown markings. *Scutellum* pale brown. *Tegmen* hyaline-colourless, evenly mottled with dull greyish-brown. *Thorax*, ventral surface with light and dark brown markings. Legs, fore tibia pale brown with dark brown markings, hind tibia pale brown, the bases of the spines brown. *Abdomen*, ventral surface, marked with light and dark brown markings. *Male Genitalia*, pygophores irregularly shaped and lacking processes, aedeagus and paramere as in Plate I., figs. 5 and 6. *Type* ♂ from Dongarra, 9/35.

NEWMANIANA gen. nov.

The ante-clypeus is flat, and the fronto-clypeus convex anteriorly and depressed medially, slightly anterior to the apex of the head. The antennal depressions are deep and continue anteriorly to the edge of the maxillary plates. The frontal sutures diverge posteriorly and terminate at the ocelli, which are not visible either in ventral or dorsal aspect. The apical margin of the head is more or less vertical and narrows medially. The crown is flat and anteriorly produced and the eyes are large. The pronotum is slightly transversely convex and the hind margin almost straight. The scutellum is large and equal in length to the combined length of the crown and pronotum. The tegmina have moderately wide appendices and the venation and the armature of the hind tibiae are typical of the family. This genus is close to *Hackeriana* Ev. and *Euprora* Ev.

Newmaniana viridis sp. nov. (Genotype).

(Plate I., figs. 7–9.)

Length 7 mm. *Head*, ventral surface pale yellowish-green, posteriorly red, medially pink ; eyes red, crown pinkish-green. *Pronotum* and *Scutellum* yellowish-green. *Tegmen* pale hyaline-green, veins pale green. *Male Genitalia* with wide pygophores lacking processes ; aedeagus and parameres as in Plate I., figs. 7 and 8. *Type* ♂ from Dongarra, 9/35.

MACROPSIDAE.

Four representatives of this family have been described previously from Western Australia. These are *Stenoscopus drummondi** Ev., *Macropsis occidentalis** Ev., *M. luteus* Ev., and *Oncopsis scopulus** Ev. (1936). All the new species described below, with one exception, have been placed in the genera *Macropsis* Lewis and *Oncopsis* Burm. according to whether the striations on the pronotum are oblique or transverse.

It is, however, appreciated that they may not all be congeneric with the genotypes of the two genera, but the differentiation of further genera is inadvisable until more material is available for study.

STENOPSOIDES gen. nov.

The head is slightly longer than wide and transversely convex, a crown is not developed. The pronotum which is enormously anteriorly produced, and which from below appears to be directly continuous with the face, has a median ventral carina. The hind margin of the pronotum is emarginate and the scutellum is large. The tegmina are apically acute and have appendices that continue around their apices as far as the costal borders. The hind wings are fully developed.

Stenopsoides turneri sp. nov. (Genotype).

(Plate II., figs. 4-6.)

Length 7 mm. *Head*, ventral surface yellow with brown punctures, eyes red. *Pronotum*, "ventral" and dorsal surfaces yellowish-brown with brown punctures; sides and apex, dark brown. *Scutellum* yellow. *Tegmen* pale hyaline-yellow. *Thorax* and *Abdomen*, ventral surface yellow. *Type* ♀ from Dedari, 1/36.

Macropsis flexus sp. nov.

(Plate II., fig. 14.)

Length 3·5 mm. *Head* buff with minute pale brown punctures, eyes reddish-brown, ocelli black: muscle impressions greenish-yellow. Crown visible from above as a narrow band of even width. *Pronotum* concolorous with the head, slightly declivous but not humped. *Scutellum* concolorous with the pronotum. *Tegmen* colourless-hyaline, veins brown with white bars. *Thorax*, ventral surface pale brownish-yellow, bases of all the spines on the hind tibia black. *Abdomen*, ventral surface brown. *Type* ♀ from Dongarra, 10/35.

Macropsis eburneus sp. nov.

(Plate II., fig. 9.)

Length 4·5 mm. *Head* ivory with brown punctures, fronto-clypeus medially brown with dense dark brown punctures; muscle impressions smooth, yellowish-brown. Crown visible only narrowly against the eyes. *Pronotum* anteriorly cream, with dense brown anteriorly-directed striations, steeply declivous, posteriorly grey with scattered brown punctures. *Scutellum* orange-brown with black punctures. *Tegmen* hyaline with scattered small brown spots, mostly on and along the sides of the veins. *Thorax*, ventral surface black, edged with brown. Legs cream with brown markings. *Abdomen*, ventral surface black, the hind margin of each segment cream. *Type* ♀ from Dedari, 1/36.

Macropsis citrinus sp. nov.

Length 4 mm. *Head*, *Pronotum*, and *Scutellum*, bright orange. *Tegmen* narrow apically, colourless-hyaline, veins pale brown. *Thorax*, ventral surface black. Legs orange, spurs on the hind tibia black. *Abdomen*, ventral surface black. *Type* ♀ from Dedari, 1/36.

Macropsis declivus sp. nov.

(Plate II., fig. 10.)

Length 3·5 mm. *Head*, anterior to the ocelli orange-yellow with reddish-brown punctures, muscle impressions pale orange; posterior to the ocelli medially grey, laterally pale pinkish-white with brown punctures; eyes dark reddish-brown. *Pronotum*, anterior third steeply declivous and more or less at right angles to the remainder, which is flat, antero-laterally orange, without punctures, the remainder greyish-brown with dense brown punctures. *Scutellum* orange-brown with sparse brown punctures. *Tegmen* whitish-hyaline with large round brown spots lying principally on the sides of the veins; veins pale brown. *Thorax*, ventral surface black. *Abdomen*, ventral surface orange-brown. *Type* ♀ from Dedari, 1/36.

Macropsis flavomaculatus sp. nov.

(Plate II., fig. 7.)

Length 4 mm. *Head* apricot mottled with whitish-yellow, eyes dark brown. *Pronotom* anteriorly declivous though not so steep as in *M. declivus*, greyish-white with apricot punctures. *Scutellum* concolorous with the pronotum, with sparse orange-brown punctures. *Tegmen* colourless-hyaline mottled with pale coffee-brown; veins pale brown with white bars. *Thorax* and *Abdomen*, ventral surface and legs, pale orange-yellow. *Type* ♀ from Dedari, 1/36.

Oncopsis aeneus sp. nov.

(Plate II., fig. 8.)

Length 4 mm. *Head*, ventral surface sordid yellow, eyes red. Crown narrow, visible only against the eyes on each side. *Pronotum* golden-brown. *Scutellum* yellowish-brown. *Tegmen* bronzy-hyaline with a longitudinal white streak lying along the first cubital vein proximally. *Thorax*, ventral surface black. *Abdomen*, ventral surface yellowish-brown. *Type* ♂ from Yanchep, 11/38.

Oncopsis gibbus sp. nov.

(Plate II., fig. 11.)

Length 3·8 mm. *Head* brownish-yellow with evenly distributed black punctures, muscle impressions yellow, eyes reddish-brown. Vertex medially dark brown. Crown only visible narrowly against the eyes on each side. *Pronotum* greyish-brown with evenly distributed black punctures, declivous anteriorly and slightly humped. *Scutellum* deep buff with scattered brown spots, anterior lateral angles yellow. *Tegmen* whitish-hyaline evenly mottled with dull brown, veins pink. *Thorax*, ventral surface black. *Abdomen*, ventral surface black, hind margin of every segment yellowish-white. *Type* ♀ from Yanchep, 12/35.

Oncopsis fuscopunctatus sp. nov.

(Plate II., fig. 13.)

Length 4 mm. *Head* pale brownish-yellow, eyes brown. Crown narrowly visible against the eyes on each side. *Pronotum* slightly declivous anteriorly, ochreous-brown with brown punctures. *Scutellum* orange-brown with a few scattered brown spots. *Tegmen* pale brownish-hyaline partially suffused with brown. *Thorax* and *Abdomen*, ventral surface black; legs yellow. *Type* ♂ from Dongarra, 9/35.

Oncopsis bicoloratus sp. nov.

(Plate II., fig. 12.)

Length 3·5 mm. *Head* yellow with dark brown punctures, muscle impressions on fronto-clypeus black. Crown narrowly visible against the eyes on each side. *Pronotum* and *Scutellum* yellow with sparse brown punctures. *Tegmen* pale hyaline brown irregularly mottled with brown; veins brown. *Thorax* and *Abdomen*, ventral surface black. Legs marked with a black and pale brown pattern. *Type* ♂ from Yanchep, 11/35.

Oncopsis luteus sp. nov.

Length 4·8 mm. *Head* yellow, eyes dark red, ocelli black. Crown visible narrowly against the eyes. *Pronotum* greenish-yellow, declivous. *Scutellum* yellow. *Tegmen* pale hyaline-yellow with a dark brown spot at the apex of the claval suture, veins yellow, venation similar to that of *O. fuscopunctatus*. *Thorax* and *Abdomen*, ventral surface yellow, the bases of the largest spines on the hind tibia black. *Type* ♀ from Dongarra, 10/35.

TARTESSIDAE.

The following species are known from Western Australia:—*Tartessus spinosus** Ev., *Tartessus fulvus* (Walk.), *Tartessoides griseus** Ev., and *Tartessella attenuata** Ev. (Evans, 1937b).

Tartessus fumus sp. nov.

(Plate I., fig. 18.)

Length 6·5 mm. *Head*, ventral surface yellow, eyes brown. Crown yellow consisting in part of the fronto-clypeus. *Pronotum* and *Scutellum* yellow. *Tegmen* pale hyaline-brown, apically smoky-brown, veins light and dark brown, appendix very wide apically. *Thorax* and *Abdomen*, ventral surface yellow. *Male Genitalia*, pygophores with strong processes, aedeagus as in Plate I., fig. 17. *Type* ♂ from Mundaring Weir, 2/36.

Tartessus mundarensis sp. nov.

(Plate I., fig. 19.)

Length 5 mm. *Head*, ventral surface, fronto-clypeus anteriorly faintly suffused with brown, sutures brown; eyes black. Crown, fronto-clypeus yellow, vertex pale whitish-brown. *Pronotum* concolorous with the vertex. *Scutellum* anteriorly pale whitish-brown, apically lemon-yellow. *Tegmen* pale hyaline-brown, apically smoky-brown; veins dark brown. *Thorax* and *Abdomen*, ventral surface black, legs yellow, bases of the spines on the hind tibia black. *Male Genitalia*, aedeagus as in Plate I., fig. 18. *Type* ♂ from Mundaring Weir, 2/36.

Tartessus rugosus sp. nov.

(Plate I., fig. 20.)

Length 7·5 mm. *Head* pale brownish-yellow ; fronto-clypeus anterior to the antennae, with brown transverse muscle impressions ; posterior to the antennae, and the vertex, rugose mottled with pale and dark brown ; eyes dark brown. Crown, consisting entirely of the vertex, pitted with light and dark brown markings. *Pronotum* and *Scutellum* pale brown with dark brown markings. *Tegmen* pale hyaline-brown, veins dark brown. *Abdomen*, ventral surface marked with a pattern of light and dark brown and black. Hind tibia pale brown, bases of the spines dark brown. *Male Genitalia*, aedeagus as in Plate I., fig. 19. *Type* ♂ from Yanchep, 11/35.

Tartessus flavus sp. nov.

(Plate I., fig. 21.)

Length 6 mm. *Head*, ventral surface pale apricot, ocelli red, eyes dark brown. Crown pale apricot consisting entirely of the vertex. *Pronotum* and *Scutellum* concolorous with the crown. *Tegmen*, hyaline-apricot. *Thorax* and *Abdomen*, ventral surface, and legs, apricot, bases of the spines, dark brown. *Male Genitalia*, aedeagus as in Plate I., fig. 20. *Type* ♂ from Yanchep, 12/35.

Tartessus rubrivenosus sp. nov.

(Plate I., fig. 22.)

Length 6 mm. *Head*, ventral surface, ante-clypeus, lora and maxillary plates brown, sparsely mottled with black, transverse muscle impressions black ; vertex, between the eyes on each side, brown, densely mottled with black. Crown rugose, pale brown, the fronto-clypeus visible as a narrow anterior border : eyes dark brown. *Pronotum* antero-laterally smooth, yellowish-brown : medially greyish-brown with transverse striations. *Scutellum* marked with a pattern of light and dark brown. *Tegmen* hyaline-brown, apical cells partially suffused with smoky-brown ; veins pink with dark brown bars. *Thorax*, ventral surface with light brown and black markings. Legs, fore and middle tibiae reddish-brown with black markings, hind tibia pale brown, bases of the spines black. *Male Genitalia*, aedeagus as in Plate I., fig. 21. *Type* ♂ from Dedari, 1/36.

Tartessus latus sp. nov.

(Plate I., fig. 23.)

Length 6 mm. *Head*, ventral surface, fronto-clypeus darker in colour than the rest of the face with a transverse dark brown bar between the ocelli and the antennae ; eyes black. Crown consisting entirely of the vertex, wider against the eyes than in the centre, rugose. *Pronotum* pale brown. *Scutellum* dark brown with very dark brown muscle impressions. *Tegmen* pale hyaline-brown, veins brown. *Thorax* and *Abdomen*, ventral surface, and legs pale brown. *Male Genitalia*, aedeagus as in Plate I., fig. 22. *Type* ♂ from Dedari, 1/36.

NIRVANIIDAE.

The species described below is the first representative of this Indo-Malayan group of leaf-hoppers to be described from Western Australia.

OCCINIRVANA gen. nov.

The head is produced and spatulate, ventrally concave and dorsally convex. The ante-and fronto-clypeus are flat and bordered laterally with deep depressions. The antennae, which are very long, are inserted close to the anterior apical border of the head. The sides of the head on each side are emarginate above the antennae and below the ocelli, and the ocelli are close to the sides of the crown and nearer to the apex than to the eyes. The coronal suture is long, and the greater part of the crown consists of the vertex. The pronotum is collar-like and parallel-sided and in the tegmen M_{1+2} appears to be more than a mere cross-vein. The hind tibiae have a row of evenly-spaced short strong spines set on enlarged bases, a row of long strong spines, another of short spines and one of hair-like spines.

Occinirvana eborea sp. nov. (Genotype).

(Plate II., figs. 1–3.)

Length 6 mm. *Head*, ventral surface ivory, lora and ante-clypeus brownish-grey, eyes black. Crown pale ivory with a median longitudinal apricot band and two narrow sinuate lateral bands; ocelli red. *Pronotum* ivory with a median apricot band and apricot mottlings antero-laterally. *Scutellum* ivory with apricot muscle impressions and a faint broad median apricot band. *Tegmen* pale hyaline-brown but for the clavus which is white; apically brown, and with a brown area at the fork of Cu_1. *Thorax*, ventral surface apricot and ivory. *Abdomen*, ventral surface ivory; last segment medially emarginate; ovipositor sheath with proximal brown and apical black spines. *Type* ♀ from Perth, 3/36, on *Casuarina* sp.

STENOCOTIDAE.

Stenocotis depressa Walk. and *Smicrocotis solomoni** Ev. are the sole representatives of this family so far recorded from Western Australia. (Evans, 1937, d.)

LEDRIDAE.

The following have been recorded from Western Australia: sub-family Ledrinae, *Platyledra monstrosa** Ev. Sub-family Cephalelinae, *Anacephaleus subreticulatus* (Kirk.), *A. minutus* Ev., *A. latus** Ev., *Paradorydium michaelseni** Jac. (probably belongs to *Anacephaleus* Ev.), *Notocephalius hartmeyeri** Jac., *Procephaleus bulbosa** Ev., *Cephalelus punctatus** Ev. Jacobi's species were described in 1909, Kirkaldy's in 1906 and the remainder in Evans, 1937, a, and 1939, c.

REFERENCES.

China, W. E., 1926—A new sub-family of the Bythoscopidae. *Trans. Ent. Soc., London*, 289.

Evans, J. W., 1933—A Revision of the Eurymelini. *Trans. Roy. Soc., S. Aust.*, 57: 73.

,, ,, 1934—A Revision of the Ipoinae. *Trans. Roy. Soc., S. Aust.*, 58: 149.

,, ,, 1936—The Bythoscopidae of Australia. *Pap. Roy. Soc., Tas.*, 61.

,, ,, 1937, a—Australian Leaf-Hoppers Pt. 4. *Pap. Roy. Soc., Tas.*, 37.

,, ,, 1937, b—Australian Leaf-Hoppers Pt. 5. *Pap. Roy. Soc., Tas.*, 51.

,, ,, 1937, c—Australian Leaf-Hoppers Pt. 6. *Mem. Queensland Mus.*, 11 (2): 149.

,, ,, 1937, d—Australian Leaf-Hoppers Pt. 7. *Mem. Queensland Mus.*, 11 (2): 157.

,, ,, 1939, a—Australian Leaf-Hoppers Pt. 8. *Pap. Roy. Soc., Tas.*, 1.

,, ,, 1939, b—A contribution to the Study of the Jassoidea. *Pap. Roy. Soc., Tas.*, 19.

,, ,, 1939, c—Some new Australian Leaf-Hoppers. *Trans. Roy. Soc., S. Aust.*, 63 (1): 14.

Jacobi, A., 1909—"Faun. S.W. Aust.," Michaelsen u. Hartmeyer, ii.: 329.

Kirkaldy, G. W., 1906—Leaf-Hoppers. *Bull. Hawaii Sug. Ass. Ent.*, 1 (9).

Myers, J. G., 1928—A note on Australian Typhlocybine Leaf-Hoppers. *Bull. Ent. Res.*, 18 (1): 311.

Plate I.

Figure 1. *Putoniessa nota*, head, ventral surface.
,, 2. *Euprora mullensis*, aedeagus.
,, 3. *Hackeriana transluc*e*ns*, aedeagus.
,, 4. *Putoniessa nota*, aedeagus.
,, 5. *Rhotidoides dongarrensis*, aedeagus.
,, 6. *Rhotidoides dongarrensis*, paramere.
,, 7. *Newmaniana viridis*, paramere.
,, 8. *Newmaniana viridis*, aedeagus.
,, 9. *Newmaniana viridis*, head, ventral surface.
,, 10. *Ipo speciosa*, sub-genital plate and paramere.
,, 11. *Ipo speciosa*, aedeagus.
,, 12. *Anipo flavens*, aedeagus.
,, 13. *Ipoella fulva*, aedeagus.
,, 14. *Anipo fusca*, aedeagus.
,, 15. *Anipo darwini*, aedeagus.
,, 16. *Ipoides fasciata*, aedeagus.
,, 17. *Stenipo grisea*, sub-genital plate and paramere.
,, 18. *Tartessus fumus*, aedeagus.
,, 19. *Tartessus mundarrensis*, aedeagus.
,, 20. *Tartessus rugosus*, aedeagus.
,, 21. *Tartessus flavus*, aedeagus.
,, 22. *Tartessus rubrivenosus*, aedeagus.
,, 23. *Tartessus latus*, aedeagus.
,, 24. *Platyscopus badius*, head and thorax, dorsal surface.
,, 25. *Platyscopus badius*, tegmen.
,, 26. *Platyscopus coloratus*, head, ventral view.
,, 27. *Platyscopus coloratus*.
,, 28. *Eurinoscopus translucidus*, tegmen.

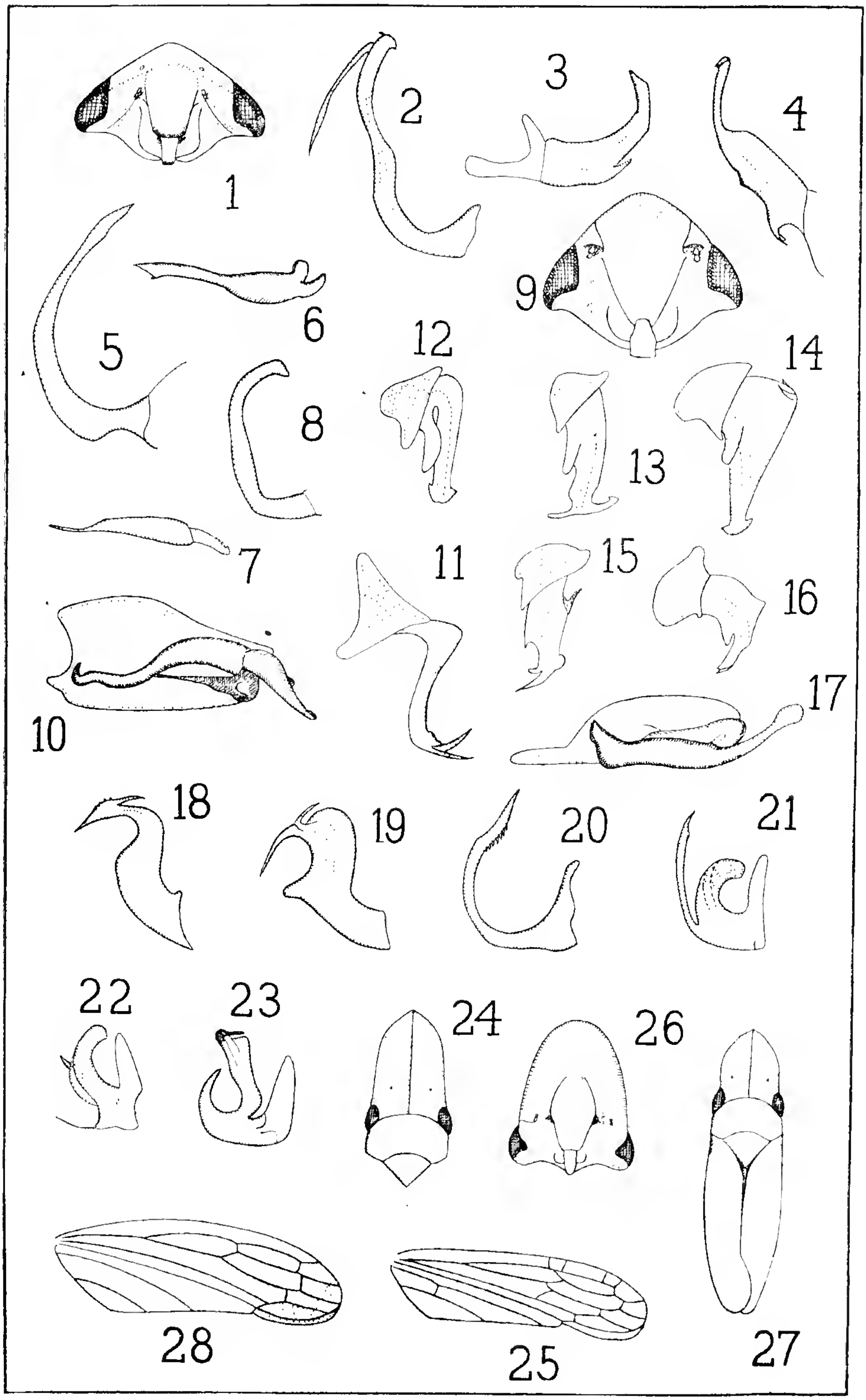
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Plate II.

Figure 1. *Occinirrana eborea*, head ventral surface.
,, 2. *Occinirrana eborea*, head and pronotum, dorsal surface.
,, 3. *Occinirrana eborea*, tegmen.
,, 4. *Stenopsoides turneri*, head and pronotum, ventral surface.
,, 5. *Stenopsoides turneri*.
,, 6. *Stenopsoides turneri*, tegmen.
,, 7. *Macropsis flavomaculatus*, head and pronotum, dorsal surface.
,, 8. *Oncopsis aeneus*, head and pronotum, dorsal surface.
,, 9. *Macropsis eburneus*, head and pronotum, dorsal surface.
,, 10. *Macropsis declivus*, head and pronotum, dorsal surface.
,, 11. *Oncopsis gibbus*, tegmen.
,, 12. *Oncopsis bicoloratus*, tegmen.
,, 13. *Oncopsis fuscopunctatus*, tegmen.
,, 14. *Macropsis flexus*, tegmen.
,, 15. *Eusceloscopus yanchepensis*, male genitalia.
,, 16. *Eusceloscopus yanchepensis*, tegmen.
,, 17. *Eusceloscopus yanchepensis*, head and thorax, dorsal surface.
,, 18. *Occiplanocephalus rarus*.
,, 19. *Eusceloscopus pallidus*, tegmen.
,, 20. *Deltocephalus decoloratus*, head and thorax, dorsal surface.
,, 21. *Deltocephalus dedarensis*, head and thorax, dorsal surface.
,, 22. *Deltocephalus dedarensis*, tegmen.
,, 23. *Deltocephalus pullatus*, tegmen.

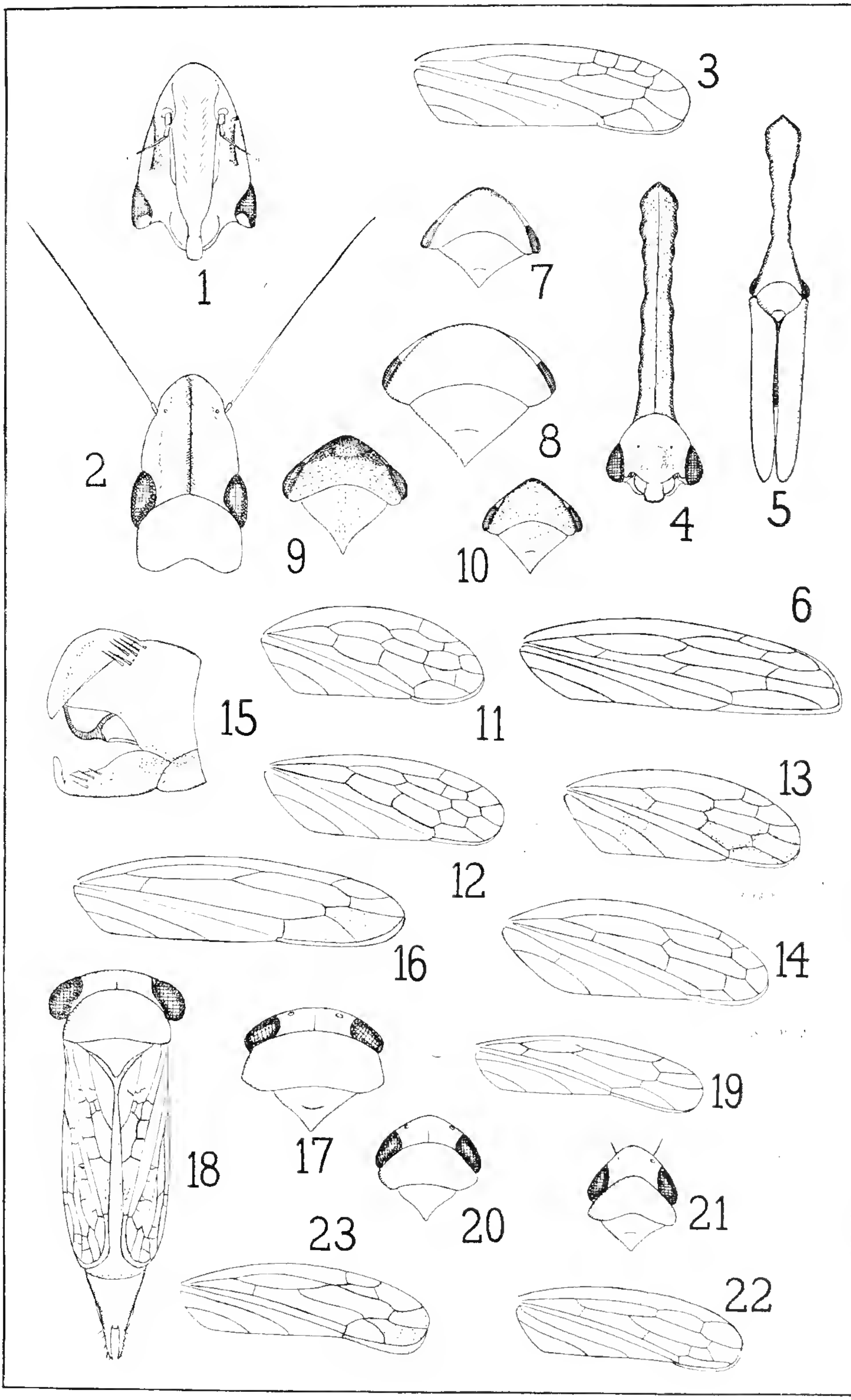
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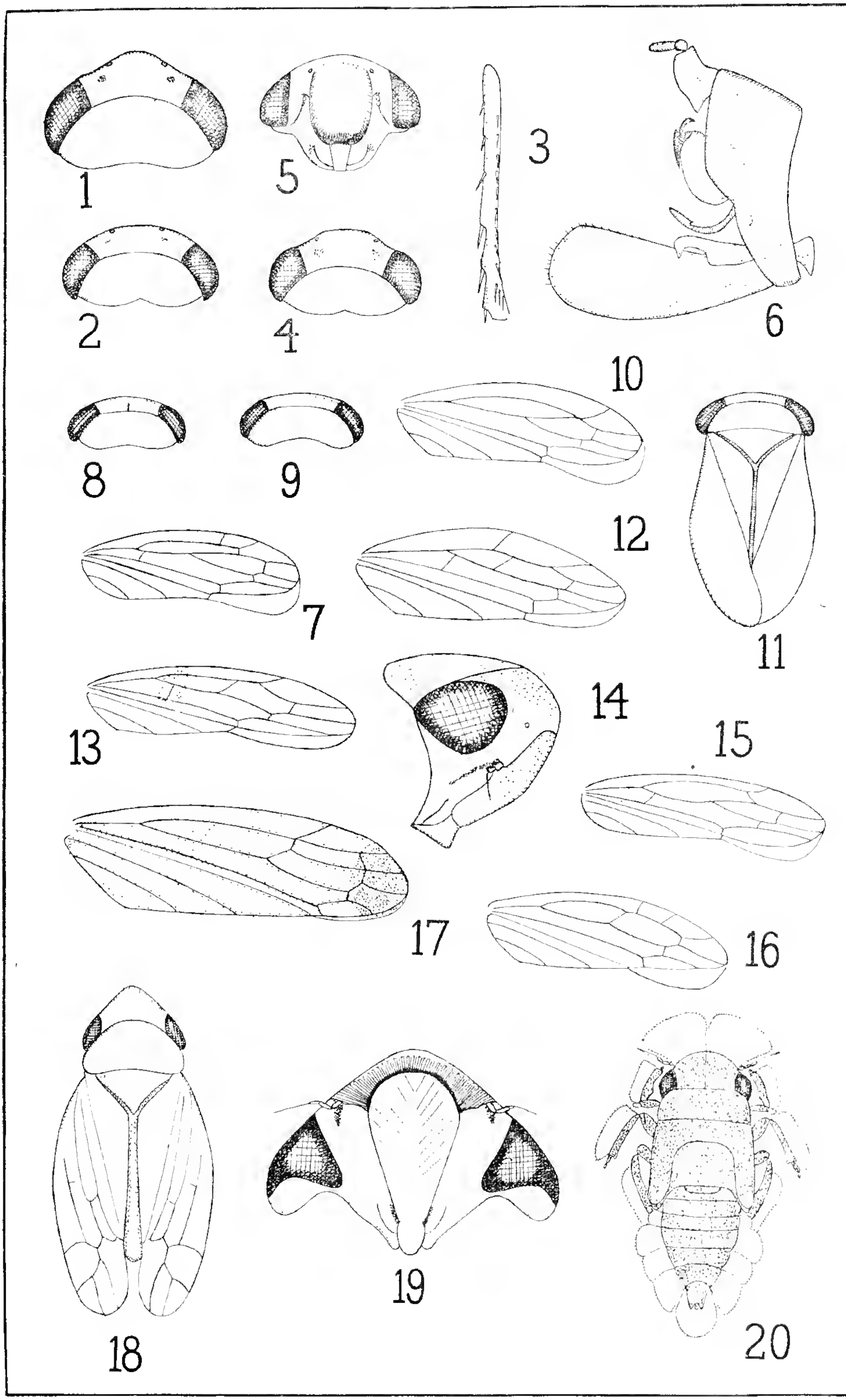
Plate III.

Figure 1. *Tumocerus grandis*, head and pronotum, dorsal surface.
,, 2. *Tumocerus meredinensis*, head and pronotum, dorsal surface.
,, 3. *Tumocerus meredinensis*, hind tibia.
,, 4. *Tumocerus varius*, head and pronotum, dorsal surface.
,, 5. *Tumocerus varius*, head, ventral surface.
,, 6. *Tumocerus varius*, male genitalia.
,, 7. *Tumocerus varius*, tegmen.
,, 8. *Idiocerus candidus*, head and pronotum, dorsal surface.
,, 9. *Idiocerus fucatus*, head and pronotum, dorsal surface.
,, 10. *Idiocerus fucatus*, tegmen.
,, 11. *Idiocerus viridiceps*.
,, 12. *Idiocerus rubens*, tegmen.
,, 13. *Gnatia angustata*, tegmen.
,, 14. *Gnatia angustata*, head and pronotum, lateral aspect.
,, 15. *Tumocerus glaucus*, tegmen.
,, 16. *Idiocerus fucatus*, tegmen.
,, 17. *Austroagalloides maculata*, tegmen.
,, 18. *Aneono venusta*.
,, 19. *Aneono venusta*, head, ventral surface.
,, 20. *Aneono* sp., nymph.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14.—CONTRIBUTIONES FLORAE AUSTRALIAE OCCIDENTALIS XI.

By CHARLES AUSTIN GARDNER.

Read 11th March, 1941; Published 7th August, 1942.

INTRODUCTION.

This paper contains descriptions of fifty new species of plants collected during recent years. It represents a portion of the unpublished species which were discovered during the work of the reorganisation of the State Herbarium, Perth, and is only a part of the total material awaiting description. Since the publication of *Contributiones* X, six species were described at Kew in Hooker's Icones Plantarum tt 3378-3384, 1939.

The material described in this paper consists in the main of selections from the collections of Dr. W. E. Blackall, and of specimens which we conjointly collected during a tour undertaken in 1931, which covered a large tract of country in South-Western Australia. In addition there are a few species collected in the North-West between the Gascoyne and Fortescue Rivers in 1932 when I accompanied the Minister for Lands and Agriculture on an investigational tour during August of that year.

More recently, whilst engaged on critical comparative studies in the Herbarium of the Royal Botanic Gardens, Kew, and the Berlin Herbarium, further new species were brought to light, and some changes in nomenclature have been necessitated. Only a few of these have been incorporated in this paper; others will follow in the next Contribution. The collections of Mr. G. E. Brockway, District Forests Officer at Kalgoorlie have resulted in the discovery of some new species of Eucalyptus, and the recording of a hitherto little known species which has been fully described.

In presenting this paper for publication, I desire to thank in the first place, Sir Arthur Hill, Director of the Royal Botanic Gardens, Kew, who extended to me every facility and courtesy in my studies there which occupied two years, and who so generously presented to the State Herbarium portions of type specimens which are of inestimable value. I am also indebted to Dr. L. Diels of the Berlin Herbarium, for the generous gift of numerous type fragments of specimens which he, in company with Dr. E. Pritzel, collected in Western Australia in 1901 and 1902.

Finally I wish to express my thanks to Dr. W. E. Blackall who has assisted me by placing at my disposal the whole of his herbarium, and for the donation to the State Herbarium of all the undescribed specimens which form the type material of many of the species herein described.

State Herbarium,

Perth, W.A., March, 1941.

MONOCOTYLEDONEÆ.

GRAMINEÆ.

Triodia Wiseana *C. A. Gardn.* sp. nov.

Laxe caespitosa, innovationes numerosae, culmis numerosis e caespite exsertis, rigidis, adscendentibus, paucifoliatis, vaginis supremis breviter exsertis; foliis arcuato-patentibus deinde horizontaliter divaricatis, glaucis, laevis, apice cartilagineo-pungentibus, ora vaginae et marginibus inferioribus exceptis, rigidissimis, tereti-involutis, basin versus exceptis; vaginis glabris, striatis, non viscosis, ab ora dense et longe albo-ciliatis; paniculis brevibus, paucispiculatis, spiculis longe pedunculatis, erectis, pedunculis scabris, flexuosis; glumis elliptico-lanceolatis, glabris, duris, dorso convexis, laevis, crassis, trinervis, apice vix acutis, glumis superioribus quam inferiores vix longioribus; lemmatis 3-5, cartilagineis, purpureis, glabris, dorso laevis, breviter et subaequaliter tridentatis, dentibus ovato-triangularibus, acutis, minute ciliolatis, nervis 9 approximatis in fasciculis 3 quorum nervo centrale ipso baso ad apices loborum producto, lateralibus incompletis; palea quam lemma breviore, tenuiter papyracea, oblonga, retusa, bicarinata; staminibus 3.

Planta usque 40 cm. alta; lamina foliorum inferiorum 16 cm. longa, superiorum 1.5-4 cm. longa; panicula usque 6 cm. longa; glumae 9 mm. longae; lemma vix 6 mm. longa; palea 3 mm. longa.

Hab. in regione tropica ab montibus Hamersley, in rupestribus ad viam "Mount Margaret Pass," circ. 1000 m. alt., flor. m. August, *Gardner*, 3129.

Hanc speciem vero pro illustrissimo Francisco Iosepho Wise nomino, cuis est Australiae occidentalis Concilio provincia Agricolares res consulere colonariasque, qui, zelo valde memoriae digno, ad plantas quae regione fluvium Gascoyne inter et Fortescue virescant investigandas anno 1932, se mihi comitem amabilissimum consociavit.

Affinity to *T. microstachya* R. Br., differing in the hairy leaves, in the much shorter culms, the much reduced and few-flowered and flexuosely-branched panicle, glabrous glumes, &c. It bears some resemblance to *T. longiceps* J. M. Black, but can be readily separated by the much shorter panicle, fewer-flowered spikelets, the teeth of the lemma which is never hairy, and in the hairs of the leaves. The comparative shape and size of the teeth or lobes in *Triodia* is not reliable to any extent, and varies considerably in *T. Basedowii* E. Pritzel.

DICOTYLEDONEÆ.

CASUARINACEÆ.

Casuarina pinaster *C. A. Gardn.* sp. nov.

Frutex 1-4 metralis altus, ramosissimus, ramis patento-divaricatis, reliquis squamorum delapsorum persistentibus indutis; ramulis confertis, divaricatis, quaternato-verticillatis, biarticulatis, membro ramulorum infero in dentes quatuor saepe marcescentes desinente, dentibus ovato-lanceolatis, apice setaceis, erectis; supero inarticulato, elongato, folium tetragonum imitante, internodiis albo-pubescentibus, demum glabris, apice pungento-acutis; internodiis amentigeris valde abbreviatis; amentis masculis in axillis dentium congestis, quaternis, brevibus, squamis subovatis, extus pubescentibus; strobilo breviter pedunculato ovoideo; bractea crassa, e basi lata dorso rufo-pilosula, in setam brevaem producta; bracteolis exsertis, apice rotundo-obtusis, crassis, extus leviter convexis, lamina exteriore sublibere, in rostrum longum triquetra producta, valvis exedente; achaenio nigrescente, ala hyalina obliqua.

Frutex 1-4 m. altus, habitus fere piniodei; membrum foliaceum 4-5 cm. longum; amenta ♂ usque ad 1 cm. longa; strobilus 2-2.5 longus ac latus.

Hab. in distr. Stirling, prope Kukerin, in arenoso-lutosis, *Gardner* 1732; prope Nyabing, W. E. Blackall 3094.

The affinity of this species is with *C. acuaria* F. Muell., but differs in the much larger size, the rigid divaricate branches, the length of the terminal (upper) internode and its distinctly tetragonal form, in the scale-leaves which are long and membranous and terminate in fine setaceous points, and ciliate on the margins; the teeth of the male spike are much larger and acuminate, and the spikes shorter, more robust, and more contracted; the cones are larger (almost twice the size of those of *C. acuaria*), and the dorsal lamina is very much reduced, and produced into a stout triquetrous spine which only shortly exceeds the valvular portion and incurved at the apex.

C. Prinsepiana *C. Andrews*, in Jour. West. Aus. Nat. Hist. Soc. i. 43 (1904).

The type specimen of this species, now in the possession of the State Herbarium, possesses no cones, the type consisting only of a small branch with a young female inflorescence. A search for material in the herbaria of the Royal Botanic Gardens, the Natural History Museum, South Kensington, and the Berlin Herbarium proved futile in this respect, and we must assume that the type cones are not in existence. In 1936, Horace Brown brought me specimens of a *Casuarina* from Wurarga, with several cones, the bracteoles of which are tricuspidate, the two lateral points are side by side very close to the extremity of the valve, with a rounded thin valve apex between them, and a third conical process from the dorsal surface. This appeared to be an undescribed species, for which I had proposed the name *C. tricuspidata*, but still further material has been received from Mullewa, and a search for another *Casuarina* which might prove to be typical *C. Prinsepiana* has been unproductive. Andrews, in describing the bracteole of *C. Prinsepiana* says "Valves much exserted with *rounded points*, back covered with long brown hair below, glabrous in the free part with two prominent ridges, obtuse and extending beyond the apex of the valve; occasionally there is a third shorter protuberance between the other two, adnate lower down and ending in a short point."

This description does not exactly apply to the Wurarga specimens, but considering that these sharp points are so easily damaged, and that the branchlets of the two are indistinguishable, it is perhaps best to consider the Wurarga and Mullewa specimens recently collected as representing *C. Prinsepiana*. The affinity of the species is with *C. acutivalvis*, the plant differing in being a tree with the habit and appearance of *C. glauca*, but the cones of *C. acutivalvis*, except that the bracteoles bear a conical dorsal appendage, and instead of a simple terminal conical point, there are two collateral conical protuberances—not "ridges" extending beyond the valvular portion.

In *C. acutivalvis* there may occasionally be found a division of the apex of the bracteole point into two points, but in *C. Prinsepiana* the two points are quite distinct, and the obtuse and thin apex of the valvular portion is plainly visible between the two.

C. bicuspidata *Diels* non *Benth.*

The specimens described as *C. bicuspidata* by Diels, collected near Southern Cross, the type of which I saw in the Berlin Herbarium, is *C. acutivalvis* F. Muell. *C. bicuspidata* as far as is known, is restricted to South Australia and Tasmania.

PROTEACEÆ.

Grevillea eriobotrya *F. Muell.* Fragm. x. 44 (1876).

G. Victori A. Morrison, the type of which is in the Edinburgh Herbarium, is synonymous with the above. The species is common in yellow sand over an area extending from Kununoppin to Koorda, and the species is a shrub 3 or 4 metres in height with white flowers. The seeds are thick, glabrous and hemispherical in an orbicular white villous follicle. They are much like those of *G. annulifera* F. Muell.

Grevillea nana *C. A. Gardn.* sp. nov.

Section *Hebegyne.*

Frutex humilis, ramis elongatis, decumbentibus; foliis pinnatis, elongatis, rhachi flexuosa, subtus bisulcata, segmentis (pinnæ) 7-9, anguste linearibus, divaricatis, rectis vel curvatis apice pungentibus, glabris, supra convexis, subtus bisulcatis; racemis terminalibus, secundis, longe pedunculatis, laxifloris, rhachi dense albo-villoso; pedicellis elongatis, albo-villosis; perianthio albido, extus dense albo-sericeo, sub limbo globoso revoluto; toro plus minusve recto; glandula hypogyna late semilunari, crassa, conspicua, a toro libera; ovario sessili, albo-villoso; stylo purpureo, glabro, stigmate obliquo.

Folia usque 20 cm. longa, segmenta 1.8-4 cm. longa; racemi 8 cm. longi; pedunculi 8-9 cm. longi; pedicelli 8mm. longi; perianthium 6 mm. longum; stylus 1.8 cm. longus.

Hab. in distr. Avon inter Koorda et Bencubbin, in arenosis apertis, flor. m. Sept. *W. E. Blackall* 3380.

Affinity to *G. asparagoides* Meissn., differing in the simply pinnate glabrous and much longer leaves, and the absence of a glandular pubescence. There is a certain similarity in the leaves to those of *G. Hookeriana* Meissn., but they are pungently acute and different in other respects.

Grevillea rufa *C. A. Gardn.* sp. nov.

Section *Plagiopoda.*

Frutex rigidus, diffusus, semimetralis altus, ramis divaricatis, ramulis pubescentibus; foliis cuneato-ovatis vel cuneato-obovatis, petiolatis, sinuato-dentatis, dentibus spino-pungentibus, remotis, conspicue reticulatis, supra scabris, subtus appresso-pubescentibus, basi leviter attenuatis, apice plusminusve truncatis; racemis terminalibus, rhachi breve; pedicellis rufo-villosis, perianthio subæquilongis; floribus rufo-purpurascentibus; perianthio dense villoso, intus glabro, sub limbo ovoideo-globoso revoluto; toro valde obliquo, glandula hypogyna inconspicua, toro concavo adnata; ovario breviter sed distincte stipitato, dense rufo-villoso; stylo vix exserto, appresso-hirsuto, crasso, complanato.

Frutex circiter 50 cm. altus; folia 4 cm. longa, 2.5 cm. lata; pedicelli 1-1.2 cm. longi; perianthium ca. 1 cm. longum; stylus 1.7 cm. longus.

Hab. in distr. Coolgardie, ad fines meridionales prope Pallarup juxta Mount Short, in clivis glareosis, fl. m. Septem. 1930. *Gardner.*

Affinity to *G. insignis* Kipp. ex. Meissn., but with an indumentum of ± rufous hairs throughout, that of the flowers being a rusty red. The leaves are cuneate at the base, and vary from obovate to ovate in outline, resembling somewhat those of *G. agrifolia* A. Cunn. in shape and texture. This interesting and apparently very rare species is known only from the original locality where only two or three plants were found.

Grevillea Dielsiana *C. A. Gardn.* sp. nov.

Section *Calothyrsus.*

Frutex ramosus, circiter metralis altus, ramis ramulisque intricato-divaricatis, glabris vel sparse appresso-pubescentibus; foliis longe petiolatis, triternatis, iterum trifidis, segmentis linearibus, divaricatis, angulato-costatis, glabris, apice pungentibus; racemis paucifloris, secundis, rhachi glabra vel pauce pubescenti, pedicellis gracilibus; perianthio aurantiaco vel coccineo, sub limbo ovoideo-globoso revoluto, extus glabro, intus albo-tomentoso; toro valde obliquo; glandula hypogyna conspicua, crassiuscula, subpatelliformi; ovario glabro, stipitato; stylo elongato, glabro, viridi, disco oblique laterali.

Frutex 70-90 cm. altus; folia 4-5 cm. longa, segmenta ultima 1-1.4 cm. longa; pedicelli 6-7 mm. longi; perianthium circiter 8 mm. longum; stylus 2.5 cm. longus.

Hab. in distr. Irwin, in arenosis fruticulosis prope fluminem Murchison, *Gardner* 2590 (Typus); atque inter Indarra et Yuna, in locis similibus *Gardner.*

Affinity to *G. teretifolia* Meissn., from which it differs in the constantly trichotomously divided leaves, larger flowers and fewer flowered racemes, the oblique torus and the saccate base of the perianth, as well as in the indumentum of the inner surface of the perianth-segments.

Grevillea obliquistigma *C. A. Gardn.* sp. nov.

Section *Conogyne.*

Frutex erectus, 2-5 metralis altus, ramis ramulisque erectis, demum glabris; foliis angustissime linearibus, integris, acuminatis, supra valde convexis et uninervis, subtus profunde bisulcatis, glabris; racemis terminalibus, erectis, densifloris, cylindricis; rhachi glabra; floribus albis; pedicellis glabris; perianthio sub limbo recurvato, extus glabro, intus pilis brevibus adpressis vestito; toro recto; glandula hypogyna parva sed distincta, reniformi; ovario stipitato, glabro, stylo glabro, breviter exserto, stigmate brevi conico, obliquo, basi marginato margine membranaceo plicato crenulato.

Frutex 2-5 m. altus; folia 16-18 cm. longa, 1 mm. lata; racemi 5 cm. (cum pedunculo 8 cm.) longi; pedicelli 4 mm. longi; perianthium ca. 4 mm. longum; stylus 5 mm. longus.

Hab. in distr. Austin, inter Pindar et Wurarga, in arenosis aridis apertis flor. m. Septem. *Gardner* 2620.

I have referred this species to the Section Conogyne, although the stigma is almost that of *G. trachytheca* F. Muell., which Bentham places in the Sect. *Lissostylis,* and from which it differs in the much longer leaves, in being glabrous, and in the presence of a hypogynous gland. It is also close to *G. didymobotrya* Meissn., and *G. nematophylla* F. Muell., but differs from both in the distinctly bilateral leaves which are convex above and deeply sulcate from the closely revolute margins; in addition it differs from *G. didymobotrya* Meissn. in the presence of a hypogynous gland, in the glabrous exterior of the perianth and the much shorter and thicker style; from *G. nematophylla* it differs also in the simple inflorescence, much longer pedicles and shorter style, while the stigma separates it from both.

Grevillea candicans *C. A. Gardn.* sp. nov.

Section *Cycladenia.*

Frutex erectus, 2 m. altus, ramis erectis, ramulis sericeo-pubescentibus; foliis erectis, pinnatis, pinnis 3-5, angustissime linearibus, rigidis, supra convexis, uninervis, subtus bisulcatis, glabris, acutis, apiculo ustulato praeditis; racemis plerumque singulis, terminalibus, erectis, plusminusve laxifloris; pedunculis brevissime pilosis; pedicellis brevissimis patentibus, pilosis; perianthio albo, extus pilis brevibus vestito, intus glabro basin excepto, sub limbo ovoideo-globoso revoluto; toro recto; glandula hypogyna conspicua, annuliformi, ovario globoso, glabro, longe stipitato, non viscoso; stylo albo, elongato, leviter plano, disco obliquo laterali.

Frutex 2 m. altus; folia usque 17 cm. longa, pinnae usque 14 cm. longae, 1 mm. latae; racemi 9-11 cm. longi; perianthium 1 cm. longum, stylus 1.5 cm. longus.

Hab. in distr. Irwin ad fines septentrionales, ab Galena septentrionem circa 60 km. versus, in locis arenosis apertis, flor. m. Septem. *W. E. Blackall* 4718. Typus in Herb. Perth.

Affinity to *G. leucopteris* Meissn., differing principally in the reduced inflorescence (usually a simple raceme or very rarely 2 together), the shortly hairy perianth, fewer leaf-segments, axis of the raceme &c.

STRANGEA Meissn.

In working over some specimens in the Berlin Herbarium in August, 1937, I found a specimen of *Strangea linearis* Meissn. in fruit, which I immediately recognised as congeneric with a plant formerly known as *Hakea ? stenocarpoides* F. Muell. ex Benth., and described in this Journal xix. 79 (1933) under the name *Diplopterа stenocarpoides* (F. Muell. ex Benth.) C. A. Gardn. Still later, in January, 1940, whilst collecting at Cockleshell Gully, I saw *Strangea cynanchicarpa* in both flower and fruit, and through the courtesy of Mr. C. T. White, the Government Botanist of Queensland, I secured fruiting material of *S. linearis*. There is no doubt that the three species constitute a separate and distinct genus, but in no case have previous authors described the seed correctly. This is solitary and pendulous on a slender funicle, and together with the funicle enclosed in a 2-seriate endocarp; the inner layer of the endocarp conforms to the shape of the cavity of the follicle and entirely encloses both seed and funicle, and is in turn enveloped by an outer layer of the endocarp which is membranous but free along the outer margin. This peculiar structure was described under *Diploptera.* Meissner, when describing *Strangea linearis* referred to "an upper follicle apparently quite developed, but only beginning to split on one edge, and showing the nerviform margin of the seed which we durst not take out for fear of spoiling the specimen, the other apparently less perfectly developed although ready to split to the base into two narrow convex and rather thick valves . . . . with one single unripe blackish seed which is ten lines long, 3 lines broad, lanceolate, tapering at both ends, flat and membranous, bordered on one side with a slightly thickened nerviform margin." This description refers to the endocarp of the fruit and not to the seed itself. Mueller, in describing the same species (*S. linearis*) refers to the "wings of the testa at the apex suddenly and obliquely obtuse, at the base gradually cuspidate; the keel of the investing membrane is seen at the margin of the follicle."*

Drummond, when describing the seed of *S. cynanchicarpa* speaks of "a single seed about an inch long, shaped like the seed of the Ash, each seed being enclosed by *three* membranous coverings, the outer and inner being smooth and brown, not unlike the wings of the seed of *Hakea* and *Banksia* in substance, the middle membrane being of a light brown colour and very brittle." Mueller, in describing the seed of *Strangea cynanchicarpa* speaks of two seeds, and proceeds to describe in some detail the envelopes as the testa of the seed, and finally the seed itself as "the embryo of the consistency, taste and colour of an almond, edible, whence the seeds are called in the Colony 'Native almonds,' scarcely longer than half an inch, oval-rotund and lenticular; cotyledons extremely slenderly convex outside, the radicle included within the minute notch of the cotyledons extremely short."* The "embryo" thus described is the seed itself, and possesses a true seed testa, and is furthermore connected to the endocarpic membranes by a slender funicle. It is therefore evident that Meissner, Bentham and Mueller were unaware of the true structure of the fruit.

I have examined the fruits of the three species, the structures of which are identical.

Strangea stenocarpoides (*F. Muell.* ex *Benth.*) *C. A. Gardn.* comb. nov. (*Hakea ? stenocarpoides* F. Muell. ex. Benth. Fl. Austr., v. 511 (1870). *Diploptera stenocarpoides* (F. Muell. ex Benth.) C. A. Gardn. Jour. Roy. Soc. West. Aust. xix., 79 (1933).

This species extends from the Denmark River almost to Nannup, inhabiting gravelly stony country, flowering in December.

Strangea cynanchicarpa (*Meissn.*) *F. Muell.* Fragm. vii. 132 (1871), *Molloya cynanchicarpa* Meissn. in D. C. Prodr. xiv. 348—*Grevillea cynanchicarpa Meissn.* in Hook. Kew Jour. vii., 75 (1855)—*Fitchia cynanchicarpa* Meissn. l. c.

Descriptione addendum: Stock woody, horizontal, creeping, spreading to a diameter of 2 metres; branches erect, straight, the younger parts closely and densely tomentose-villous, becoming glabrous, the plant less than a metre high, and often only 50 cm.; leaves alternate, soon becoming glabrous, erect, linear to linear-spathulate, straight or falcate, mucronate or acute, entire or slightly toothed towards the apex, attenuated towards the base, 1-3-nerved, 5.5-9 cm. long, the secondary nerves spreading and anastomosing with the lateral primary nerves, but not conspicuous; pedicels erect, axillary and solitary in the upper axils, or in a small but dense terminal cluster, rather thick, tomentose-villous, 5 mm. long, bracteolate at the apex; bracteoles 4, free or united in the lowest third, ovate, densely ciliate; torus straight; perianth broad at the base and saccate on the upper side, green and red, becoming purple, tomentose-villous, the segments ultimately deciduous: segments irregular, the lowest segment the narrowest, and adnate for some distance from the base to the horizontal stipes of the ovary, the uppermost with a thick almost conical callosity at the point of constriction of the tube which is deflected on to the gland, limb of somewhat irregular lobes, all horned on the back near their apices, all ovate, the lateral lobes or segments irregular, the uppermost with a broad and prominent spur below the anther, absent in the others; anthers 2-celled, broadly ovate. Hypogynous gland adnate to the stipes, and forming a concave boss at the upper side of its base; stipes of the ovary thick, glabrous, almost horizontal and flattened. Ovary silky-villous, 2-ovulate: style straight, thick, the stigmatic disc broad and orbicular, slightly lateral, with a prominent conical point in the centre. Follicle erect, stipitate, oblanceolate in outline or almost narrow-elliptical, beaked, opening longitudinally along the upper margin, 2-3-ribbed on each side, after dehiscing becoming broadly cymbiform and incurved, quite glabrous.

Seed solitary, seceding from the apex of the follicle, together with two envelopes (the endocarp), the outer black and membranous, free along the outer margin, the inner enclosing the seed and indehiscent, somewhat spongy in texture; seed ovate, lenticular, with a thin brown testa, dark towards the base, pale upwards, the funicle short and erect.

On the Moore River and the great sandplain north of Diamond Spring, *Drummond* vi. 190. Near the "Diamond of the Desert" Spring, *Gardner,* 11th February, 1940; gravelly sandheaths, Mount Lesueur, *Gardner*, 13th February, 1940.

I am indebted to Mr. F. Grigson of Cockleshell Gully, who assisted me in locating this species, which is nowhere common. It has, as Drummond remarked, the habit of a *Persoonia,* and its flowers, although rather large, are inconspicuous by reason of their colour. The follicles however are conspicuous, especially in the year after seeding, when they open out almost flat.

CHENOPODIACEÆ.

Kochia thesioides *C. A. Gardn.* sp. nov.

Frutex vel suffrutex 50 cm. altus, glaber, axillae foliorum exceptæ ramis erectis, tenuibus: foliis lineari-lanceolatis, alternis, sparsis, carnosis, breviter petiolatis, planis, acuminatis, lanatis dense in axillis foliorum; perianthio fructifero sessili, glabro, fere sphaerico, apice segmentis 5 subverticalibus connatis, segmentorum marginibus lanoso-ciliatis, perianthii tubo hemi-sphaerico, alis ad apicem horizontalibus vel reflexis in membrana disciformem amplam integram coalitis siccando nigrescente.

Planta 50 cm. alta; folia usque 1.5 cm. longa; perianthium fructiferum 5.5 mm. diam., 4.5 mm. longum.

Hab. in distr. Austin inter vicos Meekatharra et Wiluna, in campis lutosis nitrosis, fruct. m. July, etiam prope Leonora, fruct. m. Septem. *Gardner.*

Affinity to *K. pyramidata* differing in the slender erect habit, in the total absence of spinescent branchlets, in being almost entirely glabrous, with acute leaves and smaller fruits with an undulate more or less reflexed wing.

AMARANTACEÆ.

Trichinium albidum *C. A. Gardn.* sp. nov.

Section *Parviflora.*

Fruticulus 30-60 cm. altus, copiose ramosus, ramulis erectis, teretibus, albo-tomentellis; foliis alternis, erectis, linearibus, sessilibus, acutis, crassiusculis, tomento adpresso brevi cinereo vestitis; spicis terminalibus, valde abbreviatis, ovoideis vel globosis, erectis, rhachi albo-tomentella; bracteis latissimo-suborbicularibus, fuscis, glabris, apiculatis; perianthii segmentis lanceolato-linearibus vel ovato-oblongis, apice acutis, glabris, ceterum extus longe albo-pilosis; interioribus angustioribus, omnibus brunneis vel viridibus et hyalino-marginatis; staminibus 5, in tubum cupulum ad basin connatis, filamentis dilatatis; squamulis intrastaminibus nullis; ovario globoso, glabro, sessili, stylo elongato.

Fruticulus 30-60 cm. altus; folia; folia 4-7 mm. longa; spica usque 1.5 cm. × 1.3 cm.; bracteae circa 3 × 4 mm.; perianthii segmenta 6.5 mm. longa.

Hab. in distr. Austin inter Meekatharra et Wiluna, in lutosis nitrosis nudis, flor. m. Jul. *Gardner* 2368.

Nearest to *T. arthrolasium* (F. Muell.) Benth., differing in the smaller and shorter spikes, the smaller sessile leaves, and in the larger flowers with relatively shorter bracts.

MIMOSACEÆ.

Acacia daviesioides *C. A. Gardn.* sp. nov.

Section *Continuæ.*

Fruticulus 30 cm. altus, ramis ramulisque valde tortilibus, intricato-divaricatis, prominenter 10-sulcatis, costis resinoso-asperatis; phyllodiis ± decurrentibus, valde recurvis, tetragonis vel sub-pentagonis, prominenter 5-nervosis, rigidissimis, acriter pungentibus, nervis scabris; capitulis pedunculatis, solitariis, axillaribus, phyllodiis aequantibus vel brevioribus, ca. 8-10 floris; floribus 4-meris; calyce tenui inaequaliter 4-5-lobato, glabro, lobis brevibus, obtusis; petalis subliberis, calycem duplo superantibus, ovatis vel ellipticis, acutis, crassis, marginibus minute fimbriolatis; ovario glabro.

Fruticulus 30 cm. altus, 60 cm. latus; phyllodia 5-7 mm. longa; pedunculi 5 mm. longi; capituli 4 mm. diam.; petala 2 mm. longa.

Hab. in distr. Irwin orientalis inter Latham et Buntine, in arenosis apertis, fl. m. Septem. *W. E. Blackall* 772 (Typus in Herb. Perth).

Affinity to *A. volubilis* F. Muell., and *A. ataxiphylla* Benth., differing from the former in the pungently acute phyllodia, more numerous ribs of the branches, shortly lobed glabrous calyx, and from the latter in the much shorter phyllodia, absence of stipules, fewer-flowered heads, and the obtusely and unequally lobed calyx.

Acacia Wiseana *C. A. Gardn.* sp. nov.

Frutex 1-3 metralis altus, ramis ramulisque prominenter sulcatis, viridibus, spinescentibus, intricato-divaricatis; phyllodiis articulatis, perpaucis, caducis, linearibus, rectis, divaricatis vel deflexis, acutis, vix pungentibus, unicostatis, planis, marginibus nervosis ad medium marginis anterioris glanduligeris; pedunculis axillaribus, patentibus, tenuibus, solitariis;

capitulis globosis, ca. 20-floris; floribus 5-meris; bracteolis lineari-spathulatis; sepalis lineari-spathulatis obtusis, sparse et breviter pubescentibus; petalis quam sepala duplo longioribus, oblanceolatis, acutis, levibus, connatis deinde liberis.

Frutex 1-3 m. altus; phyllodia 1 cm. longa, 1 mm. lata; pedunculi 1 cm. longi; petala 2 mm. longa.

Hab. in distr. Minilya prope Wandagee, in fruticetis ripariis fluminis Minilya lutosis solum, flor. m. August. *F. J. S. Wise* et *C. A. Gardner* n. 3283.

The affinity of this species is with *A. spinescens Benth.*, from which it differs in the smaller phyllodia which are rarely present, the long peduncles and more numerous flowers, in the free sepals and proportionately longer calyx. *A. spinescens* is not recorded from Western Australia.

Acacia aurea *C. A. Gardn.* sp. nov.

Section *Oligoneuræ.*

Frutex; ramulis phyllodiis junioribus pedunculisque hirsutis; phyllodiis erectis vel patentibus, obovatis, obliquis, plurinerviis, nervis crassis, prominenter reticulato-ramosis, apice mucronulatis, basi abrupte contractis, breviter petiolatis; stipulis ovatis, deciduis; pedunculis flavido-hirsutis, axillaribus, solitariis, 2-ramosis, duobus bracteis e basi ramorum secondarium; bracteis ovatis, brunneis, concavis, hyalinis; capitulis globosis, ca. 30-floris, densis, floribus 5-meris; sepalis subliberis, oblongis vel oblongo-cuneatis, obtusis, extus dense pubescentibus; petalis liberis, quam sepala vix duplo longioribus, lineari-oblongis, basin versus attenuatis, apice crassiusculis, aureo-pubescentibus.

Phyllodia usque 1 cm. longa, 5 mm. lata; petioli 1 mm. longi; pedunculi communi 1 mm. longi, pedunculi secondarii 6 mm. longi; capituli 4.5 mm. diam.; sepala ca. 1 mm. longa; petala 1.7 mm. longa.

Hab. in distr. Stirling, prope Gnarming, comm. *W. E. Blackall.*

The affinity of this species is with *A. Kingiana* Maiden and *A. deflexa* Maiden. It differs from the former in the compound inflorescence, the shape of the phyllodia, the free sepals and the petals; from *A. deflexa* it differs in the inflorescence, the shape of the phyllodia and the broader calyx-lobes.

Acacia Yorkrakinensis *C. A. Gardn.* sp. nov.

Section *Juliforæ.*

Frutex 2-3 metralis altus; ramis erectis vel patentibus, gracilibus; ramulis angulatis, pruinosis, demum brunneo-purpurascentibus, nitentibus; phyllodiis erectis, oblongis vel oblongo-lanceolatis, paulo falcato-curvatis, glaucis, apice obtusatis vel acutis, interdum oblique mucronatis, basi breviter contractis, brevissime sed distincte petiolatis, rigidis, tenuiter longitudinaliter multistriatis, costa centrale vix conspicua, marginibus prominentibus, crassis, purpurascentibus; stipulis nullis; pedunculis axillaribus vel terminalibus, binis vel racemosis precipue in partibus superioribus; spicis cylindraceis, densis, quam pedunculi aequilongis vel brevioribus; calyce late cupuliformi, extus albo-pubescenti, breviter 5-lobato, lobis obtusis, ciliolatis, demum subliberis; petalis liberis anguste oblanceolatis, acutis, calyce duplo longioribus; legumine non viso.

Phyllodia 2-5 cm. (superiora minus), usque 1.2 cm. lata; pedunculi 1-1.3 cm. longi; spicae usque 1.7 cm.; petala 2.5 mm. longa

Hab. in distr. Avon prope Yorkrakine, ca. 18 km. a Bungulla septentrionalem versus, in campis arenosis aridis, flor. m Aug. *Gardner*.

The species is very close to *A. signata* F. Muell., differing in the shorter and very much broader phyllodia which are never linear, nor have they the accuminate curved apex of the latter. It might be considered as a variety of *A. signata* but its habit, and the much shorter and broader distinctly pruinose phyllodia give it a very different appearance, and these differences are quite as distinct as those separating many other species of this large genus. The pods when obtained may possibly exhibit further differences. The lobing of the calyx is variable. In one specimen the calyx is very deeply lobed, while in another from the same locality the lobes are short and almost hemispherical. The Western Australian species of Acacia are in urgent need of revision.

CAESALPINIACEAE.

Labichea teretifolia *C. A. Gardn.* sp. nov.

Frutex densus, submetralis altus, ramis ramulisque appresso-pubescentibus, plusminusve intricatis; foliolis 3, digitatis, sessilibus, lineariteretibus, supra canaliculatis, subtus profunde unisulcatis, breviter pubescentibus, acriter pungentibus; racemis terminalibus vel axillaribus, paucifloris; bracteis ovato-lanceolatis, cymbiformibus, acutis, pubescentibus; sepalis 5, exterioribus extus sericeo-pilosis, interioribus minoribus, glabris; petalis flavis obovatis, obtusis vel retusis; staminibus 2, antheris subsessilibus, una breviori quam altera, uterque obtusis; ovario sessili, albo-villoso, 2-ovulato; stylo glabro.

Frutex submetralis altus; folia usque 1.3 cm. longa, vix 1 mm. lata; pedicelli 4 mm. longi; sepala ± 5 mm. longa; petala 5.5 mm. longa; anthera major 5 mm., minor 3.75 mm. longa.

Hab. in distr. Irwin, 60 km. a flumine Murchison septentrionalem versus, in arenosis aridis in fruticetis, flor. m. August-Sept., *Gardner* 2575.

Affinity to *L. nitida* Benth., differing in the number of leaflets which is constantly three, narrow-linear and subterete, deeply sulcate underneath, in the much smaller flowers and the 2-ovulate ovary.

Labichea eremaea *C. A. Gardn.* sp. nov.

Frutex nanus, diffusus vel caespitosus, vix 50 cm. altus, ramulis albo-pubescentibus; foliolis 5, petiolo communi brevi; stipulis parvis, subulato-setaceis, persistentibus; laminis elliptico-lanceolatis, duris, valde concavis, marginibus involutis, crassis, breviter petiolulatis, in apicem pungentem attenuatis, basin versus angustatis, prominenter uninerviis, marginibus crassis, utrinque sparse pubescentibus; floribus saepius binis in axillis superioribus, rarius solitariis; pedicellis quam foliolis brevioribus; sepalis 5, exterioribus glabris, planis; petalis obovatis, calycem subaequalibus; stamina 2, antheris inaequalibus, subsessilibus, una breviori quam altera utrisque obtusis; ovario sessili, albo-villoso, ovulis 2, stylo glabro.

Frutex vix 50 cm. altus; foliola usque 1.5 cm. longa; pedicelli 3-4 mm. longi; sepala 7 mm. longa; petala 8 mm. longa.

Hab. in distr. Austin prope Anketell, a vico Sandstone ca. 25 km. occidentalem versus, in arenosis aridis apertis, *Gardner* 2505.

Key to the Western Australian species of Labichea.

A. Anthers equal; undershrub with almost simple stems; leaves not pungently acute .. .. .. 1. L. punctata *Benth.*

B. Anthers unequal; branched shrubs with pungently acute leaflets (or leaves).

- a. Leaves pinnate with an elongated rhachis .. .. 2. L. cassioides *Gaud.*
- b. Leaves digitate or simple.
  - *α*. Sepals 4; petals 4; glabrous shrub with mostly simple leaves 3-8 cm. long, or the leaflets 3 with the middle leaflet usually the longest, all rather broad .. .. 3. L. lanceolata *Benth.*
  - . Sepals 5; petals 4 or 5; branchlets and leaves pubescent; leaflets 3 or 5, less than 2 cm. long.
    - I. Leaves narrow-elliptical or elliptical-lanceolate with involute margins .. .. .. 4. L. eremaea *C. A. Gardn.*
    - II. Leaves, terete or very slightly compressed, deeply grooved underneath .. .. 5. L. teretifolia *C. A. Gardn.*

PAPILIONACEÆ.

Gompholobium obcordatum *Turcz. var.* **pachyphyllum** *C. A. Gardn.* var. nov.

Fruticulus humilis divaricate ramosissimus, ramis ramulisque viscidissimis; foliis trifoliatis, petiolo brevissimo; foliolis parvis lato-cuneatis, retusis, glabris, crassis, supra convexis, viscosis, marginibus recurvis; stipulis minutissimis; floribus solitariis, terminalibus, pedicellatis; calyce glabro, viscoso, profunde subaequaliter 5-lobato lobis valvatis, acutis; petalis quam calyx vix longioribus, flavis; vexillo orbiculato, emarginato, alis minoribus, oblongis acutis, carina obtusa; ovario subsessili, ovato, glabro, ovulis 4, stylo incurvato, subaequilongo, crassiusculo, stigmate minuto; legumine maturo depresso-globoso, glabro, duro.

Fruticulus circa 15 cm. altus; foliola 2-3 mm. longa et lata; pedicelli 3.5 mm. longi; calyx 6 mm. longus; vexillum 6 mm. longum, 7 mm. latum, carina 6.5 mm. longa.

Hab. in distr. Avon prope Yorkrakine, in fruticetis apertis arenosis, flor. m. Decem. et Jan. *Gardner.*

Mirbelia longifolia *C. A. Gardn.* sp. nov.

Frutex erectus, 1-2 m. altus, ramulis griseo-pubescentibus, angulatis; foliis alternis, linearibus, petiolatis, exstipulatis, erectis vel subpatentibus, marginibus arcte revolutis, breviter mucronatis, supra convexis, laevis, uninervis, subtus bisulcatis; racemis terminalibus, elongatis, paucifloris, folia multo excedentibus, rhache angulato, pubescenti; pedicellis alternis, brevibus; bracteolis deciduis, verisimiliter setaceis; calyce campanulato, lobis valde inaequalibus, lobis superioribus majoribus late truncatis, ad apicem connatis, retusis vel emarginatis, lobis inferioribus ovatis, acutis; petalis flavis vexillo cuneato-orbiculare, alis dolabriformibus, carina obtusa; ovario breviter stipitato, ovoideo, glabro, 2-ovulato, stylo erecto, crasso, uncinato.

Frutex 1-2 m. altus; folia usque 4.5 cm. longa; calyx 9 mm. longus; segmenta postica 3.5 mm. longa; vexillum 9 mm. longum; alae 7 mm. longae, carina 6.5 mm. longa; ovarium cum stylo 7 mm. longum.

Hab. in distr. Avon prope Morawa, in fruticetis glareosis, flor. m. Septem. *Gardner* 2671 (Typus), necnon circa oppidulum Mullewa, in arenosis lapidosis, fl. m. August, *Gardner*.

Near *M. taxifolia*, but inter alia a much larger shrub with sparse and longer leaves, slender elongated racemes with fewer flowers and an angular rhachis closely pubescent and not villous.

Mirbelia taxifolia *C. A. Gardn.* sp. nov.

Frutex erectus, densus, ramis ramulisque cinereo-pubescentibus; foliis sparsis, raro apicem ramorum versus oppositis, linearibus, breviter petiolatis, exstipulatis, erectis vel patentibus, marginibus arcte revolutis, breviter mucronatis, supra sulcatis, viridibus, minute asperatis; racemis densifloris, terminalibus, folia multo excedentibus, rhache villosa; pedicellis brevibus, sparsis, bracteolis linearibus, dense ciliatis, acuminatis; calyce campanulato, sericeo, 5-nervis, segmentis valde inaequalibus, lobis superioribus majoribus late truncatis; petalis aurantiacis, vexillo cuneato-orbiculare, alis dolabriformibus, carina obtusa; ovario glabro, breviter stipitato, ovoideo, stylo erecto, glabro, crasso, apice uncinato; ovulis 2.

Frutex solemniter 1 m. altus; folia 1-1.7 cm. longa; calyx 9 mm. longus, segmenta postica (labium superum) 4 mm. longa, 6 mm. lata; vexillum 1.2 cm. ovarium cum stylo 8-9 mm. longum.

Hab. in distr. Coolgardie prope Karalee, in fruticetis arenosis apertis, flor. m. Septem. *Gardner*. 4875.

Affinity to *M. aotoides* F. Muell., ***M. longifolia*** C. A. Gardn. and *M. densiflora* C. A. Gardn.

Mirbelia densiflora *C. A. Gardn.* sp. nov.

Frutex erectus, densus, ramis ramulisque erectis, cinereo-vel albo-pubescentibus; foliis sparsis, densis, linearibus, erectis, breviter petiolatis, exstipulatis, marginibus arcte revolutis, breviter mucronatis, supra canaliculatis, viridibus, asperatis, subtus bisulcatis; racemis terminalibus, densifloris, brevibus, folia vix excedentibus, subspicatis, rhache villosa; floribus subsessilibus; bracteolis linearibus, dense hirsutis, acuminatis, quam flores brevioribus; calyce late campanulato, sericeo, enerve, segmentis subaequalibus, lobis superioribus ad medium connatis, omnibus acutis; petalis aurantiacis, vexillo cuneato-orbiculare, alis subaequalibus, dolabriformibus, carina breviore, obtusa; ovario subsessili, ovoideo, 2-ovulato, glabro, stylo erecto, uncinato, crasso, stigmate capitato.

Frutex 30 cm. altus; folia usque 1.3 cm longa; calyx 6.5 mm. longus, lobi 3.2 mm. longi; vexillum 10 mm. longum ac latum, alae 8.5 mm. longae, carina 7 mm.; ovarium cum stylo 6.5 mm. longum.

Hab. in distr. Coolgardie ad fines meridionali prope Young River, *Gardner* Jany. 1936.

The three species described above may be differentiated by the following key:

A. Calyx very unequal, the two upper segments united almost to the summit into a truncate or emarginate lip.

a. Racemes slender, loose, the rhachis angular and shortly pubescent: leaves 4-4.5 cm. long; shrub 1-2 metres high. .. .. M. longifolia

b. Racemes dense; rhachis not angular, densely villous; leaves 1-2 cm. long; shrub less than a metre high .. .. M. taxifolia

B. Calyx regular or almost so, the two posterior lobes united to the middle; leaves 1-1.5 cm. long .. M. densiflora

With the exception of *M. oxyclada* F. Muell., a species referred with some doubt to this genus, the three species described above differ from all other Western Australian species in the number of the ovules which is constantly two. This brings the group close to *M. reticulata* and *M. aotoides*, species restricted to Queensland and New South Wales. The habit of the plants is much like that of *Oxylobium* § *Podolobium*, but the ovary in each case is completely 2-celled when young. The character upon which *Mirbelia* is established, namely the longitudinal division of the pod into two cells is not always readily observable in flowering specimens. In *M. dilatata* and *M. floribunda* it is at once apparent, but in most of the other Western Australian species the partial intrusion of the false dissepiment from either one or both sutures is often very imperfect and easily overlooked. The development of this false dissepiment requires further study. In *M. racemosa* Turcz., for example, it is entirely absent, and what was described as such by Turczaninow and Bentham is in reality a development of cellular tissue characteristic of *Callistachys* and some species of *Oxylobium*, e.g. *O. graniticum*. *M. racemosa* is in fact a true *Oxylobium*, and was described by the author under the name *Oxylobium Bennettsii* in this Journal. The type species has been matched with the type number of *Mirbelia racemosa* at Kew, and the two are identical.

Oxylobium racemosum (*Turcz.*) *C. A. Gardn.* comb. nov.

(*Mirbelia racemosa* Turcz.: *Oxylobium Bennettsii* C. A. Gardn.)

Mirbelia seorsifolia (*F. Muell.*) *C. A. Gardn.* comb. nov.

The pod of this plant is typical of *Mirbelia*. Mueller described the ovules as being two in number, but in reality 4 and 6 ovules are commonly present. The species had already been regarded as an anomalous *Gastrolobium*.—*Gastrolobium seorsifolium* F. Muell.

Gastrolobium pauciflorum *C. A. Gardn.* sp. nov.

Section *Axillares.*

Frutex divaricate ramosus, ramis teretibus, junioribus cano-pubescentibus; foliis oppositis, petiolatis, obovatis vel lato-oblanceolatis, obtusis acutis vel mucronatis, subplanis, glabris, glaucis, rigidis, coriaceis, prominenter pallide reticulatis; stipulis setaceis, fuscis; floribus 1-3, axillaribus, breviter pedicellatis; bracteolis parvis, rigidis, cuneatis, tridentatis, pubescentibus, pedicelli excedentibus; calyce dense sericeo-pubescente, lobis quam tubus brevioribus, 2 superioribus truncatis vel emarginatis, latioribus; petalis quam calyx vix duplo longioribus, vexillo flavo, latissimo emarginato, alis vix brevioribus, carina purpurascenti obtusissima; ovario longe stipitato, dense villoso, 2-ovulato, stylo falcato, lateraliter compresso, glabro.

Frutex forsan 50 cm. altus; folia usque 2 cm. longa, 8-10 mm. lata; petioli 3 mm. longi; pedicelli 2-3 mm. longi; calyx 5 mm. longus; vexillum 1 cm. longum ac latum.

Hab. in distr. Irwin, ca. 9 km. a Three Springs occidentalem versus, in fruticetis apertis arenosis, fl. m. Septem. *W. E. Blackall* 4895.

Affinity to *G. obovatum* Benth., differing in the flat, not complicate leaves, fewer-flowered clusters without any evident peduncle, the shorter pedicels etc. The flowers are frequently solitary in the axils.

Gastrolobium Bennettsianum *C. A. Gardn.* sp. nov.

Section *Racemosæ.*

Frutex erectus vel patens, 1 m. altus, ramis ramulisque angulatis, cinereo-puberulis; foliis ternis vel oppositis, breviter petiolatis, oblanceolato-complicatis, apice recurvatis, obtusis, pungento-mucronatis, coriaceis, glaucis, erectis; stipulis setaceis, firmis, petiolo aequilongis; racemis terminalibus vel axillaribus, folia multo excedentibus, densi-floris, rhache puberula; bracteolis ovato-lanceolatis, obtusis; calyce parce pubescente, segmentis posticis altius connatis; vexillo reniforme-orbiculare, alis obtusissimis carina aequilongis; ovario anguste-ovoideo, villoso, stipitato, stylo incurvo, lateraliter compresso, inferne villoso, ceterum glabro.

Folia 2 cm. longa; stipulae fuscae, 2-2.5 mm. longae; racemi 4-5 cm. longi; pedicelli 1-1.5 mm. longi; ovarium 2 mm. (stipes 2.5 mm. excepta); stylus 1 mm. longus.

In collibus glareosis regionis *Eucalypti reduncae* distr. Avon proprium. Adest ad Yorkrakine prope Tammin meridiem versus ad usque Wagin, fl. m. Septem. Typus est North Bungulla, *Gardner* Sept. 1936.

Collegae assiduo in herbis venenatis investigandis, excellentissimo viro Haroldo Gulielmo Bennetts, scientiae veterinaris doctori, gratissimo dedicatum.

This species has a close affinity to *G. microcarpum* Meissn., and *G. floribundum* S. Moore. It differs from both, however, in the recurved apex of the leaf which is furthermore distinctly pungently mucronate. In this respect it closely resembles *G. obovatum* Benth., with which it might easily be confused when not in flower or fruit, but in *G. obovatum* the leaf is always acute or acuminate. From *G. microcarpum* and *G. oxylobioides* Benth. it differs in the complicate leaves, as well as in the shape of the leaf blade which does not taper to the apex. The leaf texture, and a cross section of the same is much like that of *G. floribundum*, but the shape, as well as the floral characters are quite different.

The species is common throughout the area of its habitat which extends eastwards to Kondinin, and it appears to be constantly associated with gravelly hills and rises, usually in association with *Eucalyptus redunca* var. *elata*. In common with the other species of the § *Racemosae* it is highly toxic to both sheep and cattle.

Gastrolobium glaucum *C. A. Gardn.* sp. nov.

Section *Racemosæ*.

Frutex erectus vel diffusus, 50 dm. altus; ramis ramulisque vix angulatis, cinereo-pubescentibus demum glabrescentibus; foliis ternis, subsessilibus aut brevissime petiolatis, late obovatis, coriaceis, conspicue retinervis, planis, obtusis, glaucis, pungento-mucronatis, ad basin obtusis, costo centrale subtus valde prominente; stipulis setaceis, fuscis; racemis terminalibus, pluri- et densifloris, villosis, folia multo excedentibus; bracteolis lanceolatis, deciduis; pedicellis villosis; calyce pubescente, segmentis posticis altius connatis, emarginatis, ceteris ovato-deltoideis; vexillo reniforme-orbiculare, alis acutis vel subobtusis, carina excedentibus; ovario ovoideo, villoso, longe stipitato; stylo compresso, glabro, ovulus 2.

Folia usque 2 cm. longa et 1.2 cm. lata; stipulae 4 mm. longae; racemi spiciformi, 2-3 cm. longi; pedicelli 1.5 mm. longi; calyx 4-5 mm. longus, lobi postici vix 2 mm. longi, reliqui 1-1.5 mm. longi; ovarium 2 mm. longum, stipes 2 mm.; stylus 2 mm.

In distr. Avon prope Wongan Hills, in arenoso lutosis apertis, flor. m. August-Septem. *Gardner* Sept. 1924.

Closely related to *G. rotundifolium* Meissn., from which it may be distinguished by the flat, not undulate, very glaucous leaves, which are widely obovate with dark-coloured points, the conspicuous reticulations, the very deciduous bracteoles, the united and obtuse posterior calyx lobes and the long stipitate ovary. The species is toxic to stock.

RUTACEÆ.

Phebalium lineare *C. A. Gardn.* sp. nov.

Frutex semimetralis altus; ramulis erectis, lepidotis, non glandulosis; foliis linearibus, erectis, planis, crassis, apice obtusis, basin versus sensim angustatis, breviter petiolatis, glabris vel minute et parce lepidotis; pedunculis axillaribus, solitariis, erectis, sursum clavatis, bracteolis 2 lanceolato-subulatis praeditis; floribus albis; calycis dentibus deltoideis, erectis vel patentibus, parvis; petalis valvatis, ovato-oblongis, obtusis, extus lepidotis, intus glabris, crassis; filamentis quam petala dimidio brevioribus, albis, lanceolatis, crassis, apice subulatis; carpidiis glabris.

Frutex 50 dm. altus; folia usque 2.5 cm. longa; pedunculi 5 mm. longi; petala 4-5 mm. longa; filamenta 2-2.5 mm. longa.

Hab. in distr. Eyre, ad montem Ragged prope Israelite Bay, in lapidosis fruticetis, flor. m. Oct. *Gardner* 2864.

Affinity to *P. rude*, differing in the entire linear leaves.

Phebalium ambiguum *C. A. Gardn.* sp. nov.

Fruticulus humilis semimetralis altus, caulis erectis, ad ima basi ramosis, cortice lepido tectis, teretibus, ramis ramulisque erecto-patentibus, lepido-stellatis; foliis linearibus, brevissime petiolatis, approximatis, coriaceis, supra scabriusculis vel asperatis, obtusis, marginibus arcte revolutis, enerviis, subtus lepido-stellatis; floribus solitariis, terminalibus sessilibus; calyce parvo, breviter dentato, patente; petalis ovato-oblongis, obtusis, extus lepidotis; filamentis glaberrimis, linearibus, petalis brevioribus; carpidiis lepidotis.

Microcybe pauciflora var. *uniflora* D. A. Herbert.

Fruticulus 50 dm. altus; folia 4·5 mm. longa.

Hab. in distr. Coolgardie, prope.

Carrabin, in arenosis lutosis, fl m. Oct. Gardner; pr. Yellowdine, W. E. Blackall 1937, pr. Hatter's Hill, Blackall 1867; in distr. Avon juxta Ballidu in fruticetis, Gardner.

With the habit and appearance of a *Microcybe,* with which it might easily be at first sight mistaken, this species, together with the following, are distinguished from all other Western Australian species by the solitary sessile or subsessile flowers.

Phebalium clavatum *C. A. Gardn.* sp. nov.

Frutex erectus, circiter 1 m. altus, pluri-ramosus, ramulis foliosis, sparse glanduloso-tuberculatis, dense argenteo-lepidotis; foliis late et obtuse clavatis, valde obtusis, petiolatis, dense lepidotis, glandula minuta terminale praeditis; floribus albis, solitariis, sessilibus; calyce parvo, acute 5-dentato, dentibus erectis, tubo subaequalibus vel longioribus; petalis leviter lateraliter imbricatis, extus dense lepidotis; staminibus subaequalibus, subexsertis, filamentis tenuibus; carpellis 5, ovoideis, obtusis, dense stellato-lepidotis.

Frutex circ. metralis altus; folia 3-4 mm. longa; calyx 2.5 mm. longus ac latus; petala 4 mm. longa.

Hab. in distr. Coolgardie, in arenoso-lutosis, prope Widgiemooltha, flor. m. November. *Gardner.*

MUIRIANTHA C. A. Gardn. nom. nov.

Mueller, in 1887, described under the name *Chorilaena Hassellii,* a plant collected by A. Y. Hassell from the west end of the Stirling Range. This was raised by me to generic rank in this journal xix., 83 (1933), under the name of *Muiria Hassellii* (F. Muell.) C. A. Gardn. A short time before this, however, N. E. Brown bestowed the name *Muiria* on an Aizoaceous plant, so that a new name has to be found for the local genus, and the name Muiriantha is here proposed. The description will be found under the reference quoted above.

EUPHORBIACEÆ.

Euphorbia boöphthona *C. A. Gardn.* sp. nov.

§ *Eremophila.*

Herba perennis, radice crasso, contorto, albo-corticato; caulibus dichotomo-divaricatis, glabris, lactiferis; foliis lineari-lanceolatis vel linearibus, acutis, remote et acute denticulatis, in petiolis brevibus attenuatis, inferioribus alternis, superioribus oppositis vel quasi oppositis, omnibus plusminusve caducis; stipulis nullis; cyathiis axillaribus, solitariis vel binis, breviter pedunculatis vel subsessilibus; pedunculis non articulatis; glandulis 4 vel. 5, latis, exappendiculatis; ovario glabro, laevi, stylis brevissimis, crassis, biramosis; fructibus subglobosis, trilobis, laevibus, seminibus cylindraceis, dense sclero- et albo-papillosis; carunculo magno, pileiforme, margine discoideo, sub semine constricto.

Planta 16-20 cm. alta; folia usque 3.5 cm. longa, 5 mm. lata; cyathium vix 2 mm. longum; stipes 4 mm.; fructus 6 mm. longus; semina 4.5 mm. longa, 2.75 mm. lata, carunculus 1.7 mm. latus.

Species eremaea Australiae occidentalis aream amplam occupavit in locis alluviis lutosis (quos dicunt "Creeks") e.g. Jimba Jimba ad fluminem Gascoyne River, *Gardner* n. 3302 (Typus); a Cue occidentalem versus prope "Stock Route," in locis similibus *Gardner;* a Laverton orientalem versus Warburton Range, *E. de C. Clarke*, fruct. m. July-August.

The affinity of this species is with *E. clutioides* Forst., from which it can be distinguished at once by its lower more widely and dichotomously branched habit, by its acute leaves, and by the seeds which are densely covered with large hard and white papilla-like excrescences narrowed towards the base, and, furthermore, the caruncle is almost hat-shaped, and its lower disciform end is separated from the seed by a short and narrow stalk or constriction.

Euphorbia boöphthona is a cyanogenetic plant toxic to stock, especially hungry travelling stock, and has accounted for the death of thousands of sheep and cattle in the Gascoyne and Murchison districts, especially in the vicinity of Jimba Jimba, the Lyons River, and in places north-west of Cue.

Euphorbia clutioides (*Forst. f.*) *C. A. Gardn.* comb. nov.

(*Croton clutioides* Forst. f. Prodr., 92 (1786).)

(*Euphorbia tannensis* Spreng., Fl. Hal. Mant. 42 (1807).)

(*E. Vieilardi* Baill. Adansonia ii. 212 (1862).)

(*E. eremophila* A. Cunn ex Hook. in Mitch. Trop. Austr. 348 (1848).)

Its range extends from the Island of Tanna in the New Hebrides to Western Australia, embracing New Zealand and the northern half of Australia. *E. boöphthona* is so far only known from Western Australia, but it appears probable that its range will be found to extend into Central Australia. *E. clutioides* does not appear to be toxic to stock.

Key to the species of the Sect. *Eremophila* occurring in Western Australia.

A. Seed smooth or covered with minute whitish tubercles; caruncle embracing the end of the seed.
- a. Involucral glands fimbriate-ciliate, prominent; seeds smooth; leaves acute .. E. Finlaysoni *J. M. Black.*
- b. Involucral glands entire, broad, inconspicuous; seeds granular rugose or nearly smooth; leaves mostly obtuse .. E clutioides (*Forst. f.*) *C. A. Gardn.*

B. Seeds prominently sclero-papillose with elongated club-shaped white excrescences; caruncle separated from the seed by a thin but distinct stalk; involucral glands exappendiculate .. .. E. boöphthona *C. A. Gardn.*

E. Stevenii Bail., has not yet been recorded from Western Australia. It belongs to the above Section.

RHAMNACEÆ.

Cryptandra grandiflora *C. A. Gardn.* sp. nov.

Frutex ramosissimus, ramis divaricatis, ramulis novellis appresso-pubescentibus, demum glabris; foliis plusminusve subfasciculatis, oblongis vel oblongo-obovatis, petiolatis, basin versus sensim angustatis, apice obtusis, mucronulo recurvo praeditis, novellis complicatis, dense sericeo-pubescentibus, adultis supra olivaceis et glabrescentibus, subtus sericeo- et appresso-pubescentibus; stipulis setaceis demum deciduis; floribus albis, in pseudo-capitulis terminalibus aggregatis; bracteis ovato-orbicularibus vel late obovatis, obtusis vel retusis, mucronatis, marginibus ciliatis, quam tubum calycis brevioribus; bracteolis spathulato-obovatis bracteis subaequantibus, toto dorso piloso; calycis tubo anguste campanulato, extus paucis pilis tenuis sericeis adpressis, lobis angusto-triangularibus, acutis, intus glabris et prominenter carinatis; petalis unguiculatis, cucullatis; disco angusto, annulari minute pubescente; ovario vertice albo-piloso; stylo crasso, quam calyx breviore.

Frutex forsan metralis altus; folia 6-15 mm. longa, majora in ramulis novellis; bracteae bracteolaeque usque 5 mm. longae; calyx 6-7 mm. longus, lobi circ. 2.5 mm. longi; petala .75 mm. longa.

Hab. in distr. Irwin ab Carnamah occidentalem versus, fl. m. Sept. *E. M. Barker*, per *W. E. Blackall.*

Affinity to *C. leucophracta,* differing in the larger leaves, larger and shortly but distinctly pedicellate flowers which are more numerous in the cluster, in the vestiture of the calyx which consists of fine silky hairs, and the longer and more acute calyx-lobes.

BLACKALLIA *C. A. Gardn.* gen. nov.

Calyx urceolatus vel ovoideus, tubo ultra discum longe producto, lobis 5, connatis, erectis, acutis; petala 5, breviter stipitata, in ore calycis inserta, cucullata; stamina 5, cum petalis inserta, filamentis breviter liberis; antherae versatiles, oblongae, rimis 2, longitudinaliter dehiscentibus discus hypogynus fundo tubi calycis adnatus, annularis, margine libero, integro vel sinuato; ovarium ovoideum vel obovoideum, fundo calycis rectum breviter attenuatum, stigmate 3-lobo. Capsula ovoidea vel cylindracea, libera, coriacea, 3-valvis, coccis crustaceis; semina erecta, cylindracea; funiculo crasso-turbinato vel subcupulato insidentia.

Frutices ramosissimi, ramulis alternis, spinescentibus; folia fasciculata, parva, stipulae fuscae, parvae, flores in ramulos breves subracemosi vel fasciculati, breviter pedicellati; bracteae imbricatae flores cinctae vel nullae.

Amicissimo clarissimoque viro, Gulielmo Edwardo Blackall, scientiae medicinae doctori, novum hoc genus dedico; qui socius humanissimus et collega de rebus Australiae occidentalis botanicis maxime eruditus, saepe saepius partes huius regionis incultas mecum peragrinavit.

A genus closely related to Cryptandra, of which it has many of the characteristics, but the completely superior ovary and the small annular free-margined disc are characters of the Tribe *Colletieae,* of which *Blackallia* is typical except that the branchlets and leaves are alternate and not opposite. It is close to *Discaria,* differing in the erect ± connate calyx-lobes, the capsular fruit, as well as in the arrangement of the branchlets and leaves. The calyx does not appear to spread its lobes, which in all the specimens examined are ± connate and erect.

1. **B. connata** (*C. A. Gardn.*) *C. A. Gardn.* comb. nov.

(*Cryptandra connata* C. A. Gardn. in Jour. Roy. Soc. West. Austr. xxiv. 80. (1928).)

Additional localities are—Near Payne's Find, *W. E. Blackall;* between Lawlers and Sandstone *Gardner.*

2. **B. biloba** *C. A. Gardn.* sp. nov.

Frutex 30 cm. altus, ramis divaricatis, ramulis alternis spinescentibus; foliis fasciculatis, lineari-cuneatis, basi attenuatis, apice bilobatis, lobis obtusis, glabris, supra concavis vel plusminusve complicatis, glabris; floribus singulis vel fasciculatis e fasciculi foliorum, longe pedicellatis; bracteis nullis; calyce gabro, cylindrico, basi saccati, lobis deltoideis, acutis, erectis, petalis subsessilibus, cucullatis, calycis limbi semi-aequantibus; disco tenuo glabro; ovario glabro, obovoideo, stylo recto, minute trilobato.

Frutex 30 cm. altus; folia usque 6 mm. longa, 1.5 mm. lata; pedunculi 4 mm. longi; calyx 5 mm. longus, lobi vix 2 mm.

Hab. in distr. Irwin inter vicum Northampton et Lynton, flor. m. Sept. *W. E. Blackall* 4517.

Differs from *B. connata* in the long pedunculate flowers, the absence of bracts, narrower and entirely glabrous calyx, and in the shape of the leaves.

MYRTACEÆ.

Eugenia Stokesii *C. A. Gardn.* sp. nov.

Arbor 7-10 m. alta, glabra, ramulis teretibus; foliis ovato-oblongis vel ellipticis, petiolatis, basin versus attenuatis, apice obtusis vel subacutis, crassis, rigidis, glaucis, irregulariter penninervis, vena intramarginali ab margine remota, nervis secondariis reticulatis; cymis axillaribus, pauci-(4-7-) floris; calyce campanulato, lobis plusminusve inaequalibus, late hemisphaericis, persistentibus, marginibus tenuibus, tubo supra ovarium in disco concavo staminifero producto; petalis orbicularibus, albo-marginatis, delapsis singulis; staminibus quam petala longioribus; ovulis circiter 10.

Arbor 7-10 m. alta; folia 7-12 cm. longa, 5-6 cm. lata; petioli 4.6 mm. longi; pedicelli 3 mm. longi; calyx 1 cm. longus; petala 9 mm. longa, 10-11 mm. lata.

Hab. in regione tropica ad Weber Range, ad finem orientalem teritorii Australiae occidentalis, flor. m. July, *S. J. Stokes* n. 51. Boundary Survey of Western Australia, 1937.

Affinity to *E. pendens* Duthie, but with glaucous thick broader and obtuse leaves, the calyx-lobes not reflexed after flowering but remaining erect, short pedicels and campanulate calyx. Among its Australian congeners it is closest to *E. myrtifolia* Sims, but the leaves are much broader and with much coarser venation, and the calyx-lobes are very obtuse.

Eucalyptus megacornuta *C. A. Gardn.* sp. nov. (§ *Cornutae*).

Arbor 7 metralis alta, ramis erecto-patentibus, cortice laevi, cinereo-brunneo; foliis primariis non visu: foliis ordinariis alternis, oblongo-lanceolatis, concoloribus, nitenti-viridibus, petiolatis, acuminatis vel obtusis, venis secondariis inconspicuis, vena intramarginali juxta margini; pedunculo elongato, pendulo, lorato, apicem versus incrassato, flores 2-3 sesisles gerente; calyce elongato-campanulato, apicem versus dilatato, multo-costato; operculo cylindrico, verrucosissimo, obtuso, quam calyx duplo longiore, basi abrupte dilatato: staminibus multi-seriatis, viridibus, erectis vel flexuosis, filamentis quadrangulatis, glandulosis; antheris longitudinaliter dehiscentibus; fructu magno, campanulato vel hemisphaerico-campanulato, rugoso-costato, margine angusto; disco hemisphaerico-depresso, striato, valvis crassis, inflexis, leviter exsertis.

Folia usque 8 cm. longa, 2.5 cm. lata (petiolus 1 cm. lamina 7 cm.); pedunculus usque 4 cm. longus, 1.7 cm. latus; calyx 3 cm. longus, 2.2 cm. latus; operculum 5 cm. longum, ad basin 2 cm. latum; fructus 3.5 cm. longus, 3.2 cm. latus.

Hab. in distr. Coolgardie ad fines australes prope Ravensthorpe septentrionem versus in clivis glareosis, flor. m. November, *Gardner*.

This species is very close to *E. Burdettiana* Blakely, differing in its arborescent proportions, its widely branched habit, much larger buds and flowers, the markedly verrucose and broadly dilated operculum, the larger costate fruits, and the broader leaves. *E. Burdettiana* is a small mallee inhabiting the quartzite hills of the south coast, between Hopetoun and the Fitzgerald River. It rarely exceeds 2 metres in height, and becomes smaller towards the western limits of its habitat. The fruits of *E. Burdettiana* are much smaller than those of *E. megacornuta*, smooth or unicostate, and almost spherical. It is very close to *E. cornuta*.

Eucalyptus erythrandra *Blakely*.

In this Journal xix 88 (1933) I described as a new variety of *E. angulosa* Schau (var. *robusta*), a plant collected by H. Steedman near Kundip. I have since received, through the Conservator of Forests, specimens of this plant collected by Mrs. Daniells of Hopetoun which exhibit a perfect series embracing on the one hand *E. tetraptera Turcz.*, and *E. angulosa* Schau. on the other. Amongst the intermediate forms is typical *E. erythrandra*, which I consider to be a hybrid. The evidence in favour of this theory is quite clear.

Eucalyptus Brockwayi *C. A. Gardn.* sp. nov.

Arbor 25 metralis alta, cortice laevi, albo vel salmoni-colorato, deciduo, ramulis acutangulis; foliis alternis, coriaceis, falcato-lanceolatis vel lineari-lanceolatis, concoloribus, utrinque nitentibus, punctatis, venis lateralibus pennato-patentibus, vena intramarginali a margine remota; umbellis axillaribus vel lateralibus, solitariis, patentibus; pedunculo leviter compresso; pedicellis brevibus angulosis vel subteretibus, calycem multo brevibus; tubo calycis paene brevicylindrico, ad basin obtusissimo; operculo hemisphaerico vel late ovoideo; staminibus ante expansionem inflexis; stylo recto; fructu parvo, ecostato, urceolato-globoso, apice contracto, margine elevato; valvis profunde inclusis; seminibus fertilibus subovatis, compressis, laevibus, nigrescentibus.

Folia usque 10 cm. longa, 1.2 cm. lata; pedunculis 1 cm. longis; pedicellis 1 mm. longis; calycis tubus 4 mm. longus; operculum 1.7 mm. longum; fructus 6 mm. longus, 5 mm. diametrus.

Hab. in distr. Coolgardie, prope Norseman, in eucalyptetis lutosis, *G. E. Brockway* et *C. A. Gardner*. 15. Decem. 1940 n. 5598.

Affinity to *E. ovularis* Maiden, differing in the venation of the leaves, the much shorter pedicels, the very obtuse operculum and globular-urceolate fruits. The fruit is much like that of *E. Flocktoniae* Maiden, but the operculum is very different. It is probably also close to *E. Cooperiana* F. Muell. An examination of the immature anthers indicates that the species may belong to the § *Platyantherae*, but this is not certain. It is also not always possible to clearly define the species of this Section, since in some there is a definite approach to the § *Macrantherae*. The anthers as seen are short, and the dehiscence appears to be by wide lateral slits, but in the absence of flowering material I think it is perhaps best to group this species, together with *E. ovularis* and *E. Flocktoniae* in the § *Platyantherae*.

The species, which attains a height of 80 feet, has a perfectly smooth salmon-coloured or whitish bark which in fracture is blood-red and gummy. It is fairly high in tannin. The heartwood is reddish like that of *E. salmonophloia*, and the two trees look much alike in the field. The species is named out of compliment to George Ernest Brockway, Divisional Forests Officer at Kalgoorlie, whose collections of Eucalyptus in his district, and the interest he has taken in the trees of the area, have added much to our knowledge of the genus Eucalyptus in eastern areas.

Eucalyptus brachyphylla *C. A. Gardn.* sp. nov.

Arbor parva, cortice aspero persistente in parte trunci inferiore, deinde in ramis laevi et deciduo, ramulis pruinosis, teretibus; foliis oppositis, breviter sed distincte petiolatis; laminis ovatis vel ovato-lanceolatis, breviter acutis, basi obtusis, glaucis, punctatis, venis lateralibus obscuris, vena intramarginale a margine valde remota; umbellis paucifloris (5-7) axillaribus vel in paniculas breves terminales et laterales collectis; pedunculis tereti-compressis, pedicellos longitudine excedentibus; alabastris obovoideis, apiculatis vel rostrato-acutis, longitudine pedicellorum vel longioribus; calycis tubo longitudine operculi vel longiore; fructibus cylindraceis, ecostatis, truncatis, apici vix constrictis, marginibus tenuis, quadrilocularis; valvis profunde inclusis, deltoideis.

Arbor altitudine 4 m., cortex in laminis duris secedens; folia pleraque 3-4 cm. longa, usque 2.5 cm. lata; pedunculi 1 cm. longi; pedicelli 3 mm. longi; operculum (in statu immaturum) 2.5 mm. longum; fructus 5 mm. longus, 3.5 mm. latus.

Hab. in distr. Coolgardie, prope Lake Cowan occidentalem versus, juxta Binyarinyinna, *G. E. Brockway*, July, 1940.

Near to *E. Kruseana* F. Muell., with which it is associated, differing in the distinctly petiolate ovate to ovate-lanceolate rather acute and larger leaves, and in the longer and differently shaped fruits which are not, or very slightly constricted at the summit.

Eucalyptus Formani *C. A. Gardn.* sp. nov.

Arbor 10 m. alta, cortice cinerascente, rugoso, in trunco ramisque persistente, ramis ultimis laevis; foliis primariis erectis, augusto-linearibus, crassis, fere semiteretibus, glaucis vel pruinosis, uncinato-acuminatis valde punctatis, utrinque subcanaliculatis; foliis ordinariis angusto-linearibus, rectis vel leviter falcato-curvatis, erectis, distincte petiolatis, apice uncinato-acuminatis, costa centrale utrinque impressis, ceteris enerviis, viridibus, glanduloso-punctulatis; umbellis axillaribus, 5-8-floris; pedunculo tenuo, apicem versus incrassato; pedicellis semiteretibus, quam alabastrum brevioribus; calyce hemisphaerico-turbinato, glanduloso, quam operculum conicum acuminatum breviore; filamentis inflexis, antheris parvis, orbicularibus (maturis non visibus); fructu globoso-hemisphaerico, laevo, margine elevato, disco concavo, valvis deltoideis, inclusis.

Folia primaria 3-3.5 cm. longa, .75 mm. lata; folia ordinaria 5-7 cm. longa, 2 mm. lata, raro 3 mm. lata; pedunculus 8 mm. longus; pedicellus 3.5-4 mm. longus; calyx 2 mm. longus; operculum 3-4.5 mm. longum; fructus 4.5 × 2.5 mm.

Hab. in distr. Coolgardie ad fines boreali prope "Die Hardy Range," a vico Southern Cross, 175 km. septentrionem versus in fruticetis apertis arenosis, *F. G. Forman* et *R. S. Matheson*, July, 1940.

Although flowers have not been seen, this species can be definitely assigned to the §*Platyantherae*. It is close to *E. Kochii* Maiden & Blakely, but is a fairly large tree with the bark of E. longicornis *F. Muell.;* the leaves however are narrower and conspicuously oil-dotted with a ± impressed midrib, the peduncle is more slender and elongated, the calyx much shorter and hemispherical-turbinate, and the operculum elongated ovoid-rostrate or ± acutely conical with an erect beak which however is variable in length. The fruit is not as long as broad, and the deltoid valves are not exserted. The primary leaves are quite unlike anything known in the genus, being almost terete.

This species commemorates the name of Francis Gloster Forman, Government Geologist of Western Australia, who brought me the first specimens of this plant.

Eucalyptus orbifolia *F. Muell.*

I have received from Mr. G. E. Brockway, Divisional Forests Officer at Kalgoorlie, through the Conservator of Forests, (S. L. Kessell, Esq.), complete material of this species from the Hospital Rocks (West of Mulline), and from Pigeon Rocks north of Bullfinch. Considering the interest that has surrounded this long lost species, of which only the small type specimen in the Kew Herbarium was previously known, the re-discovery of the species is of exceptional interest. The following description is taken from Mr. Brockway's specimens:—

Mallee, attaining a height of 25 feet, although usually about 18 feet high (Brockway); stems 5-6 cm. thick, with a warm red flaky striated thin persistent bark with decorticates leaving a pale green bark between the strips, heartwood pale red, closely grained. Branchlets reddish-pruinose, terete. Leaves alternate, broadly obovate-orbicular, shortly tapering at the base into a slender petiole of 1.5-2 cm., the lamina 3-7 cm. long and about of equal breadth or even broader, obtuse to retuse, glaucous, rather prominently veined, the secondary veins roughly parallel but remote, the intramarginal vein distant from the margin. Peduncles axillary or lateral, erect-spreading, straight, pruinose or reddish, slightly 2-angled, slightly thickened towards the apex, 1.5-2.5 cm. long, bearing an umbel of from 2 to 5 flowers; pedicels thick, subterete, 5-9 mm. long, divaricate; calyx-tube almost hemispherical, but shortly tapering into the pedicel, 5 mm. long, and 8 mm. broad; operculum hemispherical-conical, not much longer than the calyx-tube, usually about as long, longitudinally striate, the striae not very conspicuous, glaucous, as well as the calyx and pedicel; stamens pale yellow, numerous, the filaments flexuose in the bud, 5-6 mm. long; anthers ovate, opening outwards in longitudinal slits, the gland small, dorsal; style thick, conical, thicker than in any other species observed. Fruit hemispherical-campanulate, 1 cm. long, 1.7 cm. broad, smooth or striate, pruinose-glaucous, the disc broad and flat, the valves subulate-deltoid, prominently exserted; seeds black, triangular-cuneate, not winged. *E. Websteriana* Maiden, is very close to this species, and perhaps a variety only.

Baeckea leptospermoides *C. A. Gardn.* sp. nov.

Frutex erectus, metralis altus, glaber, ramulis strictis, erectis, teretibus; foliis erectis, petiolatis, oblongis, crassis, planisque, obtusis, basi breviter contractis rotundis, petiolis tenuibus; floribus solitariis, albis; pedicellis axillaribus, quam folia multo longioribus; bracteolis 2, late ovatis, acutis, carinatis, a medio pedunculi insertis; calyce late cupuliformi, lobis quam tubum brevioribus, semiorbicularibus, marginibus tenuibus, albis; petalis quam calycis tubum triplo longioribus, orbicularibus, albis; staminibus 25, annulo undulato disco margine sinuato insertis, lobis disci extra stamines processus subulatos gerentibus, aliqui staminibus regulariter dispositis, subaequis, quam petala duplo vel triplo brevioribus, filamentis teretibus, tenuibus, incurvis, antheris dorsifixis, longitudinaliter dehiscentibus, glandula albida, conspicua, globosa, quam anthera dimidio vel breviore; ovario triloculari, ovulis numerosis, placentam peltatam affixis, stylo brevi, filamentis aequante.

Frutex 1 m. altus; folia usque 5 mm. longa; calycis tubus 4.5 mm. longus ac latus. lobi 1.5 mm.; petala 4 mm. diam.

Hab. in distr. Coolgardie prope Karalee, in fruticetis arenoso-glareosis, flor. m. Sept. *Gardner.* (Typus.) Prope Merredin, *E. H. Wilson* et *D. A. Herbert.*

Affinity to *B. crassifolia* var. *icosandra,* F. Muell, differing in the number of stamens and the lobed staminal disc which bears about 20 setae or subulate processes external to the stamens opposite each petal. In this latter respect it resembles *B. Maideni* Ewart and White.

Astartea clavifolia *C. A. Gardn.* sp. nov.

Frutex metralis altus, glaber, multi-ramosus, ramulis erectis, densis; foliis ovato-clavatis, leviter compressis, distincte petiolatis, apice basique obtusis; floribus axillaribus, pedicellatis, calycis tubo turbinato, laevo, lobis suborbicularibus; petalis quam lobi calycis fere triplo longioribus, orbicularibus, roseo-albis; phalangibus distinctis, circiter 8-antheras gerentibus, apicem versus attenuatis; filamentis brevibus, tenuibus, plusminusve incurvis; antheris ovatis, longitudinaliter dehiscentibus; disco lato, concavo; ovario 2-loculato, ovulis in loculis 6, in annulum lateraliter dispositis.

Frutex metralis altus; folia 1.5-2.5 mm. longa, usque 1.2 mm. lata; petioli .5 mm. longi; pedicelli 2 mm. longi, a medio articulati; bracteoli 1.3 mm. longi; calycis tubus 2.5 mm. longus, lobi 1 mm. longi; petala 2.5 mm. diam.

Hab. in distr. Avon prope Maya, in lutosis arenosis, flor. m. Septem. *Gardner* 2704.

Affinity to *A. clavulata* Turcz. and *A. fascicularis* (Labill.) D. C., differing in the 2-celled ovary, the much shorter and broader clavate leaves which are never clustered, as well as in other minor features.

CALYTHROPSIS *C. A. Gardn.* gen. nov.

Myrtaceæ-Chamaelaucieæ.

Calycis tubus obovoideus, 4-gonus, ovario adnatus, segmenta vel sepalæ nulla; petala 4, integra, patentia, decidua. Stamina indefinita, numerosa, pluriseriata, libera; filamenta glabra, filiformes; antherae versatiles, loculis parallelis, longitudinaliter dehiscentibus, connectivo glandula parva, globosa, appendiculato. Ovarium inferum, calycis tubo subaequale, 1-loculare; ovula

2, erecta, placenta filiformi e fundo ovarii oriunda et usque ad apicem extensa, collateraliter affixa; stylus filiformis, glaber, stigmate parvo, capitato. Fructus siccus, indehiscens, calycis tubo adnatus; semen solitarium.

Frutex ericoideus. Folia sessilia, sparsa, plusminusve densa, parva, integerrima, marginibus hyalinis. Stipulae nullae. Flores sessiles, in capitula terminalia conferti singuli in axillam bracteae vel folii floralis. Bracteolae 2, subfoliaceae vel ad margines scariosae, persistentes, basi connatae, rigidulae, parte libera imbricatae tubumque calycis includentes.

Species 1. Australiae occidentalis incola.

The affinity is with *Calythrix* and *Lhotzkya* with similar ovules and placentation, while the plant has much the aspect of *Calythrix aurea* Lindl. It differs from *Calythrix* and *Lhotzkya* however, in the complete absence of any sepals or calyx-lobes, in the number of petals, and in the strongly 4-ribbed calyx-tube which is quite sessile and constricted at the apex. The calyx tube is almost that of *Actinodium*, while the bracteoles are those of some species of *Calythrix*.

C. aurea *C. A. Gardn.* sp. nov.

Fruticulus metralis altus, glaber; ramis erectis, ramulis inferne crebo cicatriciferis, superne dense foliosis; foliis erectis, oblongo-lanceolatis, breviter petiolatis, apice acutis vel mucronatis, supra concavis, subtus carinatis, uninervis, glandulis perpaucis inspersis, marginibus ciliolatis; floribus sessilibus in capitulis ad apicem ramulorum, foliis floralibus vel bracteis foliis subsimilibus sed brevioribus; bracteolis ad medium usque connatis, calycem excedentibus, obtusissimis vel breviter mucronatis, marginibus hyalinis; calycis tubo obovoideo, fortissime 4-gono, superne constricto, glabro; petalis flavis, oblongo-ovatis, imbricatis, quam calycis tubus multo longioribus; staminibus numerosis, (? fuscis); stylo quam petala stamines breviore, apice minutissime capitato, glabro.

Folia 5-7 mm. longa; calycis tubus 2.5-3 mm. longus; petala 7-8 mm. longa; fructus imperfectus quam bracteoli breviori.

Hab. in distr. Irwin, ad ripas fluvii Arrowsmith, flor. m. Septem. *W. E. Blackall* 4449 (Typus in Herb. Perth).

Although ripe fruits have not been observed, the ovary after flowering becomes cylindrically elongated with a short constricted portion below the summit, but retains the four strong ribs of the flowering calyx-tube. I have described the ovules as being 2 in number, and they are the same as those which I have seen in specimens of *Calythrix* and *Lhotzkya* as far as I have examined specimens of those genera. These ovules, which are erect near the middle of a filiform placenta, appear to be almost or quite separate when viewed from one side, but from the opposite side they appear to be fused to about the middle. It is possible that they represent a single lobed ovule.

Darwinia Meeboldii *C. A. Gardn.* sp. nov.

Frutex rigidus, erectus; 2-3 metralis altus, glaber; cortice albo-suberosa; foliis densis, decussatis, erectis vel subpatentibus, lineari-oblongis, sessilibus, basi breviter contractis, apice obtusis, non evidenter nervosis, planis vel marginibus leviter recurvis; capitulis terminalibus, magnis, nutantibus; bracteis involucrantibus pluri-seriatis, ovatis vel oblongo-lanceolatis vel lanceolatis, acutis vel acuminatis, exterioribus brevioribus, viridibus, interioribus praesertim sursum purpureis, omnibus integris; bracteolis linearibus, tenuibus, integris, acutis, valde concavis vel cymbiformibus, quam calyx vix longioribus; calycis tubo cylindrico, duro, crustaceo, laevo et nitente, minute foveolato, sursum papilloso, lobis erectis, duris, crassis, apicem acutis, sursum atro-violaceis; petalis quam calycis lobi vix longioribus, triangulari-lanceolatis, acutis, integris: staminibus brevibus; staminodiis subulatis, quam filamenta brevioribus; stylo elongato, per anthesin ruguloso-contracto, sub apice barbato, demum elongato.

Frutex 3 m. attingens; folia usque 9 mm. longa, 1.5-2 mm. lata; capitula 3 cm. longa; bracteae interiores 3 cm. longae; flos 11 mm. longus.

Hab. in distr. Stirling prope Cranbrook. *A. Meebold;* a pede Peak Donnelly in clivis lapidosis, fl. m. Novem., *W. Porteous* et *C. A. Gardner.*

Affinity to *D. leiostyla* (Turcz.) Domin, differing in the larger size and more robust habit, the broader and longer leaves, the much larger and narrower acuminate bracts of the involucre and the larger flowers. The two species look entirely different in the field.

Verticordia Etheliana *C. A. Gardn.* sp. nov.

Section *Catocalyptra.*

Fruticulus semimetralis altus, ramis patentibus; foliis breviter petiolatis, erecto-patentibus, orbiculari-obovatis, obtusis, subglaucis, imbricatis, concavis; floribus axillaribus, paucis, magnis, purpurascentibus, bracteolis amplis, hyalinis, subpersistentibus; calycis tubo turbinato, 5-costato, segmentis primariis in lobos penniformes 11-incisis, lobis accessoriis hyalinis, reflexis sed non a basi erectis, orbicularibus, ciliatis, appendicibus herbaceis inter tubi costas conspicuis, acutis, subliberis, lineari-triangularis; petalis tubo stamineo adnatis, oblongo-cordatis, ad apicem versus longe ciliatis; staminibus cum staminodiis basi in tubum stamineum coalitis, antheris parvis, oblongis; staminodiis subulatis, stylo sub apice barbato.

Folia 4-5 mm. longa; pedicelli usque 8 mm. longi; tubus calycinus 5 mm. longus; segmenta primaria 7 mm. longa, accessoria 5 mm. longa; petala 7 mm. longa; staminodia staminaque 3 mm. longa.

Hab. in distr. Irwin, inter Yaringa et Northampton, fl. m. Septem. *W. E. Blackall* 4724.

Novam hanc nominando pulcherimamque speciem Ethel commemoro, quae, et operum et explorationum socia devotissima, una cum doctore clarissimo Gulielmo Edwardo Blackall, viro suo, specimenibus tum colligendis tum ordinandis enixe laboravit.

Affinity to *V. chrysostachya* Meissn., from which it differs in the much larger crimson or scarlet flowers, the longer pedicels and larger herbaceous appendages, as well as in the much shorter inflorescence. Neither in this, nor in any other species of the Sect. *Catocalyptra* investigated are the accessory calyx-segments reflexed upwards on the calyx-tube.

VERBENACEÆ.

Pityrodia maculata *C. A. Gardn.* sp. nov.

Section *Eupityrodia.*

Suffrutex 50 cm. altus; ramis erectis, strictis, teretibus, pauce glanduloso-pilosis; foliis distantibus, sessilibus, basi auriculato-dilatatis, ellipticis, tenuibus, dentibus utroque circiter 10, acutis, venis pinnatis, grosse anastemosis, pauce glanduloso-pilosis vel subglabris; floribus in axillis foliorum superiorum, in racemis 2-3-floribus dispositis, bracteolis herbaceis, ovatis, setaceo-denticulatis, persistentibus, fere glabris; pedicellis gracilibus, apicem versus stellato-tomentosis; calycis segmentis subliberis, oblongo-lanceolatis, acutis, extus laxe stellato-hirsutis, intus glabris; corolla lilacina, e basi sensim ampliata, limbi lobis 2 superioribus altius connatis, 3 inferioribus ovato-orbicularibus; staminibus inclusis, basin versus tubo insertis, antheris omnibus breviter appendiculatis; ovario apice tomentoso, stylo glabro, bifido.

Folia 2 cm. longa et 8 mm. lata; racemi 2.5 cm. longi; calyx 6 mm. longus; corolla 1.3 cm. longa.

Hab. in distr. Avon, prope Ballidu, in arenosis apertis, flor. m. Septem. *Gardner* 2708.

Affinity to *P. dilatata* (F. Muell.) Benth., differing in the ovate dentate thin subglabrous leaves which are not bullate, the abbreviated axillary racemes, ovate bracteoles, oblong-lanceolate calyx-segments, and in the indumentum. The corolla is conspicuously brown spotted in the throat. The flowers have been damaged by insects due to early neglect, and thus the shape of the corolla lobes has been described from undeveloped flowers.

Dicrastyles flexuosa (*Price*) *C. A. Gardn.* comb. nov.

A specimen collected by W. E. Blackall between Menzies and Broad Arrow is identical with Ince's plant described by Price as *Pityrodia flexuosa* in Herb. Kew., of which I have seen the original. The corolla is nearly regular, and there are five perfect stamens and a two-branched style. It must therefore be transferred to the genus *Dicrastyles*.

SOLANACEÆ.

Anthotroche myoporoides *C. A. Gardn.* sp. nov.

Frutex erectus, 2-3 m. altus, ramis patentibus, tomento cano omnino vestitis, foliis alternis, longe obovatis, basi attenuatis in petiolum distinctum, planis, obtusis, densissime cano-tomentosis; floribus in axillis singulis vel pauce aggregatis, subsessilibus vel breviter pedicellatis; bracteis parvis, oblongis vel ellipticis, cano-tomentosis, crassis, deciduis; calyce 5-lobato, extus albo-tomentoso, lobis tubo aequilongis, ovato-deltoideis, subacutis corollæ tubo calycem vix excedente, extus albo tomentoso, intus glabri, baso excepto, sub insertione filamentorum barbato, prominenter atro-violaceo striato, lobis intus albo-tomentosis; staminibus 5, omnibus fertilibus, in tubum corollae insertis, filamentis brevibus, ad basin barbatis; disco glabro, crasso; ovario ovoideo, glabro, loculis 2, 4-5-ovulatis; stylo elongato, glabro.

Frutex usque 3 m. altus; folia usque 3.5 cm. longa, usque 1.8 cm. lata; calyx 6 mm. longus; lobi 3 mm. longi; corolla 8 mm. longa et lata.

Hab. in distr. Irwin prope Indarra, in arenosis apertis, fl. m. Sept. *Gardner* 2650 (Typus); atque septentrionalem versus flumen Murchison River transgreditur, ubi in arenosis apertis adest flor. m. October.

Affinity to *A. Blackii*, differing in the close hoary tomentum of the branchlets and leaves, the shape and size of the leaves, the smaller whitish (not deep violet) flowers with acute corolla lobes &c. It has the indumentum of *A. Walcottii*, from which it differs in stature, the subsessile flowers, and from both species in the distinctly tubular corolla, the shape of which is that of *Myoporum*.

PEDALIACEÆ.

Josephinia Eugeniae *F. Muell.*

This species is recorded from Tambrey Station in the vicinity of the Hamersley Range, where it is reported as spreading and becoming a troublesome weed.

ACANTHACEÆ.

Dicladanthera Forrestii *F. Muell.*

An undershrub almost a metre high, with pale pink or white flowers. It grows in stony watercourses along the Upper Hardie River near Mount Samson; fl. m. August. *Gardner* 3168.

Ruellia primulacea *F. Muell.*

A very attractive species which is either a small shrub, or semi-scandent and attaining a height of several feet; the flowers are a rich violet in colour.

Barrabiddy Creek, Minilya River, *Gardner* 3020; 90 kilometres north of Carnarvon, *G. R. Meadly.*

This is the first record of this species from Western Australia.

MYOPORACEÆ.

Eremophila lachnocalyx *C. A. Gardn.* sp. nov.

Section *Eriocalyx.*

Frutex erectus 2 m. altus, ramis ramulisque dense albo-tomentosis, demum glabris, reliquis foliorum evanidorum indutis, sursum dense foliatis; foliis parvis, imbricatis, patentibus vel reflexis, orbiculari-obovatis vel ellipticis, basin versus contractis, late sessilibus, obtusis, utrinque canotomentosis; floribus conspicuis, axillaribus; pedunculis solitariis, tenuibus, quam folia paulo longioribus, dense floccoso-tomentosis; calycis segmentis aequalibus, linearibus, acutis vel acuminatis, intus glabris, extus dense floccoso-tomentosis; corolla basi vix constricta, campanulata, calycem duplo superante, intense violacea, lobis subaequalibus, ovatis, subacutis, 2 superioribus alte connatis, mediano quam ceteri paulum longiore; staminibus inclusis; ovario lanoso, stylo plusminusve glabro.

Folia 4-5 mm. longa, 3-3.5 mm. lata; pedunculi 7-8 mm. longi; sepala 1 cm. longa, 1 mm. lata; corolla vix 2 cm. longa.

Hab. in distr. Austin prope Paynesville, in lapidosis lutosis, fl. m. August, *Gardner* 2515; pr. Cue, in rupestribus lutosis, *Gardner* July, 1931; Nannine, lutoso-nitrosis, *Gardner, C. Andrews;* Mount Gascoigne, *E. S. Simpson* Septem. 1927.

Affinity to *E. Mackinlayi* F. Muell., and *E. strongylophylla* F. Muell., differing in the smaller leaves, the corolla not constricted above the ovary but gradually widened into a campanulate base, the longer acute corolla lobes, much narrower and more deeply divided calyx covered with a long floccose wool. This white wool is sometimes suffused with violet, and always forms a subglobular woolly mass which quite conceals the calyx. The specimen from Mount Gascoigne has more acute and erect leaves, but is otherwise typical: it may perhaps constitute a distinct variety.

Eremophila inflata *C. A. Gardn.* sp. nov.

Section *Eremocosmos.*

Frutex gracilis, erectis, glaber (floribus exceptis), ramis ramulisque virgatis, ramulis pauce resinoso-tuberculatis; foliis lineari-oblanceolatis, obtusis, nonnunquam breviter uncinatis, basin versus attenuatis vel breviter petiolatis, siccando nigrescentibus, costa centrale solum conspicua; floribus axillaribus, solitariis, graciliter pedunculatis; pedunculis glabris, patentibus vel recurvis, sub calyce clavatim incrassatis; calycis segmentis oblongo-ellipticis, solutis, obtusis, tenuibus, valde reticulato-nervosis, marginibus et nervis ciliolatis, post anthesin deflexis; corolla pallide violacea, glabra, tubo campanulato, basi inflato, sursum contracto, plusminusve uncecolato, extus parce piloso, intus glabro, lobis brevioribus, obtusis, subaequalibus; staminibus inclusis; ovario longe hirsuto, stylo glabro, uncinato.

Frutex 2 m. altus; folia usque 3 cm. longa, 3.5 mm. lata; sepala 3.5 mm. longa, 1.6 mm. lata; corolla 7.5 mm. longa.

Hab. in distr. Coolgardie prope Mount Holland, juxta Lake Cronin, leg. *H. Steedman,* Decem. 1929.

A very distinct species with affinity to *E. Sturtii* R. Br., but with several differences. The reflexed calyx-segments and the much dilated base of the corolla, as well as the very short and obtuse corolla-lobes are features peculiar to the species within the §*Eremocosmos.*

Eremophila Macmillaniana *C. A. Gardn.* sp. nov.

Section *Platychilus*

Frutex robustus, 2 metralis altus, rigidus, erectus; ramulis erecto-patentibus, reliquis foliorum delapsorum persistentibus indutis, cano-tomentosis, sursum foliatis; foliis congestis, patentibus, lato-spathulatis vel spathulato-obovatis, basin versus attenuatis, breviter petiolatis, junioribus albo-tomentosis demum glabris et argenteo-nitentibus, apice abrupte acutis et recurvis nonnunquam complicatis; floribus axillaribus vel terminalibus, solitariis; pedunculis erectis vel leviter patentibus, sursum complanato-clavatis, albo-tomentosis, angularibus; calycis segmentis magnis, oblanceolato-obovatis, inaequalibus, fere liberis, acutis vel mucronatis, extus sparse tomentosis, demum glabris, prominenter reticulato-nervosis, post anthesin leviter amplificatis, ad basin vix imbricatis; corolla atro-purpurea, extus fere glabra, tubo supra ovarium constricto, deinde sensim ampliato, plusminusve recto, intus prope basin dense lanoso, lobis subaequalibus, 2 superioribus angusto-ovatis, acutis, alte connatis, lobis inferioribus ovatis, obtusis vel mucronatis; staminibus breviter exsertis; ovario longe cylindrico, minute aureo-granuloso, stylo elongato, glabro.

Frutex 2 metralis altus; folia 3 cm. longa, 1 cm. lata; calycis segmentis usque 2.6 cm. longi, 8 mm. lati; corolla usque 3.3 cm. longa, lobis 8 mm. longis.

Hab. in distr. Austin, ab lato orientale montium Barloweerie, in clivis lapidosis sterilibus, fl. m. Jul-Aug. *Gardner* 2533; atque ad vicum Cue, in collibus lapidosis.

Quam speciem honoris causa pro illustrissimo Roberto Furze Macmillan Equite, nomino; qui vero, multos per annos Judicatus in Australia occidentali primatum tenens, haud minore ingenio quam urbanitate artium simul ac scientiarum hac in republica fautor excellebat.

Affinity to *E. Fraseri* F. Muell., and *E. spathulata* W. V. Fitzg., differing from both in the shape of the calyx-segments and in the corolla. The calyx is almost that of the species of § *Eremocosmos*. There is also some resemblance to *E. Freelingii* F. Muell., but the leaves are broader, the calyx-segments larger and of different shape, and the stamens exserted.

Eremophila spectabilis *C. A. Gardn.* sp. nov.
(§ Platychilus)

Frutex 1-2 metralis altus; ramis patentibus, inferioribus pendulis, ramulis foliaceis, resinosis et breviter pilosis: foliis linearibus vel lineari-lanceolatis, remote denticulatis, acuminatis, basin versus attenuatis vix petiolatis, viridibus et glaucis, breviter pilosis, supra subtiliter canaliculatis; pedunculis axillaribus, solitariis, elongatis, sigmoideo-patentibus, apicem versus angulatis et valde incrassatis; calycis segmentis valde imbricatis, inaequalibus, segmento exteriore unilateraliter decurrente, ovato-acuminatis, ceteris angusto-lanceolatis, omnibus minute hispidulis et viscidis; corolla intense violacea, subglabra, tubo cylindrico, supra ovarium leviter constricto, deinde ampliato, lobis ovatis vel obovatis, acutis, 2 superioribus alte connatis, mediano cuneato-obovato, fauce intus lanosa; staminibus inclusis; ovario ovoideo, dense hirsuto, ovulis in loculis 5, stylo tenui apice uncinato, piloso.

Frutex 2 m. altus; folia usque 6 cm. longa, 3 mm. lata; pedunculi 2 cm. longi; sepala usque 2.4 cm. longa et usque 9 mm. lata post anthesin vix amplificata; corolla 3.5 cm. longa, limbi lobi 1.5 cm. longi.

Hab. in distr. Austin a Meekatharra 60 km. septentrionem versus, in fruticetis apertis, in lutoso lapidosis, flor. m. July. *Gardner* 2328 (Typus).

This very attractive plant is closely related to *E. Freelingii*, from which it differs in the sessile denticulate leaves, much longer sigmoid peduncles and acute corolla lobes, as well as in the calyx. It also has some points of resemblance with *E. Gilesii*, differing in the distinctly and somewhat coarsely denticulate leaves, shorter and thicker peduncle, imbricate calyx-segments, acute corolla lobes etc.

E. Freelingii, E. spectabilis, E. Gilesii and E. foliosissima have all the same characteristic indumentum of short stiff curled white hairs accompanied by some viscidity, but the marked decurrence of the right hand margin of the outer sepals of *E. spectabilis* is a feature not observed in the other species.

Eremophila miniata *C. A. Gardn.* sp. nov.
(§ Platychilus.)

Arbor parva vel frutex elatus, cortex nigro-suberosa; ramis rigidis, rectangulariter divaricatis, crassis; foliis apice ramulorum versus congestis, lato-linearibus vel lineari-oblongis, sessilibus, subplanis, pubescentibus, apice acutis vel acuminatis, costa centrale solum conspicue; pedunculis solitariis, sigmoideo-patentibus, pubescentibus: calycis segmentis valde imbricatis, liberis, inaequalibus, lato-ovatis vel subrotundis usque ellipticis, mucronatis, roseis, reticulatis, post anthesin amplificatis et prominenter venosis, puberulis vel glabris; corolla miniata, sparse et breviter pilosa, intus glabra, fauce brunneo maculata; tubo basi cylindrico, supra ovarium sensim ampliato, lobis 2 superioribus obovatis, acutis, alte connatis, inferioribus ovatis, acutis; staminibus exsertis; ovario styloque glabro.

Planta usque 5 m. alta; folia 2-2.5 cm. longa, 2-4 mm. lata; pedunculi 1.5 cm. longi; sepala 1.5 cm. longa et 1.3 cm. lata, usque 2 cm. longa et 8 mm. lata; corolla 3.3 cm. longa; limbi lobi 1.2 cm. longi.

Hab. in distr. Avon, in fruticetis apertis lutoso-nitrosis prope Cowcowing, flor. m. Septem. *Gardner* 2740 (Typus); in distr. Coolgardie, ad Penny's Find prope Kurnalpi, *J. H. Frank*, fruct. m. Decem., prope Broad Arrow, *W. E. Blackall* 2144, flor. m. Septem.

Apart from the shape of the corolla and its lobes, this species might, from the description, be mistaken for *E. Duttoni* F. Muell. It belongs, however, to the Section Platychilus, and should be placed next to *E. viscida* Endl., from which it differs in several features, such as the shape and size of the leaves which are not viscid, the size and lobing of the corolla, etc.

E. viscida Endl., previously known only from the single specimen in the Vienna Herbarium, has been collected by the author from Ballidu in granitic soil, and by F. E. Victor from Kununoppin. It is a handsome shrub of 3 to 4 metres in height, with white flowers, the throat spotted with violet. The calyx segments enlarge after flowering, but become membranous, and are elliptical to almost obovate in shape.

Eremophila virens *C. A. Gardn.* sp. nov.

Section *Stenochilus.*

Frutex erectus, virgatus, 3-5 metralis altus; ramulis erectis, viscidis; foliis alternis, patentibus, petiolatis, planis vel complicatis, oblongo-lanceolatis, lanceolatis vel ovato-lanceolatis, longe petiolatis, viscidis, virescentibus, glabris, basi inaequaliter abrupte contractis, apice acutis vel acuminatis; floribus viridibus; pedunculis solitariis vel binis, axillaribus, elongatis, tenuibus, sigmoideo-incurvatis, quam calyx multo longioribus; calycis segmentis liberis, imbricatis, exterioribus ovatis, interioribus oblongo-obovatis vel oblanceolatis, intus lanosis, omnibus post anthesin amplificatis; corolla viridi, extus albo-tomentosa, sed perfecta non visu, tubo supra ovarium contracto sursum leviter ampliato, sub limbo attenuato, limbi lobis acutis; staminibus exsertis; ovario subgloboso, glabro, stylo glabro.

Frutex 3-5 m. altus; folia 7.2 cm. longa vel minus, usque 2.6 cm. lata, petiolus 1.5 cm. longus; pedunculi usque 2 cm. longi, graciles, calyx 6 mm. longus, post anthesin 1.3 cm. longus; corolla 1.3 cm. longa.

Hab. in distr. Coolgardie prope Campion, in fruticetis graniticis, deflor. m. Septem. *Gardner* 2765.

Affinity to *E. serrulata* (A. Cun.) Druce, but with much larger and quite entire differently shaped leaves, the corolla woolly-tomentose outside. The habit of the two is also quite different.

When collected, the specimens were past flowering, and but few somewhat damaged flowers were obtained, while one or two were immature. The structure of the corolla is however, entirely that of § *Stenochilus*, with four small deltoid teeth forming the upper lip, and a much more deeply separated lower lip formed from a single ovate-oblong lobe.

LABIATÆ.

Hemigenia divaricata *C. A. Gardn.* sp. nov.

Section *Diplanthera.*

Frutex divaricato-ramosus, ramulis oppositis, rectangulariter divaricatis, teretibus; foliis oppositis, in ramulis junioribus saepissime fasciculato-oppositis, linearibus vel lineari-spathulatis, sessilibus, concavis, vix acutis, glabris, apice saepissime recurvatis; floribus axillaribus, solitariis, brevi-pedunculatis vel subsessilibus, supra medium bibracteolatis; bracteolis parvis, lineari-lanceolatis, acutis, ciliatis, quam calyx multo brevioribus, deciduis; calycis tubo campanulato, laxe hirsuto, lobis subaequalibus, ovato-lanceolatis, acuminatis, conspicue costatis, tubo subaequantibus; corolla violacea, extus laxe hirsuta, intus glabra, tubo e basi cylindrico sub limbo ampliato, limbi lobis emarginatis vel bilobis, labii superioris lobis 2 ovatis, labii inferioris lobis 3, quam superius longioribus; antherarum superiorum loculo altero sterili in appendiculam glabram producto, antherarum inferiorum altero globoso sterilescente.

Frutex 1-1.5 m. altus; folia 4-6 mm. longa; pedunculi circ. 1 mm. longi; bracteolae 2.5 mm. longae; calycis tubus 4 mm. longus, lobi usque 6 mm. longi.

Hab. in distr. Austin prope Pindar occidentalem versus in locis graniticis apertis, flor. m. Septem. *Gardner* 2624.

This species is most closely related to *H. diplanthera* F. Muell., differing principally in the broader hirsute ecostate calyx-tube and the hairy corolla.

Hemigenia coccinea *C. A. Gardn.* sp. nov.

Section *Euhemigenia.*

Frutex divaricatus, usque 20 cm. altus, pilis appressis vestitus; ramulis intricato-divaricatis, teretibus; foliis oppositis, erectis vel leviter patentibus, lineari-oblongis, valde concavis, sessilibus, obtusis, apice leviter recurvatis, supra glabris, subtus appresso-pilosis; floribus axillaribus, longe pedunculatis; pedunculis medio bibracteolatis; bracteolis lineari-setaceis, deciduis, calycis tubo cylindrico-campanulato, parce piloso, 10-costato, lobis triangulari-lanceolatis, acuminatis, subaequalibus, quam tubus longioribus; corolla coccinea, extus fere glabra, intus glabra, basin excepta, tubo e basi angusto-cylindrico, sensim ampliato; labii superioris lobis 2 ovato, oblongis, truncatis, supra medium connatis, labii inferioris lobis 3, quam superius longioribus, lobo mediano emarginato, lateralibus oblongis brevioribus, omnibus serrato-dentatis; antherarum loculo altero sterili, in appendiculam glabram producto.

Frutex 20 cm. altus; folia 7-8 mm. longa; pedunculi 6-7 mm. longi; tubus calycis 2.5 mm. longus, lobi 3 mm. longi; corolla 1.8 cm. longa.

Hab. in distr. Irwin ad fines orientalem versus, prope Canna, in lutosis graniticis, flor m. Septem. *Gardner* 2661.

Amongst the species of the Sect. *Euhemigenia* this species has its closest affinity to *H. humilis* Benth., differing in the narrower deeply concave leaves, the longer peduncles and narrower bracteoles, the much longer corolla, and in having all the anther appendages glabrous. It is a low intricately divaricate shrub with the aspect of *H. divaricata* C. A. Gardn. but has scarlet flowers with a much longer corolla-tube. The differences between the Sections *Diplanthera* and *Euhemigenia* are not entirely satisfactory.

Prostanthera magnifica *C. A. Gardn.* sp. nov.

Frutex 1-2 metralis altus, fere glaber, ramis ramulisque divaricato-patentibus, glabris vel breviter crispo-hirsutis; foliis ellipticis vel obovatis, crassis, integris vel pauce denticulatis, basin versus attenuatis, in petiolo brevi; floribus magnis, in axillis supremis spicis foliatis formantibus; pedunculis erectis, sub calyce bibracteolatis; bracteolis lineari-lanceolatis, demum deciduis; calyce roseo, tubo glabro, brevi, striato, labio supero integro, magno, rotundo-ovato, quam corolla vix breviore, eleganter nervoso, obtuso, labio infero ovato vel oblongo-ovato, quam superius duplo breviore; corolla purpurea vel coccinea, extus breviter albo-pilosa, intus farinosopubescente, subaequaliter 5-lobata, lobis dense ciliatis; labio supero late rotundato, emarginato, vel lobis 2 brevibus anctis; labii inferi lobis lateralibus ovatis, subacutis basi subcordatis, lobo mediano emarginato-bilobo; antherarum calcare longitudinem loculi duplo excedente; stylo glabro.

Frutex 1-2 m. altus; folia usque 2.5 cm. longa, 1 cm. lata; pedunculi 4-5 mm. longi; bracteoli 4-5 mm. longi; calyx usque 2.4 cm. longus, labium superum 1.7 cm. latum, inferum 1 cm. longum, 6 mm. latum; corolla 2 cm. longa, limbi lobi circiter 3.4 mm. longi.

Hab. in distr. Irwin, ad vicum Mullewa 30 km. occidentalem versus, flor. m. Septem. *W. E. Blackall* 2783; (Typus); atque 45 km. ab orientalem versus Ajana, *Mrs. D. L. Carson*, Oct. 1940.

var. **asperata** *C. A. Gardn.* var. nov.

Foliis minoribus, asperatis, minute asperato-denticulatis; floribus coccineis, minoribus.

Ad summum montem Churchman in rupestribus graniticis, flor. m. Septem. *W. E. Blackall* 3458.

This species is very distinct. It belongs to the Section *Eupostanthera*, but has no clear affinities. The rich purple or scarlet colour of the calyx, and the scarlet or purple corolla, the size of the flowers, small stature and floriferous habit render it a most attractive species for horticultural development.

GOODENIACEÆ.

Goodenia Hilliana *C. A. Gardn.* sp. nov.

(Eugoodenia-Bracteolatae-Racemosae.)

Herba perennis vel suffrutex, erecta vel ramosa, 45 cm. alta; ramis teretibus, crassis, dense et breviter glanduloso-pubescentibus; foliis herbaceis, erectis, planis, oblongo-obovatis, glanduloso-pilosis, basin versus attenuatis, vix petiolatis, apice obtusis, margine dentatis; racemis densifloris, erectis, terminalibus, foliis multo excedentibus; pedicellis basi bracteatis, sub calyce bracteolatis; bracteis foliaceis, erectis, oblongo-obovatis, integris, glanduloso-pubescentibus, quam pedicelli longioribus, apice obtusis, basin versus attenuatis; bracteolis similibus bracteis sed minoribus angustioribusque, glanduloso-pubescentibus; corolla caeruleo-violacea, extus sparse hirsuta, intus glabra, lobis 3 inferioribus supra medium connatis, 2 superioribus profunde divisis, apice acutis, omnibus alatis, alis loborum aequilatis; staminibus liberis, antheris quam filamenta duplo brevioribus, oblongo-linearibus; stylo sparse piloso, quam stamina subduplo longiore, indusio compresso-cupulato, margine breviter et dense ciliato; ovario 2-loculari, dissepimento incompleto, ovulis 3-5; capsula oblonga, quadrivalvata, seminibus anguste marginatis.

Planta 45 cm. alta vel minus; folia usque 3.5 cm. longa, 6-7 mm. lata; racemi usque 10 cm. longi; pedicelli 3 mm. longi; calyx 7 mm. longus, tubo 2 mm. longo; segmentis 5 mm. longis; corolla 1.4 cm. longa, lobi cum alis 4 mm. lati.

Hab. in distr. Irwin, in collibus glareosis ad fluvium "Hill River," flor. et fruct. m. Feby. 1941. *Gardner*.

Hanc species viro celeberrimo praeclarissimoque Arthur W. Hill, equiti, Horti Botanici Regii Kewensis Directori nominavi, qui peregravit Australiam occidentalem in anno 1927, quique specimena tanta contulit hujus regionis.

A very distinct and handsome species nearest to *G. quadrilocularis* R. Br., but differing in the whole plant being densely glandular-pubescent throughout, in the long leafy calyx-lobes and the equally winged segments of the zygomorphic corolla. The lateness of its flowering season, together with its floriferous nature make it a species worthy of horticultural development.

STYLIDIACEÆ.

Stylidium galioides *C. A. Gardn.* sp. nov.

(Tolypangium — Verticillatæ)

Perennis, omnino glabra, caulibus teretibus, flexuosis, diffusis, probabiliter scandentibus, parce ramosis; foliis in verticillis saepissime circiter 8-9, inter sese distantibus congestis, oblanceolatis, apicem versus abrupte contractis et acutis, basin versus sensim attenuatis, planis vel marginibus leviter recurvatis, exterioribus squamis redactis; racemis terminalibus, laxis, paucifloris, longe pedicellatis; bracteis lineari-lanceolatis, acutis, basi ultra insertionem in processum brevem productis; pedicellis calycem semper superantibus, duobus bracteolis bracteis similibus sed minoribus instructis; calycis tubo ovoideo, lobis oblongis, tubo aequilongis, obtusis vel vix acutis, minute ciliatis, fere aequalibus; corolla lutea, tubo brevi, segmentis late oblongis, integris, basin versus marginibus glanduloso-ciliatis, subaequalibus; faucis appendiculis 8, anterioribus 2 late ovatis, integris, valde conspicuis, posterioribus 6 multo minoribus, subulatis; labello ovato, serrato-denticulato, appendiculis basalibus erectis, oblongo-ovatis, tenuibus, integris.

Planta 30-50 cm. alta; folia usque 4 cm. longa, 4.5 mm. lata; racemi 7 cm. longi; pedicelli usque 1.3 cm. longi; calycis tubus 5 mm. longus, segmenta 4-5 mm. longa, 1.5 mm. lata; corollae tubus vix 3 mm. longus, lobi circiter 7-8 mm. longi, 4 mm. lati.

Hab. in distr. Eyre, a summam montium East Mount Barren, inter rupestres, flor. m. Novem. *Gardner* 2955.

Affinity to *S. verticillatum* F. Muell., but with larger differently shaped leaves, the inflorescence reduced to a raceme with glabrous pedicles and calyx, and with more throat-appendages, the colour of the flowers is also different.

Stylidium laciniatum *C. A. Gardn.* sp. nov.

(Tolypangium — Junceæ)

Perennis, innovationes perpauces, adscendentes aut simplices; foliis omnibus radicalibus, dense rosulatim confertis, parvis, obovatis vel late spathulatis, acutis, subtus plusminusve carinatis, marginibus scariosis, sub anthesin evanescentibus; scapis volubilibus, glabris, 3 metralis altis, plusminusve robustis vel flexuosis, efoliatis, raro partibus superioribus bracteis perpaucis lanceolato-linearibus acutis basi calcaratis instructis; floribus in racemis terminalibus dispositis, pedicellis calycem aequilongis; bracteis simul marginibus hyalinis vel subscariosis lanceolatis, basi ultra insertionem in processum angustum curvato-patentem productis; bracteolis bracteis similibus sed minoribus; tubo calycis parce glanduloso-pubescente, oblongo, lobis tubi quam ovarium vix longioribus, valde inaequalibus, posterioribus anguste lineari-subulatis, 2 anterioribus longioribus, anguste lineari-lanceolatis, omnibus valde acuminatis et margine scarioso-limbatis; corolla rosacea, tubo lobis calycis posterioribus subaequilonge, lobis extus parce glanduloso-pubescentibus, ovatis vel obovatis, omnibus profunde incisis vel laciniatis, posticis quam laterales longioribus, a sinu lato separatis, dentibus linearibus vel lineari-lanceolatis; faucis appendiculis duobus minutis, subulatis, e basi posticum segmentorum ortis; labello ovato, obtuso, mucronato, exappendiculato; ovario oblongo, ovulis numerosis e placenta basalia libera.

Folia 5-6 cm. longa; scapus usque 3 m. altus; bracteae 1 cm. longae; bracteolae 5 mm. longae; pedicelli 5 mm. longi; calycis tubus 6 mm. longus; segmentis posticis 4 mm., anticis 7 mm. longis; corolla 1.2 cm. longa, lobis ± 8 mm. longis.

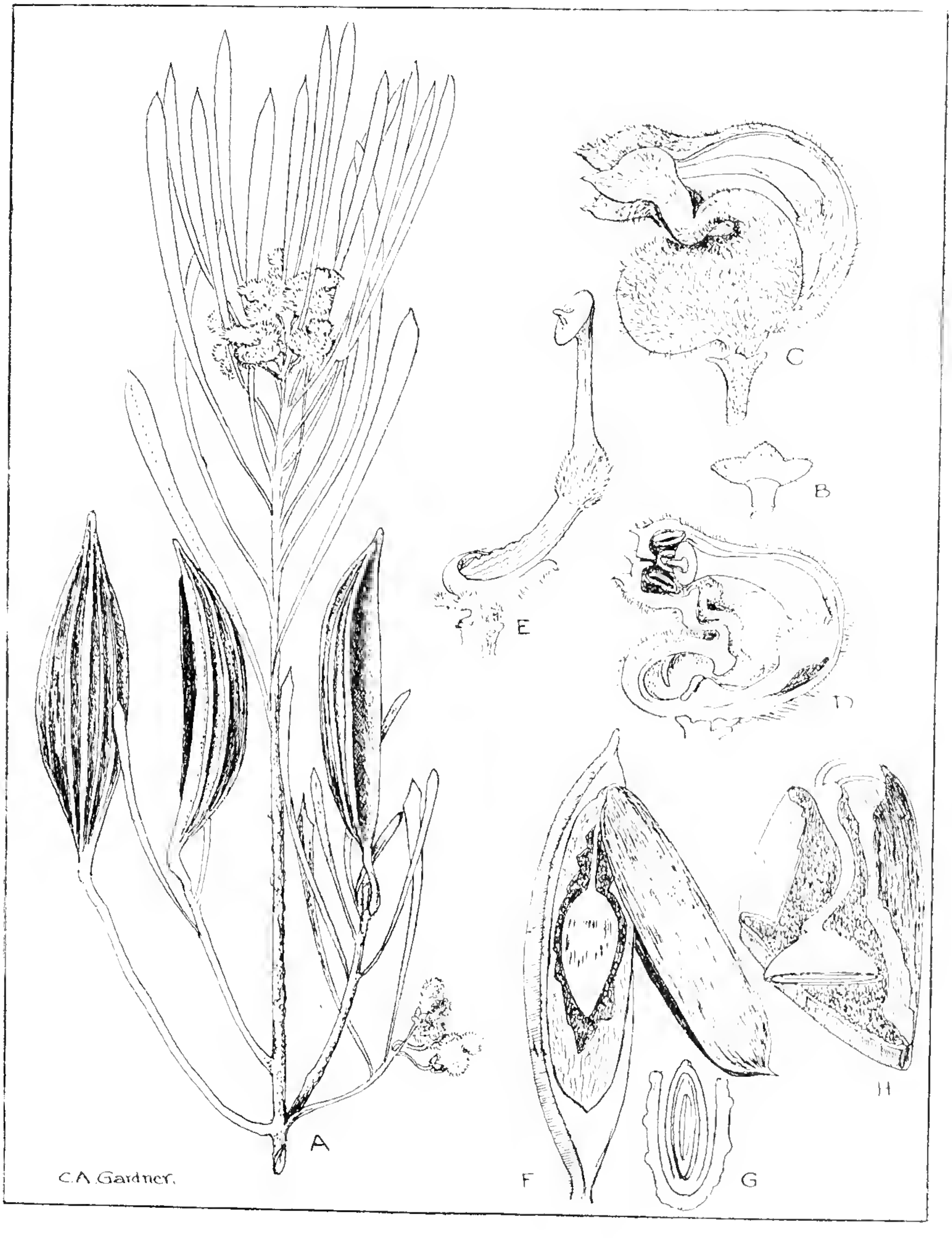
Hab. in distr. Warren prope fluvium Frankland, in lutosis paludis humosis, flor. m. Jan.-Febr. *Edward Gardner* Jan. 1936 (Typus); atque prope Denmark. juxta "Hell's Hole," in locis similibus, *C. E. Lane-Poole* n. 324, Febr. 1923.

A very distinct species allied to *S. junceum* R. Br., but with a different habit, loose racemose inflorescence and deeply dentate corolla lobes, as well as in the shape of the capsule.

PLATE I.

Strangea cynanchicarpa (Meissn.), F. Muell.

A—Habit, showing flowers and fruits. B—Bracteoles. C—Perianth. D—Perianth in section. E—Torus and pistil. F—Section of follicle, showing position of ovule, with the inner layer of the endocarp partially removed, and the outer membranous layer placed to one side. G—Section of follicle, showing relative position of inner layers of fruit. H—Upper part of endocarp, showing attachment of inner and outer layers, with funicle and base of ovule.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B
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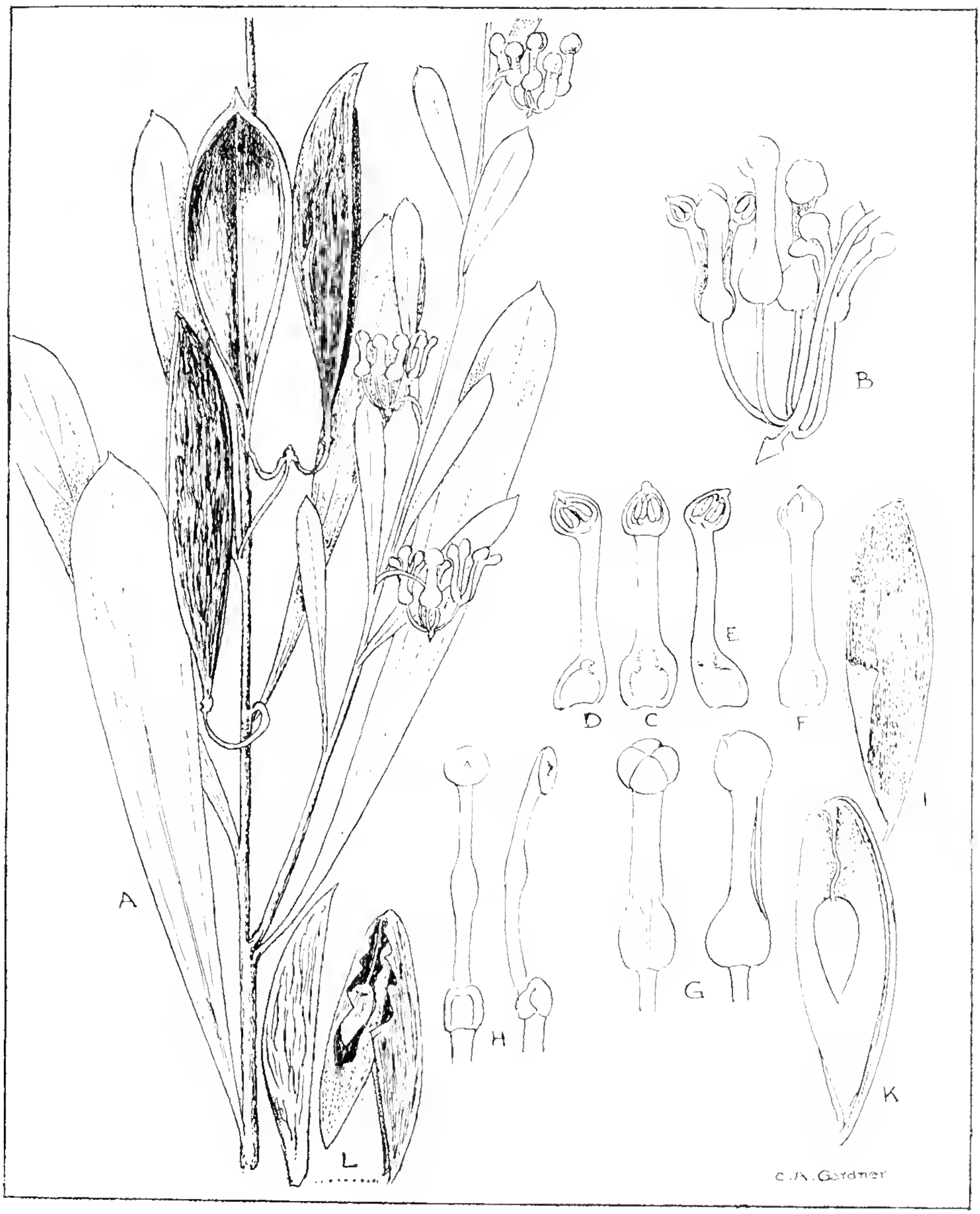
C.A.Gardner.

PLATE II.

Strangea stenocarpoides (F. Muell, ex Benth.), C. A. Gardn.

A—Habit, showing flowers and fruits. B—Inflorescence. C, D, E, and F—Perianth segments. G—Flower-buds. H—Pistil. I—Endocarp. K—Section through the endocarp, showing ovule in position.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C. A. Gardner

PLATE III.

Euphorbia boöphthona, C. A. Gardn.

A—Plant (half nat. size). B—Leaf. C—Branchlet with cyathia. D—Cyathium. E—Involucral gland. F—Seed. G—Base of seed with caruncle. H—Peduncle, a persistent axis of fruit.


H
F
D
G
A
E
B
C
C.A. Gardner

PLATE IV.

Euphorbia clutioides (Forst. f.), C. A. Gardn.

A—Habit. B—Leaves. C—Cyathium. D—Seed.


A
B
C
D

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INDEX—*continued.*

15.—MINERALOGY OF THE DONNYBROOK SANDSTONES, WESTERN AUSTRALIA.

By DOROTHY CARROLL.

Read 13th May, 1941; Published 7th August, 1942.

INTRODUCTION.

Sandstones, Permian or Triassic in age (Maitland, 1939), outcrop along the western edge of the Darling Plateau in the vicinity of Donnybrook (Lat. 33° 10′ S. Long. 116° 10′ E.) about 130 miles south of Perth, Western Australia.

It has been supposed on lithological grounds that these sandstones, known as the Donnybrook sandstone (Saint-Smith, 1912), are a remnant of the Collie Coal Measure Series which are Permian (Maitland, 1939, p. 185), but there is as yet no supporting palaeontological evidence although farmers in the district have discovered fossil footprints, not yet identified, in the upper part of the formation. Beyond some lithological resemblance to the Coal Measure series at Collie and the occurrence of some poorly developed thin beds of coal, there is nothing to show that the Donnybrook sandstone formation is of the same age as the Collie beds; however, both appear to be of estuarine or lacustrine origin and to have been laid down on an uneven, eroded surface of the Pre-Cambrian complex. There is apparently no continuity between the two formations.

The Donnybrook sandstone formation varies from coarse, unevenly graded and bedded sandstone with pebble bands near the base, to fine-grained, evenly bedded, ripple-marked sandstones with clay partings towards the top. The beds dip at about 4° to the south-west. The thickness is not definitely known, but bores have penetrated it to a depth of 200 feet (Maitland, p. 183).

The Donnybrook sandstone forms flat-topped hills, covered by laterised sandy soils, to the west, north and south of Donnybrook. Laterite (duricrust) above the sandstones is distinguishable from that formed from the Pre-Cambrian rocks by its abundant quartz grains.

The distribution of the Donnybrook sandstone is shown in Figure 1 where the formation is seen to overlap the edge of the Pre-Cambrian shield, indicating that the sandstones were in part laid down on an eroded surface of Pre-Cambrian rocks (Forman, 1936, p. 4). The Pre-Cambrian rocks immediately to the north-west of Donnybrook are at a much higher level than the sandstones. A range of sandy hills, known to be underlain in some parts by sandstone, occurs to the south-south-west of Figure 1, suggesting a continuation of the formation in this direction. The contact of the sandstone with the Pre-Cambrian just west of Nannup, about 30 miles south of Donnybrook, is similar to that at Donnybrook. Economically these sandstones are of importance, for the finer, evenly-bedded types provide an easily-worked, durable building stone.

In 1897 gold was discovered in the Donnybrook sandstones which were worked until 1906, yielding about 850 ounces of gold from 1,650 tons. The gold is thought to have been derived from small quantities in the surrounding Pre-Cambrian rocks (Maitland, p. 181) and to have been deposited from solution in the sandstones. An unsuccessful attempt was made about ten years ago to recover gold from the Pre-Cambrian rocks near where the old mines are situated in the sandstones.

Various reports, dealing with the distribution of the Donnybrook sandstone, with its use as a building stone (Simpson, 1917), with the possibility

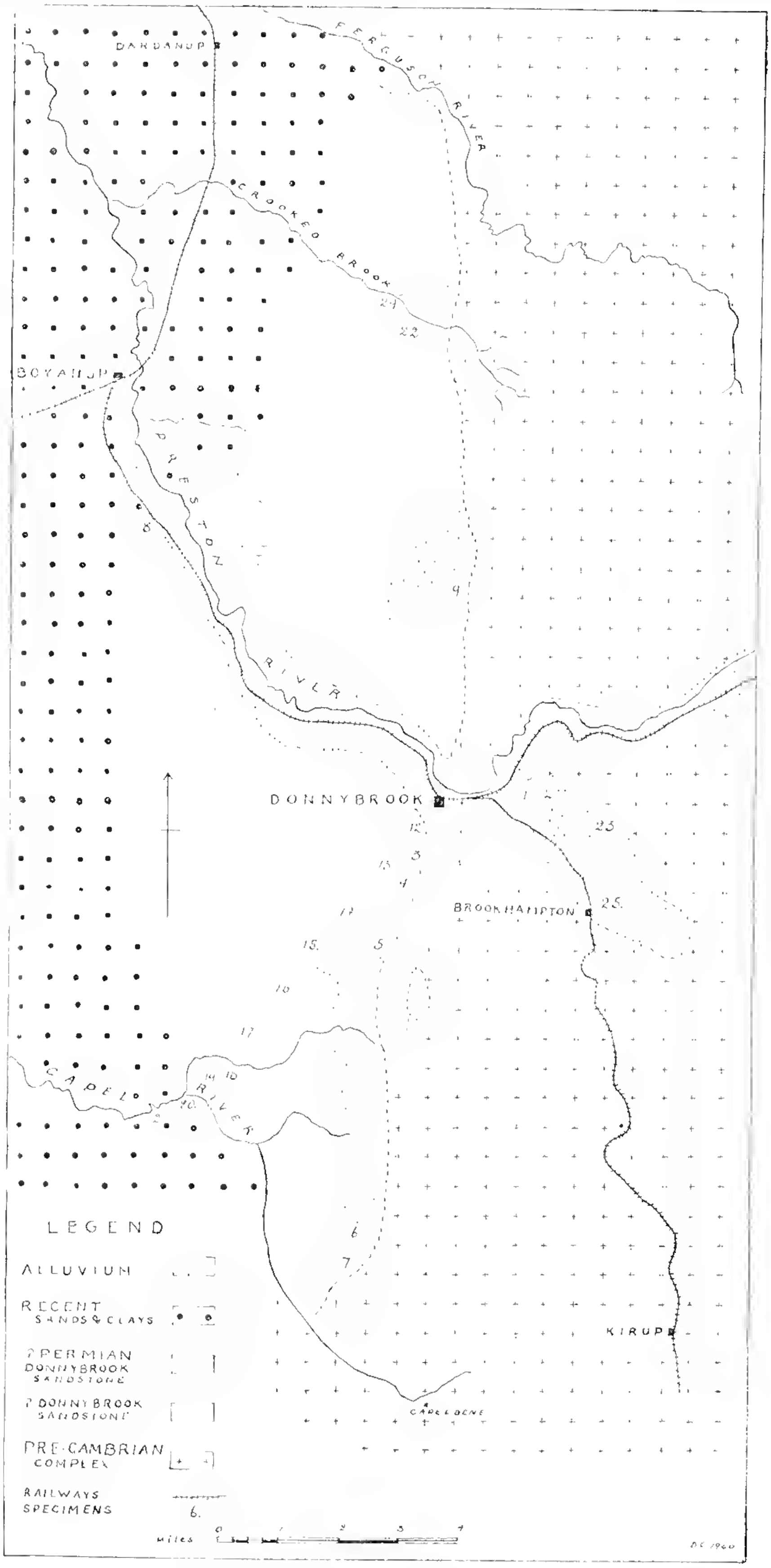

Fig. 1.

Geological sketch map of Donnybrook and environs. Compiled from Lands Department Lithos. 411/80, 414/80, and Plate I., Bull. 44, Geol. Survey, W.A., 1912.

of finding workable coal seams in the district, and with the occurrence of gold have been summarised by Gibb Maitland (1939) but actually there is little detailed knowledge either of the sandstones or of the Pre-Cambrian complex, which lies to the east, north and south of the sandstones (Figure 1). The Pre-Cambrian is represented predominantly by gneisses at Donnybrook, and, in the valley of the Preston River, there are numerous pegmatite dykes some of which carry large crystals of beryl and tourmaline; garnetiferous gneisses, associated with mica schists, are also common. Granite occurs farther to the east.

The soils overlying the Donnybrook sandstones are generally sandy, forming sand-plains. In places, however, the clay in some parts of the formation is sufficient to give a loamy soil with a clay sub-soil evidently well suited to the requirements of Jarrah (*Eucalyptus marginata*) which provides timber for the mills near Donnybrook and Nannup. The sand-plain, lying as it does in a region of 35-40 inch annual rainfall may constitute a distinct type in the sand-plains of Western Australia, and the investigation given below was begun several years ago when the writer was examining the heavy minerals of sandplain soils generally. The results for some other types of sand-plain have already been published.

MINERALOGY OF THE DONNYBROOK SANDSTONES.

The specimens examined fall into two groups, actual rock specimens, and soils derived from the weathering of the sandstones. The sandstones were examined by thin section as well as by concentrating the heavy minerals.

The sandstones were crushed until a large quantity of the material passed an 85 B.S. sieve (approximately 70 I.M.M.), the finest particles were washed out, the sample dried, and about 10 to 15 grams were separated in bromoform. The soils were sieved in a similar way and the clay grade of material washed out before bromoform separation. A few of the sands were treated with HCl to remove ferruginous coatings from the grains, but most of them were white or almost white in the natural state so that acid treatment was unnecessary. The heavy residues were not weighed so that no percentage figures are available, but it was found that the residues were fairly large and would have, in all probability, been at least 1 per cent. of the sand separated. Before mounting, magnetite was removed from each residue.

In thin section the Donnybrook sandstone is seen to be a medium to fine-grained rock consisting of about 75 per cent. quartz; the remainder is felspar, both oligoclase and microcline, kaolinite or other clay mineral supplying the binding. The quartz grains are rounded to sub-angular in shape and often show re-growth at the edges; such grains were also found in some of the soils directly derived from the sandstones. The felspars in the sandstones are somewhat kaolinised.

The heavy mineral assemblages contain the following minerals:— magnetite, ilmenite, leucoxene, zircon, tourmaline, rutile, sphene, epidote, zoisite, garnet, amphibole, chlorite, anatase, monazite, kyanite, sillimanite, staurolite, spinel, and muscovite. The suites are rather similar throughout as is shown in Table 1, where the relative abundance is indicated.

Notes on Individual Minerals.

Magnetite, ilmenite, and leucoxene require no comment except to state that all are rather abundant in the residues, particularly magnetite and ilmenite.

TABLE I.

Heavy minerals in the Donnybrook Sandstones and Derived Soils.

Sample Nos.	1	2	3	4	5	6	7	8	9	12	13	14	15	16	17	18	19	20	21	22	23	24	25	4005*
Magnetite	+				+			A+	S	A+	+	+	+	A+	A+	A+	A+	A+	A+	A+	A—	A+	A	+
Ilmenite	+	+	A	A	+	+	+	+	+	+	A+	A+	A+	A	A	A	A	A+	A+	A	+	+	A	+
Leucoxene	+	+	+	+	+	+	+	+	A	+	+	A	A	+	+	+	+	+	+		+	+	+	+
Zircon	+	A	+	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Tourmaline	+	+	+	+	+	+	+	+	+	S	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Rutile	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	A	+	+	+
Anatase						+	+	+	+		S				+					+				+
Sphene	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+
Monazite					+	+		+	+							S								+
Epidote	+		+	+	+	+	+			+		S					S	+	+	S		+		+
Zoisite		+	+																					
Amphibole	+		+		+	+	+			+	S	+	S		+	S		S		+	+	+		
Chlorite	+		+							+						+		S	S					
Garnet	+		+														S					S		
Kyanite	+	+	+			+		+		+	S	S	S	+	+	S	+	S	S	+	S	S		
Staurolite								+		+	S		+	+	+	S		+	+	+		S	+	
Sillimanite		+						+				+	S	S	+		S	S	S	S		S		
Spinel		+											S		+		+							
Muscovite																							S	

*5005 is a residue of a sandstone from one of the main quarries; specimen examined by R. A. Hobson some time ago.
A+ = very abundant; A = abundant; + = present, up to 5%; S = scarce, a few grains only.

Zircon: Zircon is a prominent constituent in all the residues. Colourless, worn grains predominate, and many of these have large inclusions of bubbles and rods; zoning is not a common feature, but occasionally finely-zoned grains occur. Purple zircon is rare, odd grains only being recorded from specimens 6, 13, 18, 25, and 4005. The most deeply coloured grains are pleochroic from a brownish-purple to deep purple and are similar to those found in other sediments in south-western Australia. Purple zircon is known as an accessory in some of the Pre-Cambrian gneisses. Tawny or brownish zircons, possibly derived from the same source as the purple, were obtained in specimens 1, 3, 12, 13, 15, and 16. Most of the zircon grains are more or less rounded but some sharp-edged crystals also occur. The rounding indicates considerable transport, and possibly more than one cycle of sedimentation.

Tourmaline occurs in a variety of colours such as bright yellowish-brown, grey, pinkish-grey, or pinkish-brown, and blue, the latter being scarce. Although tourmaline is a noticeable constituent because of its colour, it does not make up a great part of each residue and little significance can be attached to it except to note that some of the grains are well-rounded and spherical, and hence are probably survivals, along with the rounded zircon, from other cycles of sedimentation.

Although the Pre-Cambrian rocks in the Preston Valley to the east of, and not far from, Donnybrook are comparatively rich in tourmaline, yet it is not a major constituent of the Donnybrook sandstone residues. This is one reason for believing that the Donnybrook sandstones have not been derived from local sources.

Rutile is a fairly prominent constituent. The grains are generally robust and rounded, and of deep reddish-brown colour. In some specimens yellowish-brown grains are also present, but these show very few signs of wear and transport. Yellowish-brown, broken, geniculate twins are found occasionally.

Anatase: As shown in Table 1, anatase is present in about one-third of the specimens. The grains generally vary from steel-grey to pale yellow in colour, but occasionally steel-blue ones are to be found. Both the tabular and octahedral habits occur, the tabular being the more common. Anatase is present only in very small amounts and it must be regarded as an authigenic constituent for the grains are euhedral, unworn, and sometimes two or more small crystals are joined together.

Sphene is fairly plentiful in angular, colourless fragments of "chunky" appearance. It is a constituent of practically all the specimens examined.

Monazite in pale yellowish-green worn grains is characteristic of a number of residues. Its presence is to be expected where granitic material has been incorporated in a sediment.

Epidote and zoisite: Epidote in pale yellowish-green, somewhat worn grains occurs in about three-quarters of the specimens, but zoisite was only recorded in two residues, Epidote never makes up a large part of any residue, and is usually restricted to a few grains.

Amphibole is present in about the same amount as epidote or less and often there are only one or two grains to each slide. The amphibole is the bright bluish-green variety common to the hornblende schists and epidiorites of the Pre-Cambrian complex. That it is not present in greater quantities indicates that greenstones were not being actively eroded during the formation and deposition of the Donnybrook sandstones, for it is a resistant mineral and not easily broken down by weathering. Its scarcity also suggests derivation of the Donnybrook sandstones from older beds or from a terrain which was almost entirely granitic.

Garnet is angular to somewhat rounded, colourless grains is one of the minor constituents, for it occurs as odd grains only in four of the residues. Garnetiferous gneisses were evidently not present to any appreciable extent in the eroded terrain, and the scanty garnet in these residues could have been passed on from a pre-existing sediment.

Kyanite, sillimanite, and staurolite: These metamorphic minerals occur in the majority of the specimens, kyanite being the most prominent. The kyanite grains are usually well-worn, some being almost round, but others are merely broken fragments with "steps" due to breaking along cleavages. Staurolite occurs in more than half the residues as bright, brownish-yellow, strongly pleochroic grains, most of which are either angular or sub-angular. The presence of kyanite, sillimanite, and staurolite indicates that at some time Pre-Cambrian meta-sediments contributed material to the Donnybrook sandstones, but in view of the scarcity of these minerals, with the exception of kyanite, it is unlikely that they were derived directly, i.e. these minerals have come to the Donnybrook sandstones via some earlier sediment. No sources for these minerals are known in the Donnybrook district, but, as mentioned previously, there is little detailed knowledge of the Pre-Cambrian complex in the vicinity.

Spinel: Odd grains of green spinel were found in four of the residues. Spinel is commonly present in residues derived from the Pre-Cambrian in the south-western part of Western Australia. These spinel grains are well-worn, but otherwise are typical.

Muscovite: With typical platy habit is only present in one residue.

SIGNIFICANCE OF DETRITAL HEAVY MINERALS IN THE DONNYBROOK SANDSTONES.

It has been stated (Saint-Smith, 1912, p. 21) that the Donnybrook sandstone has been derived more or less directly, with little transport, from the weathering of the Pre-Cambrian rocks upon which it rests. The heavy residues show that this is rather unlikely, for the minerals which are known to be present in the underlying and surrounding Pre-Cambrian rocks are poorly represented in the residues separated from the sandstones. Moreover, a feature which was not known when Saint-Smith's statement was made, is that most of the heavy mineral grains have been rounded by abrasion during transport. Again, although there is a considerable number of minerals in the residues, zircon is the only one of the non-opaque minerals which is present in large quantities, and this suggests that part at least, of the formation was derived from a pre-existing sedimentary series.

The assemblages are dominantly granitic as shown by zircon, tourmaline, sphene, and monazite. Minerals derived from greenstones occur very sparingly, as do the metamorphic minerals of which the most conspicuous is kyanite, the most resistant of these to weathering and abrasion. Andalusite, which generally accompanies these metamorphic minerals, is absent. This suggests some transport of the material, from the place of origin, for andalusite does not seem to be able to survive much abrasion. The almost complete absence of garnet and the scarcity of tourmaline in most of the residues is conclusive evidence that the source was not in the Donnybrook district, for garnetiferous and tourmaline-bearing rocks are plentiful in the Preston Valley, but these rocks were evidently not uncovered when the sandstones were being laid down. The scarcity of amphibole, which makes up a very minor part of the residues, suggests deposition some distance from the source and also possible re-working of a sedimentary series.

The above interpretations of the mineralogy must be regarded as tentative only, for the specimens examined come from a rather small area. It is known, too, that most have come from near the top of the formation, so that a very different picture might be obtained if the lower members could also be examined. Nevertheless, this investigation will, it is hoped, provide a basis for future work on these sediments, and it is also hoped that the Collie Coal Measures may be examined. It has been suggested, on the one hand, that the Coal Measures have been protected in a graben (Woolnough, 1916, p. vi), and, on the other that they were deposited in a separate basin, (Woodward, 1894, p. 548). Examination of the heavy minerals may be expected to indicate which of these theories is correct. If the graben theory is supported, then the heavy minerals may afford a means of correlation between the Donnybrook sandstones and the Collie Coal Measures. If the separate basin theory seems more probable, then it is unlikely that the detrital heavy minerals will be helpful in the correlation of the coal measures with any part of the Donnybrook sandstones. Saint-Smith (1912 p. 22) has suggested that the Donnybrook sandstones are stratigraphically above the Coal Measures; the examination of the detritals in the Donnybrook sandstones suggests the possibility that part of the Coal Measure sandstones was eroded to form the Donnybrook sandstones. Few outcrops, lateritic cappings, and heavy timber make field work difficult. Also, over a considerable part of the area where Coal Measures or Donnybrook sandstone occur, more recent lake beds further obscure stratigraphical details (Woolnough, 1916, 9. v.)

The fact that the latest dissection of the plateau has uncovered and eroded large hills in the Pre-Cambrian along the Preston Valley, and that these hills are higher than most of the Donnybrook sandstone outcrops, suggests that the lake or estuary in which they were laid down had an irregular floor caused by previous erosion, and that some of these older surfaces are now being once again eroded, possibly because of a general uplift of this part of the country. The Pre-Cambrian rocks on the northern side of the Preston Valley may have been a land surface which effectively blocked any communication between the Collie "lake" and the Donnybrook "lake." Erosion appears to have removed a considerable thickness of the Donnybrook formation, and this has contributed to the Tertiary beds in the coastal plain.

ACKNOWLEDGMENTS.

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My thanks are due to Professor E. de C. Clarke for reading through this paper and for many helpful suggestions.

REFERENCES.

Forman, F. G., 1936: Inspection of Gold Prospecting at Donnybrook: *Ann. Prog. Report Geol. Survey W. Aust.* for 1935, p. 4.

Maitland, A. Gibb, 1939: The Donnybrook Sandstone Formation and its Associates: *Jour. Royal Society W. Aust.*, Vol. **XXV**., p. 177.

Saint-Smith, E. C., 1912: A Geological Reconnaissance of a Portion of the South-West Division of Western Australia: *Geol. Survey W. Aust.*, Bull. 44.

Woodward, H. P., 1894: Notes on the Geology of Western Australia: *Geol. Mag.* (Dec. IV.), Vol. **I.**, p. 545.

Woolnough, W. G., 1916: Report of the Royal Commission on the Collie Coal Industry, Perth, By Authority, pp. v.-x.

16.—THE OCEAN BIRDS OF THE PERTH BEACHES.

By L. GLAUERT.*

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The study of the ocean birds cast away on our local beaches may be said to have commenced in the winter of 1915, when W. B. Alexander, M.A., then on the staff of the Museum, collected a number of Prions and a Petrel at Cottesloe Beach. Two years later, the late F. L. Stronach, a retired civil servant living at North Cottesloe, became interested, and during the next few years was partly responsible for the rapid growth of the Museum's collection of Procellariiformes, his bag on one occasion consisting of no less than 20 specimens, representing six species, and ranging from a yellow-nosed Albatross or Mollymawk to the white-faced Storm Petrel.

On my return from active service in 1920 I took up residence near the coast and from then onwards regularly patrolled the local beaches in the winter time, now and again securing specimens of unusual interest. To my lasting regret I failed to realise the importance of a flock of over 20 Prions which had come to grief against the wall of a dressing shed at North Cottesloe in 1921.

My successes induced Dr. A. L. Serventy to become interested, and he in turn influenced the veteran collector, H. Lawson Whitlock, then living in Perth, to participate in the search for "Ocean Derelicts." Unfortunately little of the material these expert collectors secured found its way into the Museum, although details published in the "Emu" have made possible the incorporation of their results in this paper.

The material obtained differed from year to year, no doubt owing to the direction, intensity and duration of the gales. In this connection it may be noted that Prions, which were very plentiful 20 years ago, have been scarce during the last year or two, whilst the Cape Pigeon or Pintado Petrel, first recorded in 1920 and subsequently a great rarity for several years, was undoubtedly the commonest victim of recent winter storms, if we except the much larger Giant Petrel or Nelly, which appears in numbers every year.

The area covered by this paper ranges from Safety Bay, south of Pt. Peron to North Beach, a distance of about 30 miles.

Birds haunting coastal waters or the shore are not included.

A key has been appended to assist in the identification of the species dealt with in this paper. It has a purely local value and so would be of little use on our south coast or in the Eastern States where a different avifauna occurs, although some forms are found both here and there.

Pygoscelis adeliæ (Hombr. & Jacq.). Adelie Penguin.

The Museum possesses a specimen, A4819, caught near City Beach on Easter Monday, 1937. As some Japanese whalers had called at Fremantle a short time before it is most probable that the bird was an escaped pet.

Eudyptes crestatus moseleyi (Math. & Iredale). Rock Hopper.

A specimen captured alive on Rottnest Island in 1909 is the only local record, although hardly a year passes without one or more living birds coming ashore somewhere in the lower South-West.

*Communicated by permission of the Trustees.

Eudyptula minor woodwardi (Math.). Little Penguin.

This bird breeds upon Penguin Island and adjacent islets where it persists in spite of the persecution suffered at the hands of visitors. Unless the protection under law is made more effective it is only a question of time before it is driven away from these local breeding grounds. The bird is said to go "far out to sea" in search of its food.

It is doubtful whether the separation of the western bird from the eastern *E.m. novæhollandiæ* (Stephens) is justified.

Diomedea exulans (Linne). Wandering Albatross.

There is no record of this bird from local beaches, the Museum material having been obtained at Bunbury, Hamelin Bay, or out at sea. The species is included because on 20th October, 1938, birds which had been following the ships all morning remained with us until Rottnest was sighted. The species breeds on Kerguelin, the home of so many of our ocean waifs.

Diomedea (Thalassarche) melanophrys melanophrys (Temminck). Black-browed Mollymawk.

This shy and solitary species is but scantily represented in the collection by A1787, an adult found at Cottesloe, 21st August, 1920, a skull, A4618, from Swanbourne, July 1935, and a young female obtained at Swanbourne on 1st June, 1941, A5490. F. Lawson Whitlock also records the bird from local beaches.

Diomedea (Thalassogeron) chlororhynchos (Gmelin). Yellow-nosed Mollymawk.

This is undoubtedly the commonest of our albatrosses. It can be seen off the south coast at all times of the year and in the winter months its range is as far as north of Shark Bay, the type of Rothschild's *carteri* having been collected at Point Cloates. There are 16 entries in the Museum register since 1912.

Diomedea (Thalassogeron) chrysostoma (Forster). Grey-headed Mollymawk.

The first local record was a bird captured alive on the sandhills at Cottesloe in June, 1917, A1257, by the late F. L. Stronach, who for several years forwarded much valuable material to the Museum. Additional specimens from Cottesloe are A1776, 21st June, 1920, A2788, 23rd July, 1926, and A4646, 2nd September, 1935.

Dr. W. Macgillivray has suggested that Australian specimens have their breeding ground somewhere in the vicinity of St. Paul or Amsterdam Islands.

Macronectes giganteus (Gmelin). Giant Petrel.

This giant among the Procellariidæ rivals the albatrosses in size and so is often wrongly identified as a Sooty Albatross of which there are, as yet, no records from local beaches. In spite of its size it is one of the most frequent victims of winter gales, a number, nearly all young birds, reaching the Museum every year. Since 1912 no less than 38 have been presented or collected locally.

The majority are in the dark first juvenal plumage with few or no white feathers about the face. Other forms are occasionally met with showing a varied amount of white about the head.

A bird which struggled ashore at Cottesloe on 1st July, 1940, and was photographed before it recovered its strength and flew off to sea had a white chin. The Museum also has a white specimen, A4837 (male), found at Busselton in June, 1937, and a breeding bird with whitish head and neck, A5076 (male), caught at Australind by Mr. E. Matters in September, 1939. A description of this bird is given in an appendix.

Another bird, A5183, with dark crown, grey face and white chin and throat was received on 25th September, 1940, from Mr. A. V. Newman of Cape Leeuwin, who killed it after it had attacked two ladies on the beach. As the internal organs had been removed the sex could not be determined. Like A5076 it had a limy incrustation at the base of the upper mandible. It has been stated that this is a characteristic of female birds, yet A5076 was sexed by the Museum taxidermist, Mr. O. H. Lipfert, as a male.

Daption capensis (Linne). Cape Petrel.

This striking bird, though known to be common to the south of Australia, was first added to the list through the late F. L. Stronach's discovery of a male at Cottesloe on 23rd June, 1920. Since then no less than 24 specimens have reached the Museum from local beaches, one storm in 1939 yielding no less than eight. Both white-chinned and black-chinned birds were represented.

Halobaena caerulea (Gmelin). Blue Petrel.

The first local specimen A2299 was found at North Fremantle by Mr. B. R. Lucas on October 26th, 1921, a second skin has the data A4669 (male) Leighton, September 24th, 1935, Kevin Jeffrey. The bird's presence is also noted by F. Lawson Whitlock and Dr. D. L. Serventy. The bird is rare in collections.

The Blue Petrel resembles the Prions from which it can be distinguished by its larger size and the white tips to the tail feather. There is also an absence of the pectinations so highly developed in the upper mandible of the Whale bird.

Genus **PACHYPTILA.**

The Prions have long been recognised as a most puzzling group of birds, superficially, except for the shape and structure of the bill, they are very much alike, forming a series which might logically be included in one species as was suggested by Loomis. However, the study of birds from different nesting sites suggests that the matter is not so simple. The most recent reviewer, R. A. Falla (1940) recognises the following species and subspecies from localities in the Southern Indian Ocean from which the birds on our local beaches may be presumed to have travelled although there is always the possibility that birds from other nesting sites are present as they are known to range far afield.

Pachyptila vittata macgillivrayi (Mathews). St. Paul Island.

Pachyptila salvini salvini (Mathews). Marion Island.

Pachyptila salvini crozeti (Mathews). Crozet Islands.

Pachyptila (Heteroprion) desolata desolata (Gmelin). Kerguelen, Macquarie Islands. Antarctica (Cape Denison).

Pachyptila (Heteroprion) belcheri (Mathews). Kerguelen, Falkland Islands.

Pachyptila (Pseudoprion) turtur fallai (Oliver). ? Southern Indian Ocean.

Pachyptila (Pseudoprion) crassirostris eatoni (Mathews). ? Kerguelen.

One hundred and thirty-five of these little birds have reached the Museum from local beaches since 1912 suggesting that along the extensive coast line of South-Western Australia thousands must be cast up every year.

The great majority of our material falls within the limits of *P.salvini* and *P.desolata*, broad-billed *P.vittata* and small-billed *P.turtur* being rarely met with. Until we know more about the nesting sites of prions and the changes that take place with increasing age the separation of forms by the size, shape and structure of the bill alone will increase not diminish the confusion existing today.

Puffinus (Ardenna) carneipes (Gould). Fleshy-footed Petrel.

This resident of the southern coast though migrating north and south each year is rarely cast up on metropolitan beaches. The Museum records are confined to A999 found at Cottesloe, May 13th, 1916, and A3861 caught alive at Como on the Canning River, May 14th, 1931. Mr. F. Lawson Whitlock mentions that a number "came ashore during October both locally and at Bunbury."

It would seem that the northward journey is undertaken in October and the movement south in May. Gould's type locality is "islands off Cape Leeuwin."

Puffinus (Thyellodroma) pacificus chlororhynchus (Lesson). Wedge-tailed Petrel.

This petrel, locally known as the Mutton Bird, breeds on Rottnest where its burrows are tunnelled in the sandy soil near Point Peron. It also inhabits Carnac. Specimens from both islands are in the Museum collection. The following may be regard as local victims of the storm A3858 Welshpool Road, 10 miles east of Perth, May 12th, 1931, A4485 (male) North Fremantle, September 19th, 1934, A5191 Cottesloe, October 8th, 1940, A5192 Cottesloe (female), October 8th, 1940.

The islands off Fremantle appear to be the southern limit of the bird's breeding range on the west coast of Australia.

Puffinus assimilis glauerti (Math.).* Little Shearwater.

This little bird every year falls a victim to winter gales. It is known to breed upon the Houtman's Abrolhos, and is probably the form recorded as breeding on Rottnest Island by Angus Robinson. Twenty-five local specimens have reached the Museum since 1912, a very high figure when it is recalled that local species rarely succumbed during the gales, probably because their knowledge of the locality enables them to find adequate shelter.

Pterodroma lessonii lessonii (Garnot). White-headed Petrel.

The first record of this rather rare petrel is A818 found at Cottesloe Beach by W. B. Alexander in August, 1915. Additional skins in the collection are A2531 found at Cottesloe, October 15th, 1922; A4456 from Leighton, July 6th, 1934, and A5005 from North Beach, June 30th, 1939. The stomach of the last bird contained a cephalopod beak and the remains, shell and flesh of a spirula.

*Mathews, G. M., *Emu*, Vol. XXXVI., April, 1937, p. 278.

Pterodroma macroptera albani (Math.). Grey-faced Petrel.

This bird which breeds on certain islets off our south coast occasionally appears as an ocean derelict on local beaches. The Museum skins are A2946 (male) Cottesloe, July 9th, 1928, A5060 (female) Cottesloe, August 28th, 1939, A5187, Cottesloe, October 7th, 1940. In addition there are A4257, Maddington, October 31st, 1932, and A3625 (young female) Northam, November 14th, 1929.

The local bird is intermediate between the typical bird from Kerguelen described by Falla and the sub-species *gouldi* from Eastern Australia and New Zealand in the amount of grey on the face and measurements.

Pterodroma mollis mollis (Gould). Soft-plumaged Petrel.

This attractive bird was first added to the local list through the discovery of a specimen on the beach at Cottesloe by the late F. L. Stronach on August 8th, 1919, A1646 (female). Other specimens from Cottesloe in the Museum are A1767 (female) May 29th, 1920, A2588 August 25th, 1923, and A5042 (female) August 21st, 1939; A5064 (female) was found at North Fremantle, August 28th, 1939. In addition there are other records of material preserved elsewhere.

Pterodroma lugens (Kuhl).* Kerguelen Petrel.

This bird distinguishable from all other dark petrels as yet known to have been found locally by its smaller size and dark grey plumage was first recorded from Australian beaches by F. Lawson Whitlock in 1927, the specimen having been found at Cottesloe Beach on June 3rd of that year.

The Museum has a skin from Leighton A4672 (female) collected September 24th, 1935, and a skull A4679 from remains found on the same beach a month later.

Further finds are recorded by Dr. Serventy.

Oceanites oceanicus parvus (Falla). (?) Wilson Storm Petrel.

Two Wilson Storm Petrels were collected on Cottesloe Beach by Dr. D. L. Serventy on May 29th, 1926. These are the only local records supported by material. The male A2790 in all its measurements, except the tail, is close to the type of Falla's sub-species from Royal Sound, Kerguelen, it also has the "less defined pale edging on the greater wing coverts." The female A2791 is somewhat larger and has well defined whitish edges to some of the greater wing coverts as in the typical form. The above name is therefore given with some hesitation.

Pelagodroma marina dulciæ (Math.). White-faced Storm Petrel.

Now and again specimens are found on local beaches after stormy weather. The Museum records are: A1631, A1644, A1650, A2960 and A5186 from Cottesloe and A2948 from Fremantle. The bird is known to breed on islets off the coast.

Phæthon rubricauda westralis (Math.). Red-tailed Tropic Bird.

This northern bird at times visits the Perth area. On December 30th, 1928, a couple flew so low in a southerly direction at Cottesloe that their characteristic tail feathers could be recognised with the naked eye. Several

***Pterodroma brevirostris* (Lesson) auct.

others have been seen since that date. The Museum has a specimen A2754 shot at Gingin and a second A5092 caught whilst incubating its eggs on the beach at Busselton. I have also had a report that a bird had been seen flying low at Albany "five or six years ago."

Morus serrator serrator (Gray). Australian gannet.

A few individuals make their appearance in Gage Road and Cockburn Sound every winter. The local specimens in the collection are A4168 found on the Fremantle Railway Bridge in June, 1932, and A4851 from North Fremantle, July, 1937. There is also a mounted specimen C461 found at Cottesloe in 1896.

Fregata minor minor (Gmelin). Greater Frigate Bird.

A specimen, A1252 caught alive on Mount's Bay Road on May 4th, 1917, is the only evidence of the presence of the species as a wanderer near Perth.

Catharacta skua lönnbergi (Math.). Brown Skua.

Two or three birds can usually be seen off Fremantle in the winter months. The bird might be mistaken for a large mutton bird but can always be distinguished by its heavy body and more laboured flight. When closer the white patch on the wings acts as a good identification mark. It is a scavenger and usually hunts its own food though it may harass other sea birds but not to the same extent as the Arctic or Parasitic Skua. The Museum possesses a single specimen A2366 secured out at sea.

Stercorarius parasiticus (Linne). Arctic Skua.

The Arctic or Parasitic Skua which breeds in the northern hemisphere is a regular summer visitor to our shores and can often be seen pursuing the twisting and turning Silvergull or Tern until the recently caught fish is disgorged. Both light and dark phases are represented every year. A character of the species is the somewhat elongated *not twisted* central tail feathers. F. Lawson Whitlock records that on one occasion he found an exhausted bird on the beach at Cottesloe, which, however, managed to elude capture.

Stercorarius pomarinus (Temminck). Pomarine Skua.

The Pomarine Skua is another northern visitor to Gage Roads in summer time. It is smaller than the Brown Skua and somewhat larger than the Arctic Skua from which it can be distinguished at close quarters by the curious twist in the somewhat elongated central tail feathers. Light and dark phases occur.

Observations made from the "Zephyr" when travelling to or from Rottnest indicate that it is rarer than the Parasitic Skua.

Sterna dougallii gracilis (Gould). Roseate Tern.

The Roseate Tern breeds upon the Houtman's Abrolhos. North-west gales at times bring it south, as is shown by the single specimen, A5029, in the Musuem collection. The bird was found dead at Scarborough in July, 1939. F. Lawson Whitlock also records its presence at Cottesloe.

Sterna fuscata glauerti (Math.). Sooty Tern.

The Sooty Tern breeds on the Houtman's Abrolhos. A specimen, A1511, obtained on the Swan River in December, 1917, is the only local material in the Museum. This bird arrives at its nesting site in September, leaving again about April.

Anous tenuirostris melanops (Gould). Lesser Noddy.

This bird, which nests in great numbers on the Houtman's Abrolhos, is now and again blown into local waters and cast ashore dead or alive after severe north-westerly gales.

Specimens obtained in the vicinity of Perth and now in the Museum collection are A2689, A2696, A2789, A4805, A4996, A5001, A5065, and A5070.

F. Lawson Whitlock also records the species from Cottesloe.

APPENDIX.

DESCRIPTION OF AN ADULT *MACRONECTES GIGANTEUS* FROM AUSTRALIND, NEAR BUNBURY.

This specimen, A5076, is of interest as it is the first representative of the mature or brownish-grey colour phase with white head and neck to reach the Museum. This bird belongs to the "intermediate phase with white head and neck." The back from the zone of transition at the neck to the tail is uniform greyish or dark-brownish grey according to the lighting, the feathers all having blackish shafts and in most cases lighter edges. The tail is lighter with less brown and the under tail coverts whitish. On the head the forehead is white, the crown mottled, some of the feathers being grey at the tip, the hind neck pale almost white, sides of the face white with a few pale grey feathers on the cheeks and near the gape, chin and throat white, the feathers in these parts being white to the base. The under parts are mottled greyish, the individual feathers being either uniform greyish or becoming darker towards the tip with, in many instances, brownish-grey edges, probably due to wear. In all cases the shafts are light, almost white. Feathers on the legs greyish, almost white towards the base. In general appearance the bird seems to resemble those illustrated by Falla (B.A.N.Z. Antarctic Research Expedition, Vol. II., Birds, figure 133, right foreground, Caroline Cove, Macquarie Island).

The soft parts of the bird when received were:—Iris dark, feet reddish slate, webs brownish-grey, claws horn, bill whitish horn with limy incrustation at the base of the upper mandible. Measurements taken:—Length 932, wing 520, tail 216, tarsus 101, culmen 99, width 33.5, depth 38.5. Sex—male. (O.H.L.)

KEY TO THE SPECIES.

1.	Flightless birds	2	
	Active flying birds	3	
2.	Large birds, white ring round eye ...	*Pygocelis adeliae* (Hombr. & Jacq.)	
	Medium sized birds with yellow crests	*Eudyptes crestatus moseleyi* (M. & I.)	
	Small birds yellow crests absent ...	*Eudyptula minor woodwardi* (Math.)	
3.	Nostrils at the end of a longer or shorter tube	... ...	4
	Nostrils normal	... ...	22
4.	Size large (Albatrosses and giant petrel)	... ...	5
	Size smaller (Petrels, Prions, Storm petrels)	... ...	9
5.	Tube extending almost to the tip, bill heavy	*Macronectes giganteus* (Gmelin)	
	Nasal tubes short	... ...	6
6.	Size large, wing spread to 12 ft. or so ...	*Diomedea exulans* L.	
	Size smaller, wing spread to 8 ft. or so ...	7	
7.	Culminicorn* and latericorns in contact behind the nostrils	*Diomedea melanophrys* (Temm.)	
	Culminicorn and latericorns *not* in contact behind the nostrils	8	
8.	Culminicorn broad, rounded basally ...	*Diomedea chrysostoma* (Forster.)	
	Culminicorn narrow, bluntly pointed basally	*Diomedea chlororhynchos* (Gmel.)	
9.	Blue-grey above, white below	10	
	Blackish above, white below	16	
	Dark brown or dark grey above and below	18	
10.	Tail broadly tipped with white ...	*Halobaena caerulea* (Gmel.)	
	Tail broadly tipped with black ...	*Pachyptila* species	11
11.	Black tip to tail wider (40 mm.), bill less than 25 mm. in length	*P.* (*Pseudoprion*)	12
	Black tip to tail narrower (to 30 mm.), bill more than 25 mm. in length ...	... ...	13
12.	Width of bill $10\frac{1}{2}$ to $12\frac{1}{2}$ mm.	*P.Ps. crassirostris* (Math.)	
	Width of bill 8 to 11 mm.	*P.Ps. turtur* (Kuhl.)	
13.	Lamellae in upper bill well developed, visible when the bill is closed ...	*P. Pachyptila*	14
	Lamellae rudimentary *not* visible when the bill is closed	*P.* (*Heteroprion*)	15
14.	Width of bill 18 mm. or *more*, length 33 mm. and more	*P.P. vittata* (Forster)	
	Width of bill 17 mm. or *less*, length to 33 mm.	*P.P. salvini* (Math.)	
15.	Width of bill 12 to 15 mm.	*P.* (*Heteroprion*) *desolata* (Gmel.)	
	Width of bill 10 to 12 mm.	*P.* (*Heteroprion*) *belcheri* (Math.)	
16.	Head dark grey, back white with black blotches	*Daption capensis* (L)	
	Head white, back grey, size large ...	*Pterodroma lessonii* (Garn.)	
	Head and back dark brownish-grey, size medium	*Pterodroma mollis* (Gould)	
	Head and back dark, below white, size smaller	... ...	17
17.	Head and back blackish, face white ...	*Puffinus assimilis* (Gould)	
	Head and back dark slate, face white, dark stripe below the eye to the ear coverts	*Pelagodroma marina* (Lath.)	
18.	Size small approximating a willy wagtail, upper tail coverts white	*Oceanites oceanicus* (Kuhl.)	
	Size larger approximating a magpie, upper tail coverts like the back ...	... ...	19
19.	Bill long and slender	*Puffinus*	20
	Bill short and deep	*Pterodroma*	21
20.	Sooty black, tail square	*Puffinus carneipes* (Gould.)	
	Sooty brown, tail wedge-shaped ...	*Puffinus pacificus* (Gmelin).	

21.	Sooty black, larger	*Pterodroma macroptera* (Smith)	
	Slaty grey, smaller	*Pterodroma lugens* (Kuhl.)	
22.	Plates of upper bill distinct	... ...	23
	Plates of upper bill fused more or less completely	... ...	25
23.	Size larger, brown with white wing patch	*Catharacta skua* (Brunn)	
	Size smaller, usually dark above and paler below †	... ...	24
24.	Central tail feathers elongated, twisted	*Stercorarius pomarinus* (Temm.)	
	Central tail feathers elongated, *not* twisted	*Stercorarius parasiticus* (L.)	
25.	Bill long, slender, hooked at the tip ...	*Fregata minor* (Gmelin)	
	Bill shorter, stouter, not hooked at tip	... ...	26
26.	Size larger	... ...	27
	Size smaller	... ...	28
27.	Middle tail feathers elongated, narrow, red	*Phaethon rubricauda* (Boddaert)	
	Middle tail feathers, *not* elongated, *not* narrow, *not* red	*Morus serrator* (Gray)	
28.	Dark with whitish head	*Anous tenuirostris* (Temm.)	
	Dark upper parts, whitish below ...	*Sterna fuscata* (L.)	
	Upper parts pale grey, under parts with rosy sufusion in life	*Sterna dougallii* (Montagu)	

* The upper bills of Albatrosses, Mollymawks, Prions and Petrels consist of three plates, the culminicorn terminating in the nail or dertrum and flanked on either side by a latericorn. The arrangement of these plates is important, in *D. exulans* and *D. melanophrys* the culminicorn is in contact with the latericorns behind the nostrils whilst in *D. chlororhynchos* and *D. chrysostoma* it is separated from them. In *D. chrysostoma* the culminicorn is broad and rounded basally but in *D. chlororhynchos* it is narrow and bluntly pointed.

† A darker phase in the species of *Stercorarius* also occurs off our coast.

BIBLIOGRAPHY.

Alexander, W. B.: Birds destroyed by Storms. *Emu*, Vol. XV., Jan., 1916, p. 195.

Alexander, W. B.: Procellariiformes in Western Australia. *Emu*, Vol. XVII., July, 1917, p. 40.

Alexander, W. B.: Crested Penguins in Western Australia. *Emu*, Vol. XIX., April, 1920, p. 295.

Alexander, W. B.: Australian species of Tubinares. *Emu*, Vol. XX., July and Oct., 1920, pp. 14 and 66.

Alexander, W. B.: The Birds of the Swan River District. *Emu*, Vol. XX., Jan., 1921, p. 149.

Alexander, W. B.: Observations and Records of Australian Sea Birds. *Emu*, Vol. XXI., April, 1922, p. 261.

Anon.: New Bird for Australia. *Emu*, Vol. XXVI., Oct., 1926, p. 136.

Campbell, A. J.: Nests and Eggs of Australian Birds, 1900. The Kerguelen Petrel. Pterodroma brevirostris. *Emu*, Vol. XXVI., Jan., 1927, p. 153.

Conigrave, C. P.: Penguin astray. *Emu*, Vol. IX., Oct., 1909, p. 92.

Falla, R. A: Birds seen between Fremantle and Durban. *Emu*, Vol. XXIX., January, 1930, p. 175.

Falla, R. A.: B.A.N.Z. Antarctic Research Expedition, 1929-1931. Reports, Series B, Vol. II., Birds Aug., 1937.

Falla, R. A.: Crested Penguins in Western Australia. *Emu*, Vol. XXXVII., Jan., 1938, p. 197.

Falla, R. A.: The genus Pachyptila Illiger. *Emu*, Vol. XL., Oct., 1940, p. 218.

Ferguson, E. W.: Observations on Albatrosses at Sea. *Emu*, Vol. XV., April, 1916, p. 243.

Ferguson, E. W.: Notes on some Australian Tubinares. *Emu*, Vol. XXI., Oct., 1921, p. 104.

Fleming, C. A.: Birds of the Chatham Islands. *Emu*, Vol. XXXVIII., Jan., 1939, p. 398.

Glauert, L.: Petrels and Albatrosses. *Jour. Roy. Soc. of Western Aust.*, Vol. VII., 1920 (1921), p. 22.

Glauert, L.: Contributions to the Fauna of Rottnest Island No. 1. *Jour. Roy. Soc. of W. Aust.*, Vol. XV., 1928 (1929), p. 37.

Glauert, L.: Victims of Storms. *Emu*, Vol. XXXIX., Oct., 1939, p. 136.

Hindwood, K. A.: The occurrence of crested Penguins in Australian Waters. *Emu*, Vol. XXXVII., Jan., 1939, p. 377.

Iredale, T.: Australian Petrel Forms; still more to learn. *Emu*, Vol. XXIII., Oct., 1923, p. 96.

Iredale, T.: The Snowy Albatross again. *Emu*, Vol. XXVI., April, 1927, p. 282.

Iredale, T. and Cayley, N. W.: Australian crested penguins. *Emu*, Vol. XXV., July, 1925, p. 1.

Kilpatrick, A. G.: Birds of Rottnest Island. *Emu*, Vol. XXXII., July, 1932, p. 80.

MacGillivray, W.: Notes on Sea Birds. *Emu*, Vol. XIX., Jan., 1920, p. 162.

MacGillivray, W.: Birds from a Coastal Boat. *Emu*, Vol. XXVII., Oct., 1927. p. 92.

Mathews, G. M.: The Birds of Australia, Vol. II., 1912-1913.

Mathews, G. M.: Austral Avian Record, Vol. III., 1916, p. 55.

Mathews, G. M.: A check-list of the Order Procellariiformes. *Novitates Zoologicæ*, Vol. XXXIX., 1934, p. 151.

Mathews, G. M.: Remarks on Prions. *Emu*, Vol. XXXVII., Oct., 1937, p. 118.

Mathews, G. M.: Pachyptila or Prions. *Emu*, Vol. XXXVII., April, 1938, p. 280.

Mathews, G. M. and Iredale, T.: A Manual of the Birds of Australia, 1921.

Robinson, A.: Little Shearwater breeding on Rottnest Island. *Emu*, Vol. XXXIV., April, 1935, p. 314.

Serventy, D. L.: Notes on Western Australian Petrels. *Emu*, Vol. XXXVII., July, 1937, p. 56.

Serventy, D. L.: Birds of the Islands off Fremantle, Western Australia. *Emu*, Vol. XXXVII., April, 1938, p. 265.

Whitlock, F. L.: Ocean Derelicts. *Emu*, Vol. XXVI., Jan., 1927, p. 154.

Whitlock, F. L.: Further Notes on Ocean Derelicts. *Emu*, Vol. XXX., April 1931, p. 263.

Whitlock, F. L.: Albatrosses and Petrels in the South West (W.A.). *Emu*, Vol. XXXVI., July, 1936. p. 14.

No. 17.—X-RAY ANALYSIS (BY THE POWDER METHOD) AND MICROSCOPIC EXAMINATION OF THE PRODUCTS OF WEATHERING OF THE GINGIN UPPER GREENSAND.

By W. F. Cole.

Read 10th June, 1941 ; Published 17th August, 1942.

INTRODUCTION.

Available geological literature has revealed to the author a scarcity of published data on the weathering products of glauconite or glauconitic greensand. It was first proposed by Glinka (1) that with the loss of lime, potash, magnesia and ferric iron, glauconite was replaced by ferruginous clay. Cayeux (2) was however of the opinion that it alters to limonite. In recent years Denison, Fry and Gile (3) have shown that muscovite and biotite when undergoing weathering in the soil, pass by continuous variations from true micas through stages corresponding to glauconite and illite in composition. The weathering of the micas was accompanied by an increase in water content, decrease in K, and increase in Al at the expense of Fe and Mg. Chemical analyses showed that the final product of alteration of both micas was of about the composition of kaolinite.

In the present study an attempt has been made to identify, by means of the X-ray diffraction method of powder analysis, the weathering products of the upper greensand of Cretaceous age at Gingin, Western Australia (latitude 31° 21′ S., longitude 115° 54′ E.). This method of analysis is briefly described in an earlier paper (4). The microscopic examination was undertaken with the object of determining to what extent the optical properties were consistent with the X-ray conclusions. This work is preliminary to an investigation of the clay content and derivation of copper deficient soils of the Gingin district.

MATERIALS.

Location.—At Gingin, the Cretaceous rocks have the following sequence in descending order :—

1. The Upper Greensand or glauconitic sandstone which contains phosphatic nodules at its base.
2. The Chalk.
3. The Lower Greensand or glauconitic sandstone.

The distribution of these rock types is shown in Fig. 1 (5). The beds are practically horizontal. It is believed that the intermediate chalk is in the form of a lens which thins out to the north and south.

The topography of the country around Gingin is strongly undulating with a number of prominent hills rising above the level of Gingin Brook which immediately west of the town is about 270 feet above sea level. The heights of these hills are : Poison Hill, 724 feet ; Moorgup, 667 feet ; Ginginup, 666 feet ; One Tree Hill, 515 feet and Molecap, 510 feet (6).

Combining the geology and topography it is apparent that the upper greensand will outcrop on the highest hills and the lower hills will be formed from the underlying chalk and lower greensand. Hence in order to obtain specimens of the upper greensand and its overlying soil, a number of localities

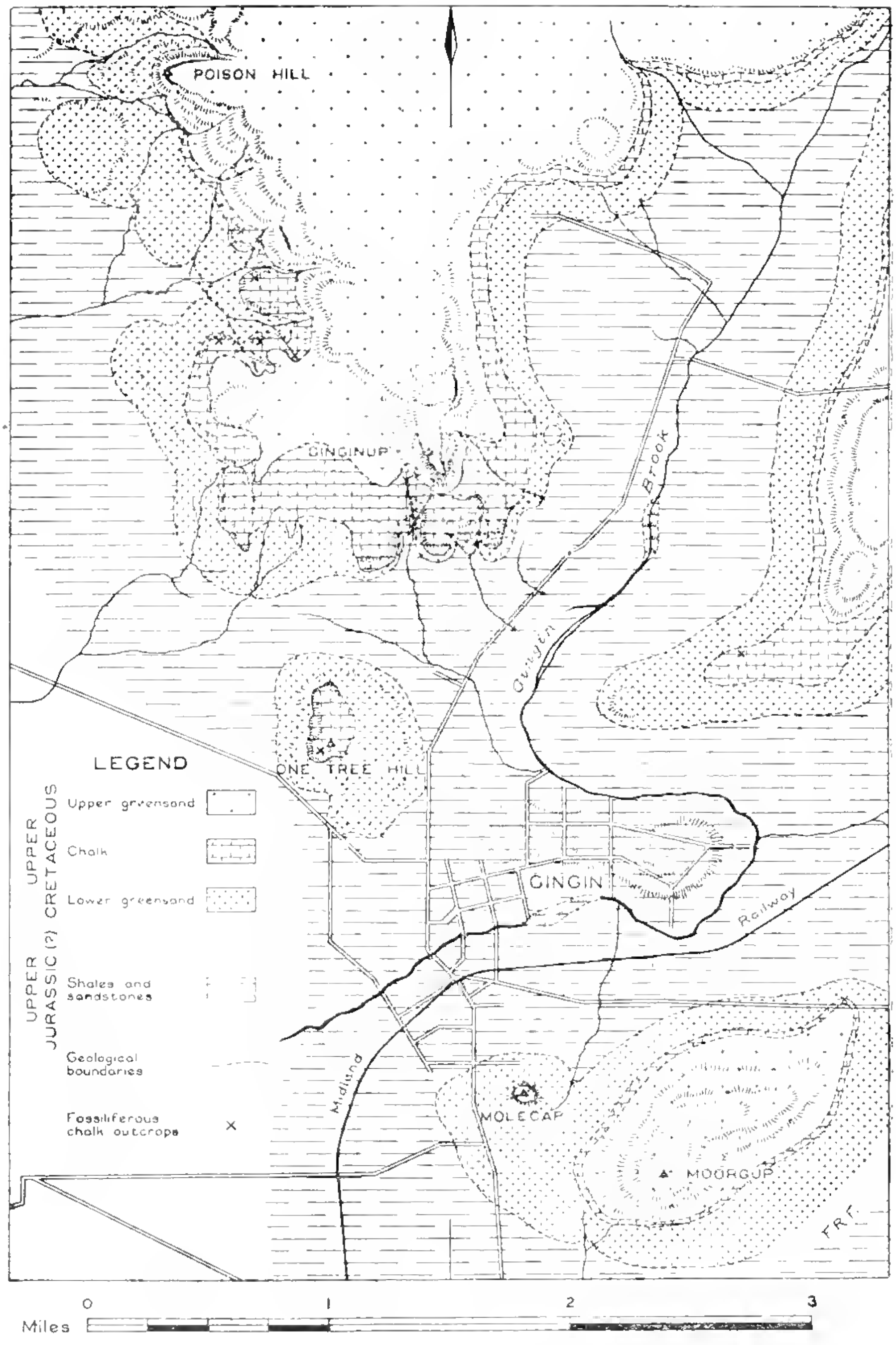

Figure 1.
Geological sketch map of Gingin. Drawn by F. R. Feldtmann and reproduced from "Junior Geology."

were possible but Poison Hill was selected because it is the highest point in the district and thus offers least chance of contamination of the covering soil. Moreover a landslide on the southern slopes of the hill provided a vertical section from which three samples representing (1) soil, (2) subsoil and (3) upper greensand could be taken in the same profile (Fig. 2). Because the various soil horizons are clearly differentiated it is believed that the landslide has not affected the main body of the hill, and that natural contamination is negligible. X-ray evidence indicates a zoning of minerals to be expected from weathering in situ. Artificial contamination would therefore appear to be also negligible.

Professor E. de C. Clarke and Dr. D. Carroll of the Department of Geology of the University of Western Australia supervised the collecting of the samples.

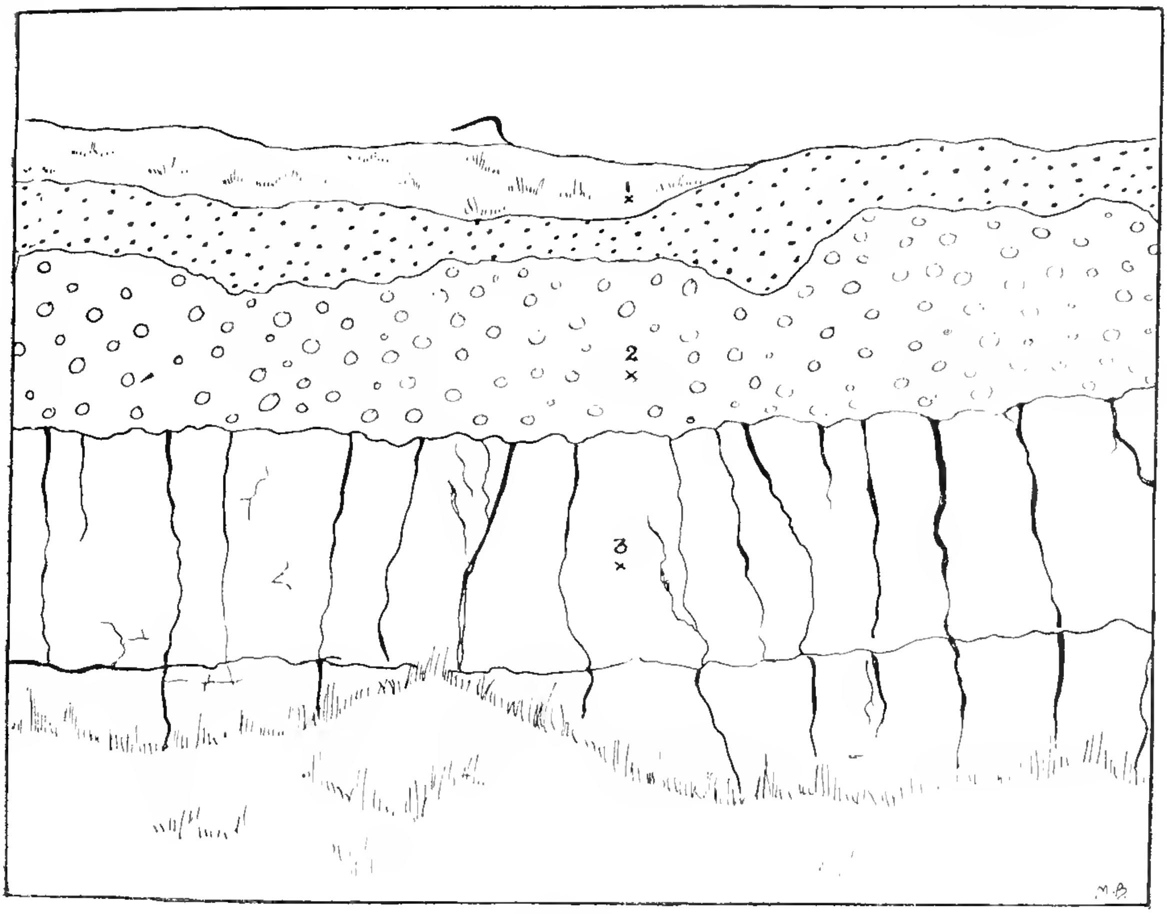

Figure 2.
Sketch of the landslide at Poison Hill, Gingin, from which the three samples representing (1) soil, (2) subsoil, and (3) upper greensand were taken in the same profile. Sample (1) was collected on the surface a little back from the edge of the landslip. The greensand carries vertical joints along which there is secondary deposit and at its base there is a line of ferruginous nodules (about four feet from the top of the greensand bed). The lower portion of the subsoil horizon, close to the greensand contact, contains much weathered greensand.

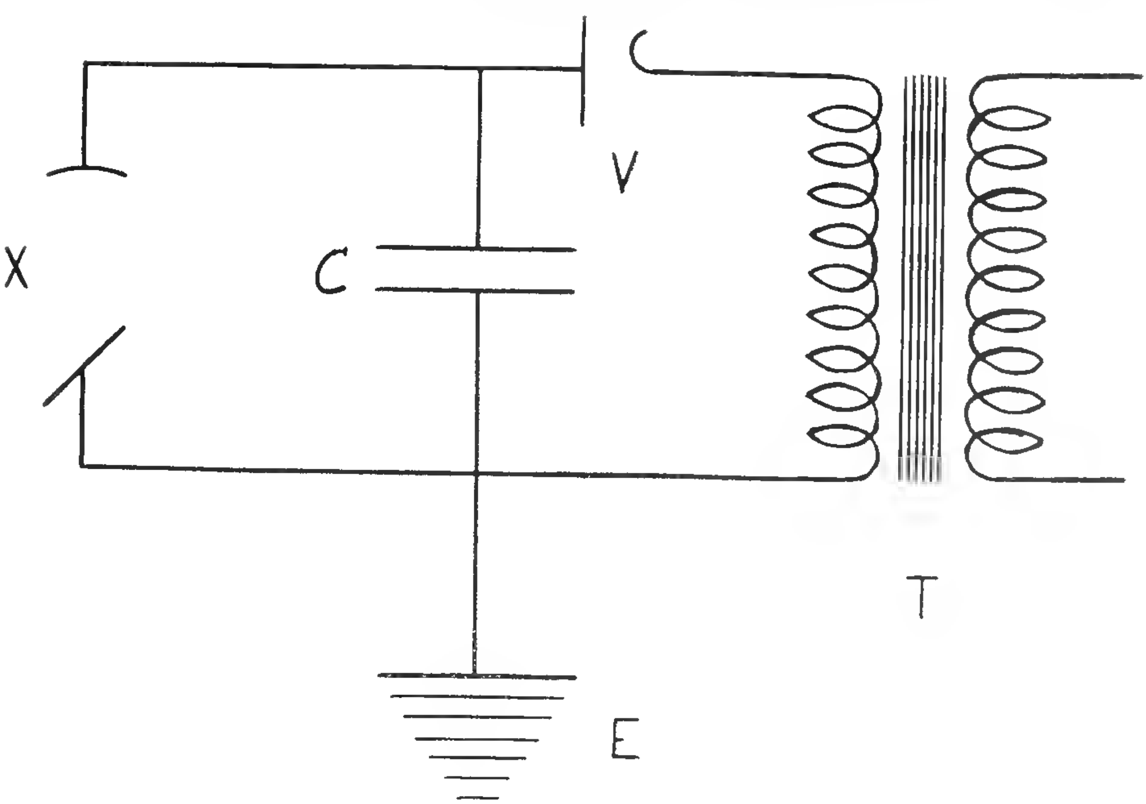

Figure 3.
Diagrammatic arrangement of the high tension unit. X-ray tube (X), Condenser (C), High Tension Valve (V), High Tension Transformer (T), Earth (E).

Method of Separation.—In the preparation of the material for X-ray analysis a number of grades of particle size were separated from each sample, but only two, a coarse fraction of particle size 61 μ and less and a fine fraction of particle size 2 μ and less, were examined.

The coarse fractions were obtained by sieving the three samples through a 250-mesh Tyler standard sieve of screen opening 0·061 mm.

The fine fractions were obtained by elutriation and settling. In the elutriation an Andrews Kinetic Elutriator was used to disperse the particles. Material of particle size 61 μ and less, obtained by sieving, was fed into the elutriator together with the washings off that material which did not pass through the 250-mesh sieve. The run off from the elutriator which carried particles of size 10 μ and less was collected in cylinders and the particles allowed to settle. Depending upon the mean temperature of the laboratory, the settling time was adjusted so that particles of effective diameter 2 μ and less, would fall a distance of 28 cms. At the end of the appropriate time the top 28 cm. was siphoned off and the clay particles removed from suspension by flocculation with calcium chloride, filtration, washing with absolute alcohol and air drying. No attempt was made to remove the organic matter present.

The coarse fractions of the soil, subsoil and greensand were dark brown brown and dark green in colour, whereas in the same order the fine fractions were chocolate brown, light brown and light green.

The amount of clay material collected in this manner was small. This, however, is in keeping with the mechanical analyses of soils overlying the Gingin greensand published by Hosking and Greaves (7). They note that the Wakea sand, which covers both the upper and lower ferruginous sandstones and grits from which it is formed in situ, rarely contains more than 10 per cent. clay.

EXPERIMENTAL DETAILS.

A Hilger-Mueller improved X-ray goniometer spectrograph was used with certain modifications previously referred to (4). Radiation was supplied by a Hilger all-steel water cooled gas X-ray tube. The tube was energised by a high tension unit arranged as in Fig. 3. This unit was modified from a Watson 200 K.V. Constant Potential Deep Therapy set.

Photographs were taken with both Fe and Cu radiation. It was found that films taken with Cu radiation showed a pronounced general scattering which was greatly improved by the use of Fe radiation. This can be explained by the facts that the samples contain minerals of high iron content and that Cu characteristic radiation is capable of exciting Fe characteristic radiation.

The Fe radiation was rendered monochromatic by the use of a manganese filter which served as a window for the X-ray tube. The action of such a filter is to suppress the Kβ radiation and transmit Kα radiation. The advantage of using filtered radiation was realized early in the work when, in examining a film of the greensand (61 μ and less) taken with Fe radiation, it was found that many lines in the central region could be possibly contributed to by the Kβ component. The manganese was electro-deposited on aluminium foil of thickness 25 μ. The method of preparation used is described by Wood (8). With the filter used in the course of this work no trace of the Kβ component appeared even after the longest exposures.

Suitable photographs with Fe Kα were obtained after 16 hours exposure with 4–5 mA tube current at 45–50 K.V. Films with unfiltered Cu radiation could be obtained with shorter exposures. When Cu radiation was used the manganese foil was still retained as a window for the X-ray tube.

For other experimental details regarding mounting of powders, films, etc., reference may be made to a previous publication (4).

ACCURACY OF RESULTS.

In this work the determination of d/n by a graphical method previously described (4) was not resorted to. The interplanar spacings were determined by a direct calculation from the Bragg equation $n\lambda = 2d \sin \theta$. This was rendered possible because quartz present in the coarse fraction of each sample produced characteristic blotchy lines which could easily be recognised and used for calibration. The blotchy character of the lines was associated with the particle size. It was found that r (the radius of curvature of the film) was constant along a film but varied from film to film. This variation was small and its extreme range was not more than 0·5 per cent.

Accuracy of Results for the Coarse Fractions.—Values of r calculated on the basis of the three quartz lines of interplanar spacing 3·34, 1·814 and 1·538 A were found not to vary by more than 0·25 per cent. Such a variation lies within the limits imposed by inability to measure any $2s$ (the separation of corresponding diffraction lines along the film in the equatorial plane) to any greater accuracy than 0·1 mm. Due then to an error in $2s$ of 0·1 mm. in lines used for calibration an error of 0·25 per cent. and 0·09 per cent. is possible for any value of d/n calculated over the range 10 A to 1 A.

On the assumption that there is no error in r involved in calibration measurements and that r is uniform across the film, the error in d/n associated with an error of 0·1 mm. in $2s$ over the range from 10 A to 1 A varies from 1·17 per cent. to 0·075 per cent.

Hence the total maximum percentage error, assuming (a) uniform radius along a film and (b) $d(2s) = 0·1$ mm. in calibration and in measurement of an unknown line, is 1·42 per cent. to 0·16 per cent. over the range 10 A to 1 A. Weak lines may have a greater percentage error.

On this basis the maximum possible error in d/n at 2·5 A becomes 0·01 A so that for smaller spacings than this, d/n is recorded to 0·001 A.

Accuracy of Results for the Fine Fractions.—In the films of the fine fractions the absence of blotchy lines rendered the certain recognition of quartz impossible. Consequently, as no lines were available for calibration purposes, it was necessary to assume a constant radius of curvature for all films. The figure adopted was 2·798 cms.

In the absence of glauconite a line appearing with interplanar spacing 3·34 A is considered due to quartz. From an examination of Table I. it is seen that the maximum variation in d/n for this line in the patterns of the fine fractions is 0·01 A. This is due to variations in $2s$ of 0·01 mm., corresponding to the maximum error considered possible in measurements of $2s$ for all but the very faintest lines. Hence, on this basis, it is considered that the assumption of a constant radius of 2.798 cms. yields results for the finer fractions which are no less inaccurate than those for the coarser fractions.

X-RAY DATA.

In Table I. are tabulated all observed values of d/n for the samples examined. This includes the patterns obtained for samples which were heated in an electric furnace in air to 500°C. for 48 hours.

It has been previously pointed out (4) and (9) that the commonly occurring minerals in soil colloids include the clay minerals, quartz and the oxides and hydroxides of Al and of Fe.

TABLE I.—INTERPLANAR SPACINGS OF THREE SAMPLES AND ASSIGNED ORIGINS. (UPPER
FILTERED Fe

Upper Greensand.									Subsoil.					
61 µ and less.			2 µ and less.						61 µ and less.					
Possible Origin.	Unheated. I.	Unheated. d/n.	Possible Origin.	Unheated. I.	Unheated. d/n.	Possible Origin.	Heated 500°C. I.	Heated 500°C. d/n.	Possible Origin.	Unheated. I.	Unheated. d/n.	Possible Origin.	Heated 500°C. I.	Heated 500°C. d/n.
(M)	?	?	(M)	?	13·95	....	....	....	M	ms	15·6*	....	....	....
												U	?	12·75
G	s	10·12*	G	?	9·43	G(M)	s	10·12	G	vw	9·56*	GM	m	10·02
									K	vw	7·20			
U	w	5·43							U	vw	5·47			
G	m	4·94	G	vw	4·99				GM	vw	4·93			
G(M)	s {	4·50	G(M)	s {	4·48	G(M)	m	4·45	GM	ms {	4·53	GM	w m	4·47
QGo		4·26							QGo		4·21	Q	s {	4·20
Cg		4·09†	Cg	m(d)	4·12	Cg	vw	4·18	Cg		4·07	Cg		4·07
														3·80
GCg	ms	3·69	GCg	vw	3·65				CgG	w	3·70	GCg	m {	3·68
QG	s	3·34	QG	w	3·34	QG	m	3·33	QG	s	3·34	QG	s	3·34
G	w(d)	3·08‡	G	vw	3·09				G	w	3·07‡			
G	w	2·97	G	vw	2·95				GM	vw	2·97			
G	w	2·84												
HGoG	vw	2·73										G(H)	?	2·69
G(M)	s	2·58	G(M)	s	2·58	G(M)	m	2·58	GM	m	2·57	GM	m(d) {	2·58
QGo	m {	2·45							QGo	w	2·45	Q		2·444
G		§2·414	G	m(d)	2·409	G	w	2·394						
Q	vw {	2·28							Q	vw	2·271	Q	w	2·275
G		§2·241	G	?	2·237									
Q		2·22				Q	?	2·216	Q	vw	2·228	Q	w	2·212
GQ	vw	2·119							GQ	vw	2·119	GQ	w	2·120
GQ	vw	1·988							GQ	vw	1·975	GQ	w	1·970
U	?	1·887										U	vw	1·910
Q	m	1·814							Q	w	1·814	Q	m	1·814
U	vw	1·749												
G	w	1·710	G	vw(d)	1·715				GM	vw	1·700	GM	w(d) {	1·698
QG	m	1·659	QG	vw(d)	1·645				QG	vw	1·667	GQ		1·665
G	vw	1·608												
G	vw	1·571												
Q	w	1·538							Q	w	1·538	Q	m	1·538
G(M)	ms	1·510	G(M)	m	1·511	G(M)	w	1·505	GM	w	1·507	GM	vw	1·515
QG	vw	1·451	QG	?	1·452	QG	vw	1·450	QG	vw	1·447	QG	vw	1·447
QG	vw	1·422	QG	?	1·415				QG	vw	1·409			
QG	m	1·376	QG	vw	1·372				QG	w	1·374	QG	m	1·374
G	w	1·305	G	w {	1·303	G	vw	1·298	G	vw	1·307	G	vw	1·316
GQ	vw	1·288	GQ		1·283				GMQ	vw	1·288	GMQ	vw	1·288
QG	w	1·256	QG	vw	1·254				GMQ	vw	1·253	GMQ	w	1·257
									Q	?	1·227	Q	vw	1·227
QG	w	1·199							QG	vw	1·196	QG	w	1·199
Q	vw	1·181							Q	vw	1·180	Q	w	1·180

s = strong ; ms = medium strong ; m = medium ; w = weak ; vw = very weak ; d = diffuse.
G = Glauconite ; Q = Quartz ; M = Montmorillonite ; K = Kaolinite ; Go = Goethite ; H = Haematite ; Cg = Candle grease.

* Estimates of d/n made on films taken with Cu radiation.

† Centre of a line unsymmetrical in intensity which on its inner edge has a diffuse region extending to the line at 4.50 A and within this diffuse region a faint quartz line occurs at 4.26 A.

GREENSAND 61 µ AND LESS TAKEN WITH UNFILTERED Fe RADIATION, ALL OTHERS WITH RADIATION).

Subsoil.						Soil.								
2 µ and less.						61 µ and less.			2 µ and less.					
Possible Origin.	Unheated.		Possible Origin.	Heated 500°C.		Possible Origin.	Unheated.		Possible Origin.	Unheated.		Possible Origin.	Heated 500°C.	
	I.	d/n.		I.	d/n.		I.	d/n.		I.	d/n.		I.	d/n.
M	m	15·4												
(G)	?	9·27	M(G)	s	9·85									
K	w	7·23				(K)	?	7·20	K	m	7·05			
(G)M	s	4·48	(G)M	w	4·45	QGo Cg	w	4·20	KCg	m	4·50	U	w	4·17
Cg	m	4·14	Cg	s	4·10						4·12	Cg	vw	4·12‡
			Cg	m	3·68	Cg	vw	3·70				Cg	?	3·65
K	w	3·55							K	w	3·55			
Q(G)	w	3·33	Q(G)	m	3·33	Q	s	3·34	Q	s	3·33	Q	s	3·33
(H)(G)	?	2·67	H(G)	vw	2·68	HGo	vw	2·68	H	w	2·69	H	w	2·67
(G)M	m	2·58	(G)M	vw	2·58				K	m	2·57			
			H	vw	2·485	H	w(d)	2·51	K H	m	2·497	H	m	2·497
						QGo	w(d)	2·44						
(G)	vw	2·418												
									K	vw	2·335			
						Q	vw	2·273						
Q	w(d)	2·197	Q	w(d)	2·216				(Q?)	vw	2·189	(Q?)	vw	2·189
						Q	vw	2·105	Q	vw	2·120	U	?	2·076
§Q(G)	w(d)	1·983				Q	vw	1·976	Q	vw	1·983	U	?	1·952
U	?	1·889												
						Q	m	1·811	Q	vw	1·811	QH	w(d)	1·824
(G)MQ	m(d)	1·683				Q	d	1·681	QK	vw(d)	1·672	QH	w(d)	1·688
						U	vw(d)	1·606	U	vw	1·593			
						Q	m	1·538	Q	vw	1·538			
M(G)	m(d)	1·515	M(G)	vw(d)	1·197									
	m(d)	1·489												
						U	vw	1·488	K	w	1·490			
						Q	vw	1·417	Q	w	1·452			
									(Q?)	vw	1·410			
						Q	m	1·371	Q	vw	1·373			
(G)	w(d)	1·305												
(G)MQ	w(d)	1·283				Q	vw	1·284						
						Q	vw	1·253						
						Q	vw	1·226						
						Q	vw	1·197						
						Q	vw	1·180						

‡ Outer edge of a faint diffuse line that extends almost to the previous line.

§ Very faint spotted quartz lines occur on the inner edge of the line at 2.414 A and on the inner and outer edges of the line at 2.211 A.

This line has been considered as an (025) glauconite reflection.

In the case of the clay minerals the fact that they may be subdivided into three groups, each group being characterised by a particular large spacing, is made use of in their identification in soil colloids.

In preparing the following particulars regarding the chemical composition of members of the three groups of clay minerals the author has consulted Hendricks and Alexander (10).

(1) *Kaolinite Group.*—The kaolinite group includes the following minerals: kaolinite, anauxite, nacrite, dickite, halloysite and hydrous halloysite. These minerals, with the exception of hydrous halloysite which possesses two easily detachable molecules of water, have the ideal formula $[Al_2]\,[Si_2]O_5(OH)_4$ in which isomorphous replacement is largely restricted to mutual substitution of Al and Si in $[Si_2]$ positions. The characteristic large spacing for all members except hydrous halloysite occurs at approximately 7 A. Hydrous halloysite, which readily reverts to halloysite by the loss of two molecules of water, has a basal spacing of 10·3 A. The patterns of all members of this group are destroyed by heating to 500°C.

(2) *Montmorillonite Group.*—The montmorillonite group includes the following minerals: montmorillonite, saponite, nontronite and beidellite. Montmorillonite has the ideal formula $[Al_2]\,[Si_4]O_{10}(OH)_2.xH_2O$ in which extensive isomorphous replacement can take place. Substitution of $[Al_2]$ by $[Mg_3]$ gives saponite $[Mg_3]\,[Si_4]O_{10}(OH)_2.xH_2O$; substitution of $[Al_2]$ by $[Fe_2]$ gives nontronite $[Fe_2]\,[Si_4]O_{10}(OH)_2.xH_2O$; substitution of Si by Al in $[Si_4]$ position together with the replacement of O by (OH) or the replacement of Al in $[Al_2]$ position by other ions gives beidellite $[Al_2]\,[Si_3Al]O_9(OH)_3.xH_2O$ in which the $SiO_2 : (R_2O + RO)$ ratio lies close to 3 : 1. The characteristic large spacing for air dried material of all members occurs at 14–15 A. Members of this group show reversible lattice shrinkage and expansion according to their water content (11). Upon heating to 500°C. the 14–15 A basal spacing shrinks to 10 A.

(3) *Mica Group.*—In this group no subdivision is at present recognised. Gruner (12) however, has shown that the structures of glauconite and mica are almost identical. Mica has the ideal formula $K[Al_2]\,[Si_3Al]O_{10}(OH)_2$ in which extensive isomorphous replacement can take place. Replacement of K by H_2O accompanied by substitution of Si for Al in tetrahedral co-ordination or (OH) for O, together with Mg and Fe replacing $[Al_2]$ with octahedral co-ordination, results in a mineral of the glauconite type. The characteristic basal spacing for the mica group occurs at 10 A. No change in pattern is produced by heating members of this group to 500°C.

As the minerals within a group cannot readily be distinguished in the diffraction pattern of a soil colloid, the terms "kaolinite" and "montmorillonite" will be used, for brevity, in the remainder of this paper to designate a mineral belonging to the kaolinite group and montmorillonite group respectively.

In the drawing up of Table 1, an attempt has been made to assign a possible origin to all the observed lines. For montmorillonite and kaolinite the data published by Kelley et al. (13) was used. This data includes only spacings to which Miller indices related to a definite unit cell could be assigned. The kaolinite spacings were those tabulated by Gruner (14) with respect to the monoclinic unit cell a = 5·14 A, b = 8·90 A, c = 14·51 A, β = 100° 12′. The montmorillonite spacings were selected from the data of Maegdefrau and Hofmann (15) who referred the mineral structure to an orthorhombic cell with dimensions a = 5·18 A, b = 8·97 A, with c variable according to the degree of hydration. The data relating to glauconite was taken from Gruner (12), who, by referring the mineral to the mica structure, was able to assign Miller indices to most of his recorded lines.

Quartz data was taken from Favejee (16) who has tabulated estimated interplanar spacings relating to the unit cell a = 4·903 A, c = 5·393 A. Data supplied by Hanawalt, Rinn and Frevel (17) was used when considering the possibility of the presence of the oxides and hydroxides of Fe and Al.

In preparing Table I. the principle was employed of only assigning an origin to a line when on intensity considerations the line was likely to be contributed to by the mineral in question.

Considerable difficulty was encountered in recording 10 A diffraction lines because a pronounced central scattering extended out to about this spacing. Measurements of spacings in this region consequently vary considerably. Films taken with Cu radiation, however, often gave clear evidence of the existence of a 10 A line.

(1) *Upper Greensand.*

The original observations of early workers on the high glauconite content of this sand have been confirmed. A comparison between the fine and coarse fractions seems to indicate that there is a higher glauconite content in the coarse fraction. The agreement between the glauconite spacings listed by Gruner and the spacings recorded for the coarse fraction of the upper greensand is sufficiently good to permit of a calculation of the unit cell dimensions of the Gingin glauconite assuming the mica structure of glauconite and the indices assigned by Gruner to the various spacings. In this calculation the following lines and corresponding indices were used: 10·12 A (002); 2·58 A $(20\bar{2})$; 1·510 A (060); 1·305 A (400).

Table II.

UNIT CELL DIMENSIONS OF GLAUCONITE.

——	Gingin glauconite.	Gruner's average of six samples.
c_0	20·21	20·03
b_0	9·06	9·07
a_0	5·24	5·24
β	94° 58′	95° 00′

Simpson (18) has noted the presence of dufrenite (a bright green basic ferric phosphate $Fe_2(OH)_3PO_4$) in the upper greensand but in the absence of any X-ray data, known to the author, with respect to this mineral and in the absence also of reasonably pure specimens from which X-ray data may be obtained, no conclusion has been reached as regards its presence in the sample examined in this study. The presence of quartz has been previously referred to.

(2) *Subsoil.*

The most noticeable differences between this pattern and the previous one are the existence of a 15 A and a 7 A spacing. The 15 A spacing shrinks to 10 A and the 7 A spacing disappears when the sample is heated to 500° C.

These lines, it is considered, are the characteristic basal spacings of montmorillonite and kaolinite. The 10 A glauconite spacing is greatly reduced in intensity. In comparing the two fractions of this sample it appears that the coarse contains more quartz and the fine contains more kaolinite.

(3) *Soil.*

In the coarse fraction quartz is the only constituent that can be definitely recognised. In the fine fraction however, in addition to the quartz pattern, there is a number of lines, including a 7 A line, which disappear when the sample is heated to 500°C. These lines, it is considered, are due to kaolinite. In both fractions there is a little haematite and/or goethite and a possible trace of glauconite.

Additional effects of Heat Treatment.

Several changes, in addition to those previously noted, occur in the X-ray patterns of the heat treated samples. In most unheated samples a broad area of strong intensity extends from 4·50–4·10 A, which after heat treatment, is resolved into two lines (4·5 and 4·1 A). In the greensand and soil samples the line with the larger spacing is the more intense whereas in the subsoil sample it is the less intense. The line with the smaller spacing is due to small amounts of candle grease which lined the walls of the celluloid containers in which the samples were mounted for X-ray analysis. The method employed for the preparation of celluloid containers using candle grease has been previously described (4). Candle grease is characterised by two strong lines which occur at 4·12 and 3·70 A and which far exceed in intensity any other lines in the candle grease pattern. It has been frequently noted that a line at 3·7 A either appears or is increased in intensity as a result of heat treatment. As the effect only appeared when kaolinite was present in the unheated sample it was suggested that the line could be due to a decomposition product of kaolinite (9). It is now believed that the appearance of this line at 3·7 A is not effected by heat treatment but is determined by the amount of candle grease present in the container. This is the origin of the 3·7 A line in the soil and subsoil samples.

It is also noteworthy that the characteristic quartz line at 3·34 A always increases or maintains its intensity after heat treatment.

MICROSCOPIC EXAMINATION.

A microscopic examination was undertaken with the object of determining whether or not the optical properties of the materials examined were consistent with the X-ray conclusions. Wherever possible refractive indices and birefringence were measured but because of the different stages of alteration present, particularly in the coarser fractions, the refractive indices in many cases are given only to the second place of decimals.

Throughout the work the samples were immersed in mixtures of clove oil and α – monochloronaphthalene for refractive indices up to 1·637, in mixtures of α – monochloronaphthalene and α – monobromonaphthalene for refractive indices between 1·637 and 1·661 and in mixtures of α – monobromonanaphthalene and methylene iodide for refractive indices higher than 1·661. The indices were determined in sodium light by means of a Pulfrich refractometer.

The Coarse Fractions.

Upper Greensand.—This sample contains an amount of crystalline material intermediate between the amounts occurring in the soil and subsoil. The main constituent minerals are glauconite and quartz. The glauconite occurs in yellow-green to brown non-pleochroic grains which show aggregate polarisation. The refractive indices lie between 1·600 and 1·620. This gives a maximum birefringence of 0·020. The quartz content is not high. The grains are subangular and are usually coated with glauconite granules.

There occurs in addition to glauconite and quartz a small amount of each of the following particles:

(*a*) A light green fibrous mineral which in its clear unaltered form has a refractive index greater than, but close to, methylene iodide (1·74). The birefringence is variable but not high. The fibres, which have positive elongation are always arranged in a radial manner, giving a spherulitic structure. The fibres when viewed end on are greenish-blue, non-pleochroic, with the birefringence masked by the original colour. In this orientation the mineral is granular in appearance, frequently coats other minerals and has a range of refractive indices from about 1·68–1·72.

Alteration readily takes place at the periphery of the spherulites, sectors of which then show a plumose structure. The alteration is accompanied by a reduction in refractive index and an increase in birefringence. As alteration advances the fibrous structure is lost and the grains take on an oolitic appearance (in the form of concentric shells) while still retaining the spherulitic cross. These grains are markedly birefringent and the refractive indices lie between 1·66 and 1·685. At this stage the grains tend to break up into smaller curved laminae formed by the splitting off of successive concentric shells. In these particles the refractive index is decreased but does not drop below about 1·58. The birefringence is also often decreased.

(*b*) Brownish-coloured grains, some of which show traces of a spherulitic cross. The birefringence of these particles is obscured by the colour, but the refractive indices vary from 1·61–1·64.

(*c*) Particles very similar to the alteration products of (*a*) but distinguished from them by the absence of a spherulitic cross. The particles are only of weak to moderate birefringence and the mean refractive index is about 1·585. The low birefringence could be due to lack of orientation of aggregating particles, but an occasional particle is sufficiently well oriented to give a biaxial figure of negative optical character and of small axial angle.

(*d*) Particles distinguished from (*c*) merely by the fact that they are only very weakly birefringent and their refractive indices vary from 1·535–1·555. Their colour is light yellow-green.

The Subsoil.—The most noticeable feature of the subsoil is the large amount of crystalline material of which only a small amount is quartz and glauconite. The quartz as before forms subangular grains coated with other minerals. The glauconite is recognised by its possessing similar optical properties to the glauconite in the upper greensand. The refractive indices are, however, a little lower, the range being from 1·58–1·60. The remainder of the sample is made up of the particles *a*–*d* considered in the upper greensand section.

The Soil. The most noticeable feature of the soil sample is the small amount of crystalline material of which quartz is the main constituent. This mineral is heavily coated with iron oxides. Occasional grains of glauconite and the alteration products previously described (of which some of the brown grains show traces of a spherulitic cross) occur but the main fraction of the sample consists of opaque grains yellow-brown in reflected light. Reddish-brown iron oxide grains are frequent.

The Fine Fractions.

In the determination of the optical properties of the 2 μ fractions use was made of the fact (19) that individual particles existing in a soil colloid suspension tend to orient themselves after drying into aggregates which possess uniform optical properties. This takes place even when two or more clay minerals are present so that the optical properties of the aggregates depend upon the proportion of the different constituents forming the aggregates.

In the soil colloids examined in this study there was no marked tendency for the aggregates to show a crystallographic orientation of the individual particles. No aggregates were found sufficiently well oriented to give an interference figure from which the optical character could be determined. However, enough oriented aggregates were found to determine the optical constants.

The upper greensand fraction when viewed beneath the microscope was seen to be in the form of light green aggregates up to 50 μ and greater in diameter. About 25 per cent. of these aggregates show fairly uniform crystallographic orientation of individual components and for these $\gamma - \alpha = 0 \cdot 01$. The remainder of the aggregates are non-birefringent.

The subsoil fraction when viewed beneath the microscope was seen to be in the form of light yellowish-brown aggregates up to 50 μ and greater in diameter. There is about the same proportion of birefringent material as in the upper greensand sample. The birefringence as measured appears to be about 0·005. This figure is probably low due to the fact that the colloid particles are probably coated with iron oxides or hydroxides which obscure the birefringence.

The soil fraction when viewed beneath the microscope was seen to be in the form of dark brown non-birefringent particles up to 50 μ and greater in diameter.

The optical properties of aggregates of the soil colloid fractions from the upper greensand, subsoil, and soil are summarised in Table III.

TABLE III.

OPTICAL DATA RELATING TO THE FINE FRACTIONS.

Sample.	α ± 0·002	Mean Refractive Index ± 0·005	γ ± 0·002	$\gamma - \alpha$
Upper greensand	1·618	...	1·628	0·010
Subsoil	1·600	...	1·605	0·005
Soil	...	1·620	...	...

DISCUSSION.

Coarse Fractions.—X-ray evidence indicates that in the coarse fractions the glauconite content decreases and the quartz content increases in passing from greensand to soil. The microscopic examination confirms this. X-ray evidence also indicates the presence of montmorillonite and a little kaolinite in the subsoil, a possible trace of montmorillonite in the greensand and of kaolinite in the soil. In view of the fact that the samples examined contain a fibrous mineral with spherulitic structure which has not been identified and which readily alters in a characteristic manner to give a variety of particles some of which have optical properties similar to clay minerals it has not been possible to verify beneath the microscope the presence of any clay minerals in these fractions.

Fine Fractions.—For the fine fractions X-ray evidence indicates that glauconite is the main constituent of the upper greensand, montmorillonite the main constituent of the subsoil, and kaolinite the main constituent of the soil. Optical data relating to pure clay minerals have been summarised by the author elsewhere (19). Members of the montmorillonite and mica groups have similar optical properties which are markedly different from the optical properties of members of the kaolinite group. In Table III. it is seen that the upper greensand and subsoil have similar optical properties, both samples being more birefringent than the soil sample which is non-birefringent. The non-birefringent character of the soil sample could be due to the presence of kaolinite or to the presence of coatings of iron oxides or hydroxides on the soil colloid particles which tend to mask the birefringence. It is believed that both play a part. It must be realised that the optical properties of aggregates of the fine fractions depend on all the constituents present, so that only broad generalisations may be drawn when the main constituents alone are considered. Generally speaking the optical properties of the fine fractions are consistent with the composition as determined by X-ray analysis.

CONCLUSIONS.

With regard to the composition of the samples X-ray data lead to the conclusions summarised in Table IV. Some modifications, the extent of which it is difficult to estimate, may be necessary in the light of the following considerations :—

(*a*) The relation between relative intensities of lines and relative quantity of corresponding diffracting material. All estimates of relative quantities of the different constituents are based on visual observation of line intensities. These estimated relative quantities may correctly indicate the actual relative quantities only if the ratio of the intensities of patterns of different constituents is equal to the ratio of the proportions of the constituents. This may not be true and may depart widely from the truth if quartz is one of the constituents since the diffracting power of quartz is markedly greater than that of any clay mineral (9).

(*b*) Microscopic evidence.

From Table IV. the following generalisations as regards mineral changes in passing from greensand to soil may be drawn :—

(*a*) The content of glauconite decreases.

(*b*) The content of kaolinite, quartz and oxides and hydroxides of iron increases.

(*c*) The montmorillonite content is concentrated in the subsoil.

It is hence suggested that in the weathering of glauconitic greensand the glauconite alters firstly to a clay of the montmorillonite group which later is replaced by a clay of the kaolinite group together with free quartz and haematite and/or goethite. The formation of kaolinite through the splitting off of silica from montmorillonite has been suggested by Kelley et al. (13) as an explanation of the occurrence of kaolinite clay overlying montmorillonite clay in the Susquehanna soil colloids.

It is quite logical to expect on this hypothesis that kaolinite would be present with montmorillonite in the subsoil fraction but it must also be borne in mind that contamination of the subsoil fraction with the overlying soil would give kaolinite in the subsoil fraction. Such a contamination of the subsoil fraction is considered to be negligible.

TABLE IV.

COMPOSITION OF THE THREE SAMPLES.

(From X-ray evidence only).

Mineral.	Upper Greensand.		Subsoil.		Soil.	
	Coarse.	Fine.	Coarse.	Fine.	Coarse.	Fine.
Glauconite ...	Very much	Much	Little	Little	Possible trace	Possible trace
Quartz	Little	Very little	Much	Very little	Very much	Little
Montmorillonite ...	Possible trace	Possible trace	Much	Much	...	...
Kaolinite ...	...	...	Little —>	Little	Possible trace	Much
Haematite and/or Goethite	Very little	...	...	Possible trace	Little	Little

Note.—An arrow (—>) indicates an increasing amount of kaolinite.

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The author wishes to express his thanks to the University of Western Australia Text Books Board and to the authors of " Junior Geology " for permission to reproduce Fig. I. To the Text Books Board the author is also very greatful for the loan of the block of this figure. To Miss M. Bowen the author's thanks are due for the drawing of Fig. 2.

BIBLIOGRAPHY.

(1) Glinka, K.: " Der Glaukonit, seine Enstehung, sein chemischer Bestand und seine Verwitterung," Saint-Pétersbourg, 1896, p. 114.

(2) Cayeux, L.: " Les Roches Sedimentaires, Paris," 1916.

(3) Denison, I. A., Fry, W. H., and Gile, P. L.: " Alteration of Muscovite and Biotite in the Soil." *U.S. Dept. of Agric. Tech. Bull.* 128, 1929.

(4) Shearer, J., and Cole, W. F.: " Analysis of Soil Colloids by X-ray Diffraction Methods." *Jour. Roy. Soc. W. Aust.* 1939–40, XXVI., pp. 121–131.

(5) Clarke, E. de C., and Hanrahan, L. F.: " Junior Geology," Perth, 1941.

(6) Feldtmann, F. R.: " The Glauconite Deposits at Gingin, South-West Division." *Ann. Prog. Rept. Geol. Surv. West. Aust.* 1933, p. 6.

(7) Hosking, J., and Greaves, G. A.: " A Soil Survey of an area at Gingin, Western Australia." *Jour. Roy. Soc. W. Aust.* 1935–36, XXII., pp. 71–112.

(8) Wood, W. A.: " Note on the elimination of the β wave length from the characteristic radiation of iron." *Proc. Physic. Soc.* 1931, 43, pp. 275–278.

(9) Shearer, J., and Cole, W. F.: " X-ray analysis of some Tasmanian Soil Colloids." *Jour. Roy. Soc. W. Aust.* 1939–40, XXVI., pp. 133–137.

(10) Hendricks, S. B., and Alexander, L. T.: " Minerals present in Soil Colloids: I. Description and Methods for Identification." *Soil Sci.* 1939, 48, pp. 257–267.

(11) Hofmann, U., Endel, K., and Wilm, D.: " Kristallstruktur und quellung von Montmorillonit." *Zeit. f. Krist.* 1935, 86, p. 340.

(12) Gruner, J. W.: " The Structural Relationships of Glauconite and Mica." *Amer. Min.* 1935, 20, p. 699.

(13) Kelley, W. P., Woodford, A. O., Dore, W. H., and Brown, S. M.: " Comparative Study of the Colloids of a Cecil and a Susquehanna Soil Profile." *Soil Sci.* 1939, 47. pp. 175–193.

(14) Gruner, J. W.: " Crystal Structure of Kaolinite." *Zeit. f. Krist.* 1932, 83, pp. 75–88.

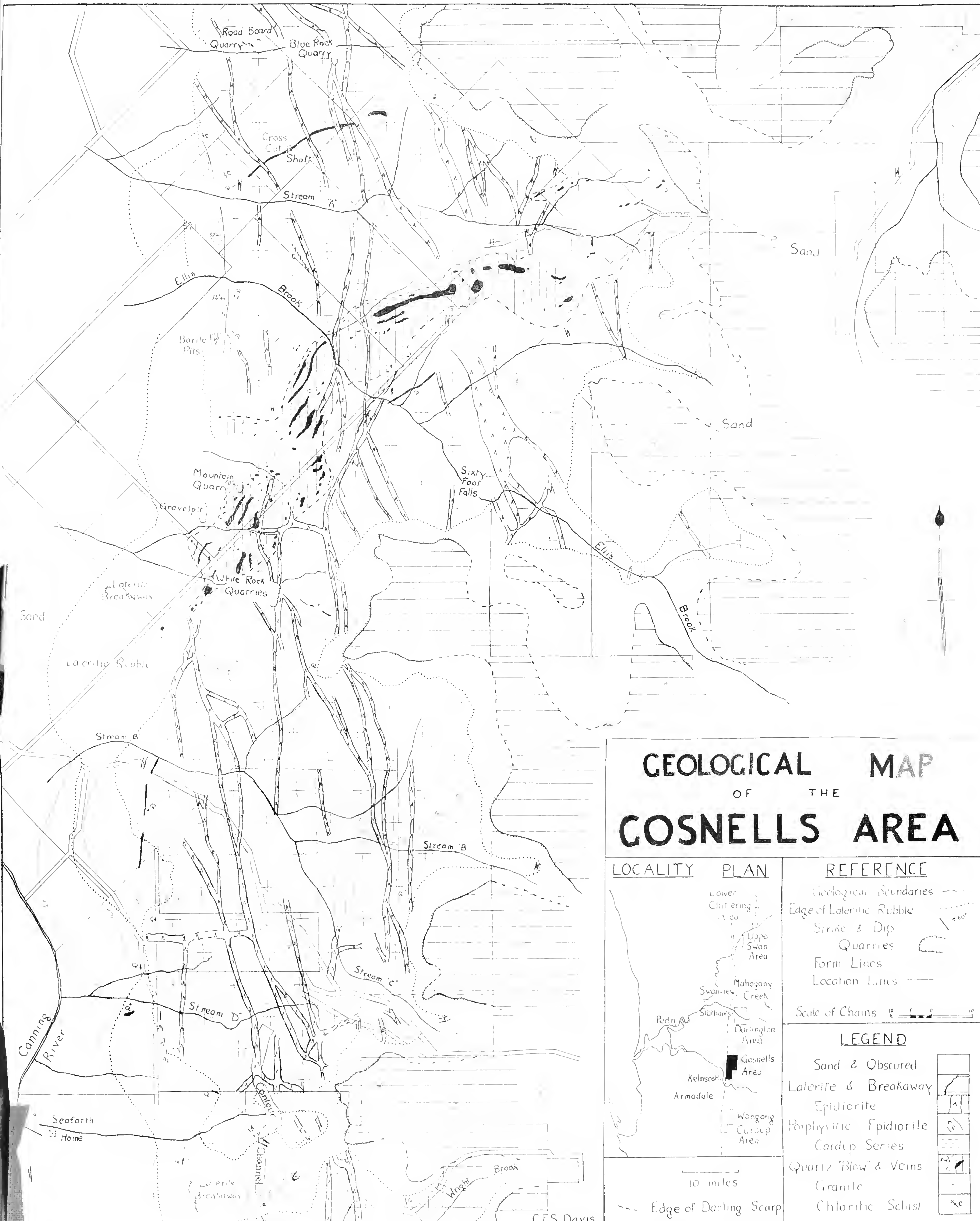
(15) Maegdefrau, E., and Hofmann, U.: " Die Kristallstruktur des Montmorillonits." *Zeit. f. Krist.* 1937, 98, pp. 299–323.

(16) Favejee, J. Ch. L.: " Zur Methodik der Rontgenographischen Boden-forschung." *Zeit. f. Krist.* 1939, 100, p. 425.

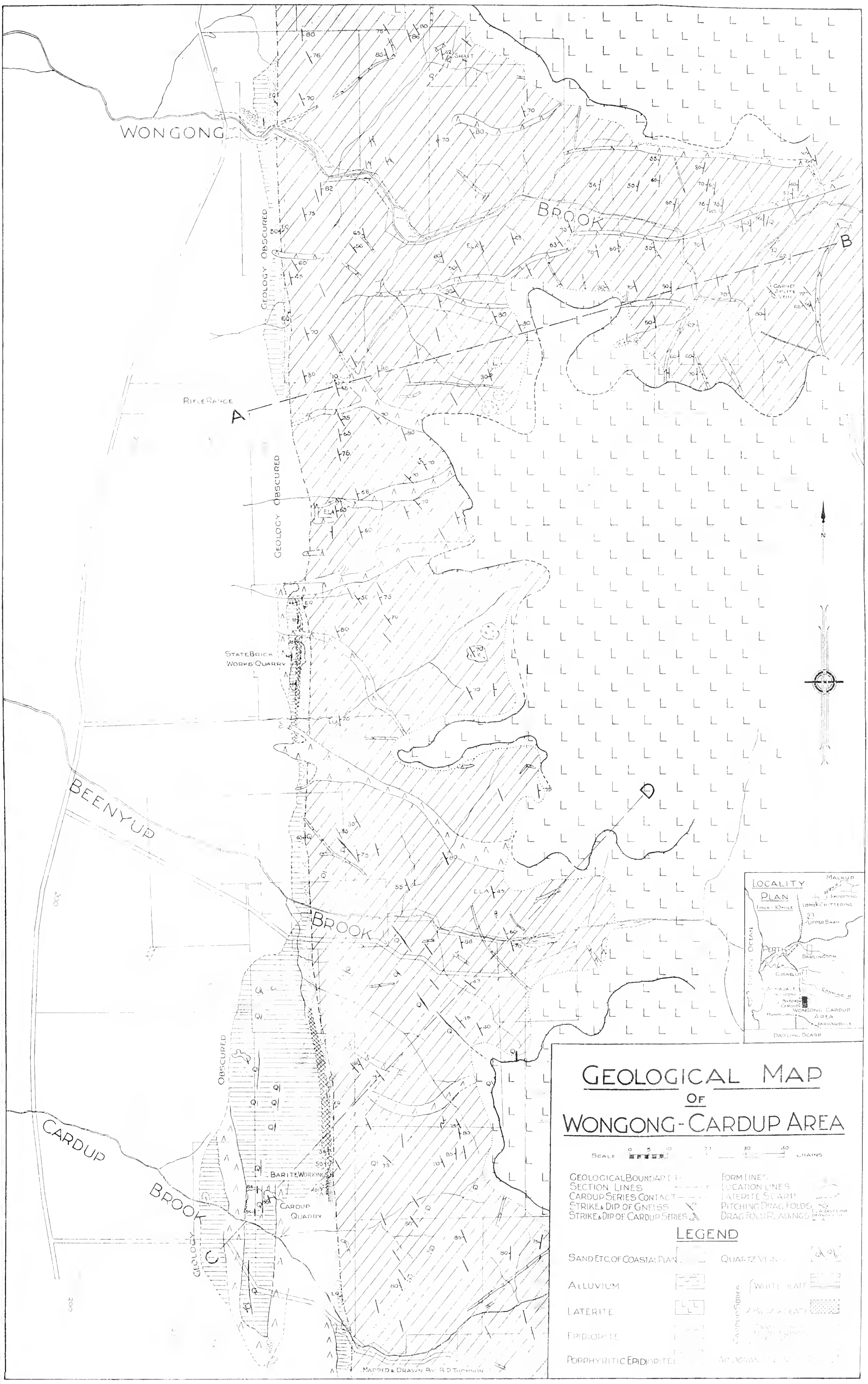
(17) Hanawalt, J. D., Rinn, H. W., and Frevel, L. K.: " Chemical Analysis by X-ray Diffraction." *Ind. & Eng. Chem., Anal. Ed.* 1938, 10, pp. 457–512.

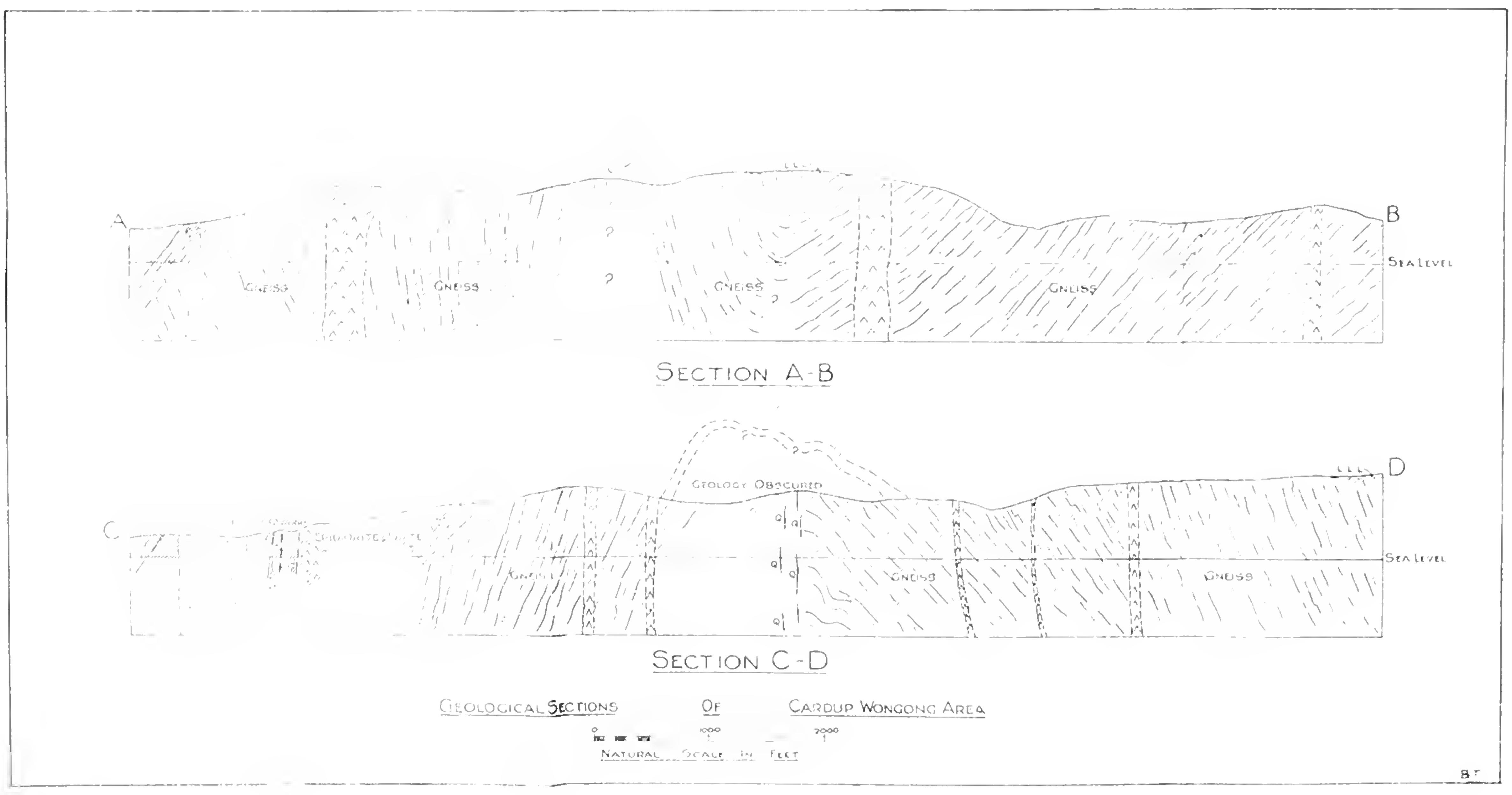
(18) Simpson, E. S.: " Contribution to the Mineralogy of Western Australia." *Jour. Roy. Soc. W. Aust.* 1936–37, XXIII, pp. 17–35.

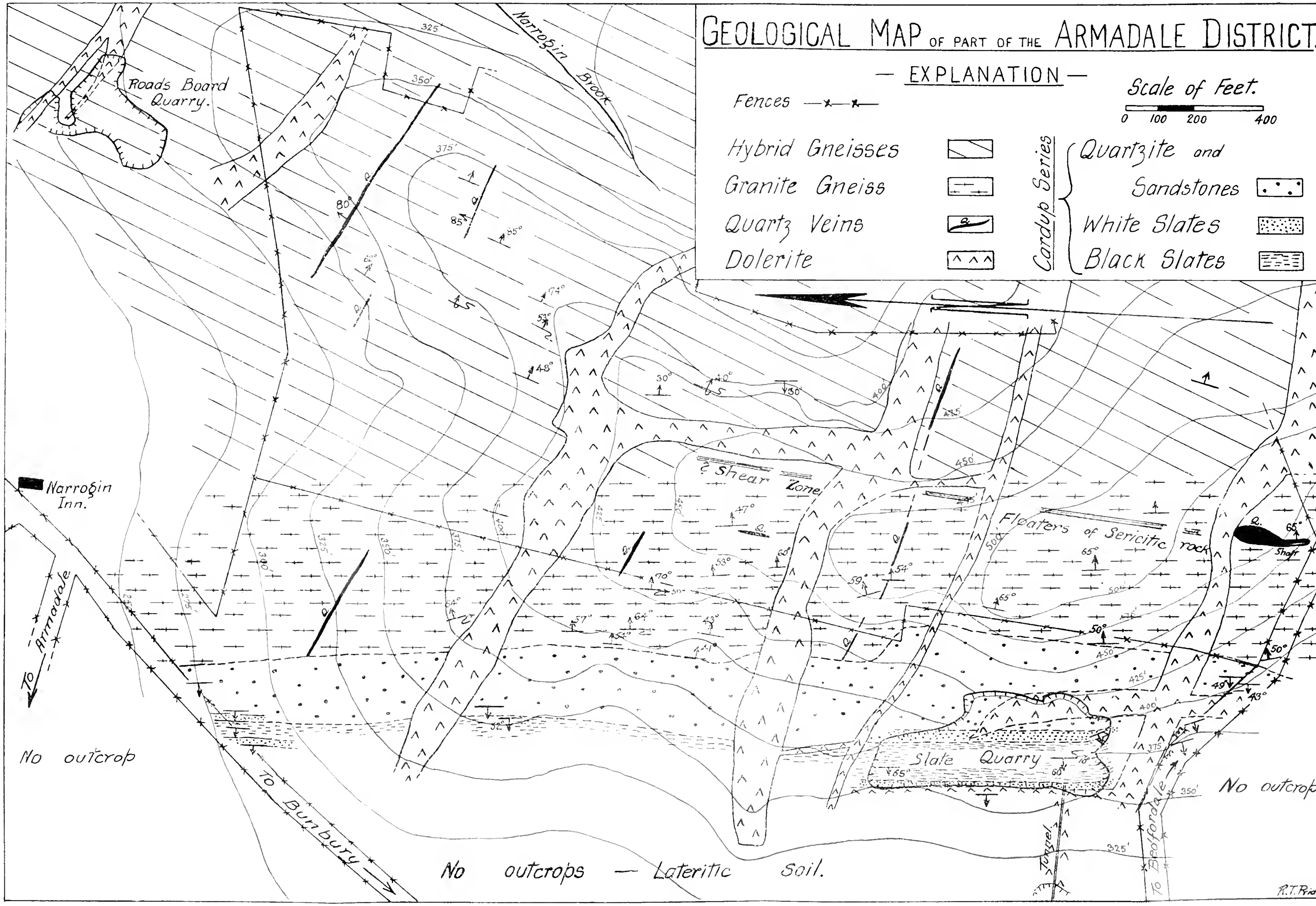
(19) Cole, W. F.: " Results of a Microscopic Study of some Soil Colloids." *Jour. Roy. Soc. W. Aust.* 1940–41, XXVII., pp. 1–7.



Road Board Quarry
Blue Rock Quarry
Cross Cut Shaft
Stream "A"
Ellis Brook
Barite Pits
Sand
Mountain Quarry
Gravelpit
Sixty Foot Falls
Laterite Breakaways
White Rock Quarries
Lateritic Rubble
Stream B
Stream "C"
Stream "D"
Canning River
Seaforth Home
Contour Channel
Laterite Breakaways
Wright Brook
C.E.S. Davis
GEOLOGICAL MAP OF THE COSNELLS AREA
LOCALITY PLAN
Lower Chittering Area
Upper Swan Area
Mahogany Creek
Swanview
Stathams
Perth
Darlington Area
Gosnells Area
Kelmscott
Armadale
Wongong Cardup Area
10 miles
Edge of Darling Scarp
REFERENCE
Geological Boundaries
Edge of Lateritic Rubble
Strike & Dip
Quarries
Form Lines
Location Lines
Scale of Chains
LEGEND
Sand & Obscured
Laterite & Breakaway
Epidiorite
Porphyritic Epidiorite
Cardup Series
Quartz "Blow" & Veins
Granite
Chloritic Schist


GEOLOGICAL MAP
OF
WONGONG - CARDUP AREA
LEGEND
LOCALITY PLAN
WONGONG
BROOK
BEENYUP
BROOK
CARDUP
BROOK
GEOLOGY OBSCURED
GEOLOGY OBSCURED
OBSCURED
RIFLE RANGE
STATE BRICK WORKS QUARRY
BARITE WORKINGS
CARDUP QUARRY
SHAFT
SAND ETC. OF COASTAL PLAIN
ALLUVIUM
LATERITE
PORPHYRITIC EPIDIORITE
MAPPED & DRAWN BY R.D. THOMSON


SECTION A-B
SECTION C-D
GNEISS
SEA LEVEL
GEOLOGY OBSCURED
GEOLOGICAL SECTIONS OF CARDUP WONGONG AREA
NATURAL SCALE IN FEET


GEOLOGICAL MAP OF PART OF THE ARMADALE DISTRICT.
— EXPLANATION —
Fences
Scale of Feet.
0 100 200 400
Hybrid Gneisses
Granite Gneiss
Quartz Veins
Dolerite
Cardup Series
Quartzite and Sandstones
White Slates
Black Slates
Roads Board Quarry.
Narrogin Brook
Narrogin Inn.
To Armadale
To Bunbury
? Shear Zone
Floaters of Sericitic rock
Shaft
Slate Quarry
Tunnel
To Beaufort
No outcrop
No outcrop
No outcrops — Lateritic soil.
R.T. Prider

18.—THE GEOLOGY AND PHYSIOGRAPHY OF THE GOSNELLS AREA

By

C. E. S. DAVIS, B.Sc. (Hons.).

Read 10th June, 1941; Published 2nd October, 1942.

CONTENTS.

I. INTRODUCTION.

The Gosnells Area lies 15 miles south-east from Perth, on the long, straight Darling Scarp which separates the low-lying plain (on which Perth stands) from the level Darling plateau whose surface is about 1,000 feet above sea level. The Darling Scarp here forms the western boundary of the Pre-Cambrian rocks which outcrop over so much of Western Australia.

In the eastern part of the country shown on the locality plan, the main rock type is granitic, covered in the higher country by a capping of laterite. The granite is cut by quartz masses (mainly thin veins, but there is also a huge quartz "blow" at Gosnells) and by basic dykes. On the western margin of the granite, steeply-dipping, slightly metamorphosed Pre-Cambrian sediments of the Cardup Series outcrop from Gosnells intermittently southwards.

The Cardup Series and granitic rocks close to the contact at Armadale were studied in 1939 (Prider, 1941), and, in 1940, areas were mapped at Gosnells and at Wongong-Cardup, respectively north and south of Armadale. At the end of the description of the Wongong-Cardup area (Thomson, 1941) the knowledge gained and the problems arising from the study of all three areas have been summarised.

The Gosnells Area is a strip of the scarp about 4 miles long and 1½ miles wide. Particular attention was paid to the northern part where the Cardup Series and quartz blow crop out, and the granite, basic dykes and quartz are exposed in quarries. The country was mapped entirely by pace-and compass-traversing by the writer working alone. These traverses were tied frequently to the Lands and Survey Department's pegs. Form lines were drawn from levels obtained by aneroid barometer readings, working from Gosnells railway station as datum.

II. PHYSIOGRAPHY.

A. *General Features.*

East of the present foot of the Darling Scarp, there was originally a laterite-covered peneplain (Jutson, 1934, p. 201). This peneplain was later elevated and youthful, westerly-flowing streams have now removed the laterite and exposed the underlying pre-Cambrian rocks along a belt, generally from half a mile to two miles wide. Pre-Cambrian rocks are exposed farther east only in the valleys of the larger streams and in some monadnocks rising above the plateau.

B. *The Darling Scarp.*

As Jutson concludes (1934, p. 87), the elevation of the Darling peneplain was effected by faulting, but the present face of the Darling Scarp is to the east of the actual fault-plane. No trace of the fault was detected in the Gosnells area.

Woolnough (1918, p. 390) believes there were two periods of uplift of the peneplain. After the first movements, mature valleys were formed which now occupy so much of the inland "wheat-belt" country; and later movements elevated the peneplain to its present height.

The topography of parts of the Gosnells area is composite, and supports Woolnough's belief. This is especially marked in the valley of Ellis Brook, which is mature above a height of 620 feet (the top of the Sixty Foot Falls). At and just below the falls, the stream bed drops over 100 feet and the sides of the valley steepen considerably. Upstream are some meanders, now slightly entrenched. In many other places, the scarp flattens above a height of about 500 feet. Clarke and Williams (1926, p. 167) note that terraces at a height of 450 feet in the Helena valley probably record a pause in uplift along the Darling fault.

As mature valleys were produced in the first cycle, more time must have passed between the two movements than has passed since the last uplift. But until we have more quantitative data of the rate of erosion of the local granite, we cannot suggest the absolute age of either movement.

C. *Streams.*

None of the streams draining the area can be described as the "major" stream. Most of them are short, flow due west down the scarp and may be explained as consequent on uplift of the peneplain. Jutson (1934, p. 169 and figure p. 171) states that the initial drainage of the elevated peneplain was to the south-east. Traces of a south-easterly drainage (now reversed so that the streams flow north-west) are found in the north-eastern corner of the country mapped. Generally, the northern sides of the valleys of streams flowing west are steeper than the southern.

Ellis Brook rises in the highest part of the area and flows a little to the north of west. It cuts through the quartz "blow" at one of its thinnest and weakest points: in this way its course has been determined by geological structure.

The course of stream B is more complex than that of the other young, westerly-flowing streams. It flows due west for most of its course, but for about 250 yards it runs a little to the west of north, parallel to the major joint-direction of the surrounding granite. Its tributary stream C has captured the head waters of stream D, and a wide, shallow wind-gap now separates the pirate and the beheaded streams.

D. *Remnants of the Peneplain.*

High, laterite-covered country of faint relief extends over most of the eastern part of the area. It has already been mentioned (under "General Features") that the peneplain (or, as it is now, the plateau) has been very completely preserved outside the Gosnells area.

E. *Effect of Geology on Topography.*

The different geological formations are unequally resistant to erosion. The quartz masses, by far the most resistant, stand up as isolated hills and occupy the crests of ridges. Basic dykes, as they are so much softer, cannot easily be traced through the quartz "blow"—in a short visit one may gain the impression that the quartz "blow" does cut the dykes. But though they are marked by depressions where they cut the quartz ridge, the dykes may be followed through the quartz by isolated boulders and red soil.

Generally the basic dykes are the most resistant of the other rocks; followed by granite, and lastly sediments (quartzite, conglomerate and shale in order). The edge of the laterite plateau may sometimes be marked by a breakaway, capping a steep scarp up to 30 feet high, but more often both breakaway and scarp are absent.

F. *Springs.*

In many places just below the laterite level, patches of greener vegetation mark the site of water seepages. So great is the amount of water which percolates through the laterite that Wright Brook and streams B and C are perennial. The only "spring" which does not issue from beneath the laterite is a small one by the side of a dyke in the quartz "blow," seven chains north-east of the Mountain Quarry. It flows only in the winter months.

III. STRUCTURE AND DISTRIBUTION OF THE ROCKS.

A. *Xenoliths.*

Small fairly equidimensional fragments of more basic rock have been found in the granite. Some of these xenoliths are gneissic, but the orientation of their banding is very irregular. In size they range from large masses 15 feet across to almost entirely assimilated wisps, so that some of the specimens classed in the field as "granites" may actually be hybridised.

There is also a large doubtfully xenolithic elongated body found near the edge of the granite, north of Ellis Brook, which is shown on the map as "Chloritic Schist." Its borders have been weathered away, so that its relation with the granite and basic dykes cannot directly be determined. The schist trends a little to the west of north, and contains several irregular quartz veinlets which in general strike north-south and dip east very steeply. Quartz veins, about two feet wide, may be traced from the granite into the schist. They resemble other quartz veins from the area, which, it will be shown, were formed at a late stage in the cooling of the granite. Thus, the schist existed before the granite had completely cooled, and it is probably a xenolith in spite of its dyke-like outcrop.

Although a large number of xenoliths was noted near Gosnells, they are actually insignificant in bulk compared with the host-rock, and, except for the chloritic schist, these small masses are not shown on the map. Innumerable xenoliths are found at Armadale (Prider, 1941, p. 29) and small xenolithic fragments occur in the granite as far north as Statham's (Clarke and Williams, 1926, p. 169).

B. *Granite.*

The granite of the area is nearly all massive, and even in the better exposures in the quarries no flow structures were detected (although these may have been largely obscured on the stained joint-surfaces forming the walls of the quarries). Faint flow-layers (and, in two places, flow-lines) are found in isolated outcrops and boulders in the extreme south and in the north-east. The strike of the flow-layers is east of north, but very variable, and their dip is to the east at 40° to 70°.

It is impossible yet to say whether the massive granite grades into or intrudes the more gneissic granite of the south of the area. Mapping and detailed petrological examination of the country immediately to the south may reveal whether the granites are the same or different.

C. *Acid Intrusives into Granite.*

Dykes of aplite and pegmatite cut the granite, but they are too short and thin (none was over two feet wide) to be noted on the map.

Quartz veins have also been found, and they intrude the pegmatites. They usually outcrop strongly, and many of them are large enough to be shown on the map. Near most quartz veins, the granite is altered and has been weathered away. The edge of the quartz "blow" shown on the map is the edge of a zone of decomposed granite throughout which quartz veins occur.

Thin quartz veins (from an inch to three feet wide) have a general north-south trend (of 22 directions measured, 14 lay between 340° and 40°). Such thin quartz veins, however, rarely persist for over a chain. A larger quartz vein, nearly 100 feet wide, forms the crest of the steep northern slope of stream A and crops out over a distance of about half a mile on a course just north of east.

A large family of veins makes up the quartz "blow." It may be traced for 1¾ miles till it is lost under the laterite cover to the east. Small pebbles of milky, sub-angular quartz in laterite nearly a mile farther east are probably derived from an extension of the "blow."

Near its southern end, the quartz body consists of four or five parallel veins (each about one chain wide), spread over a width of 20 chains. Between these veins, the underlying rock is obscured by soil and by quartz talus. In quarries and cliffs in the "blow," however, schistose quartz sericite rock and thin quartz veins are exposed between the strongly outcropping veins.

The "blow" runs slightly obliquely to the course of individual veins. The latter trend about 30° south of Ellis Brook, and between 50° and 90° farther north. Vertical major joints are common in quarries and cliffs, and strike 135° near the White Rock and Mountain Quarries and 65° north of Ellis Brook. Sericite schist and quartz are roughly banded near the Mountain Quarry: the strike and dip of these bands (strike 20°, dip west at 60°) may possibly be the strike and dip of some of the veins. The banding may be thought to be a relict sedimentary structure, and the quartz "blow" to be a huge xenolith of sedimentary rock in which quartzose bands now appear as quartz veins. But there is no further sign of sedimentary structures even near the centre of the mass, and petrologically, both in hand specimen and in thin section, the quartz of the "blow" resembles that of the smaller veins, and is thus igneous in origin.

The acid igneous solutions from which the quartz veins are derived rose along planes of shearing and faulting in the granite. But, as the granite is structureless, there is no apparent explanation why these directions of weakness trend predominantly slightly east of north.

Many of the quartz veins have been examined for gold. The large vein just north of stream A has received particular attention. Five costeens have been dug in it, and Messrs. Ross and Son, in 1909, put in an adit-crosscut 175 feet long and a shaft 27 feet deep. The State Mining Engineer, A. Montgomery, visited the prospecting allotment and reported (1910, p. 124) that "the reef is very poor indeed in gold and quite unpayable at present." The cross-cut was extended 40 feet, but mining was then abandoned and nothing has since been done.

The quartz of the "blow" was recently quarried as an aggregate for concrete and for bitumen roads, but owing, it is said, to the heavy wear of the rock-crushing machines, it has not been worked since 1929.

D. *Cardup Series.*

This series outcrops west of the granite, near Ellis Brook. It strikes nearly due north, parallel to its contact with the granite and dips west at (usually) 50° to 55°. The dip steepens to vertical near the barite pits, but this is due to buckling by the nearby basic intrusion. Faint jointing, practically normal to the strike, is developed in the slates, but no fracture cleavage or dragfolding was noted.

Outcrops are poor, and sandstone rubble often obscures slate and conglomerate beds. There are thin bands and lenses (from an inch to six inches thick) of arkose in slate and bands of sandstone in conglomerate, so that the succession deduced from exposures in pits just north of Ellis Brook has been slightly generalised. It is, in descending order:—

Hematitic Sandstone	? (Western boundary obscured.)
Sandstone with Cherty lenses ..	30 feet.
Slate	20 feet.
Conglomerate	24 feet.
Vughy Sandstone (with barite) ..	8 feet.
Basal Conglomerate	15 feet.

Although coarser-grained than those which have been worked at Armadale and in the Wongong-Cardup Area, the Gosnells slate is of excellent quality for brickmaking. Shallow trenches have been dug to prove its extent and it is expected that, although the slate crops out over such a small area, it will be worked in the near future.

The contact between sediments and granite is nowhere exposed, but it may be mapped within five feet on the hill just north of Ellis Brook, and within 10 yards in several other places. No granite apophyses are found in the sediments, and small quartz veins in the granite may continue right to the contact but do not intrude the sediments, just as has been found at Armadale (Prider, 1941, p. 30). This indicates that the Cardup series is younger than the granite and quartz veins, a conclusion which is consistent with their very low grade of metamorphism.

E. *Basic Dykes.*

All previously mentioned rocks have been intruded by epidiorite dykes. Most of these dykes trend slightly west of north with dips (where measurable) to the east at 60°. A few trend north-west, or very rarely, due west.

Their width varies from five inches to about five chains—it is usually about a chain. In the centre of the wider dykes exposed in the quarries, "ladder" joints (Balk, 1937, p. 97) are developed perpendicular to the dyke walls, but their marginal three feet is schistose and contains segregations and veins of quartz, pyrite, calcite and epidote. Epidote veins may thread the epidiorites and also enter the surrounding granite.

Thin, irregular, basic veins (nowhere more than two feet wide) have been exposed in the White Rock Quarry. They occupy joint-cracks in the granite and resemble the schistose margins of the dykes in mineralogical composition.

A porphyritic basic rock (porphyritic epidiorite) intrudes the Cardup sediments. The dumps of two shallow pits dug in this rock contain small masses of barite, up to about four pounds in weight. Nothing is now visible to indicate further the mode of origin of the mineral.

Non-porphyritic epidiorite dykes intrude the Cardup series at Armadale (Prider, 1941, p. 43), but no such intrusions were found over the small area where the sediments crop out at Gosnells.

F. *Edge of the Pre-Cambrian Rocks.*

The western boundary of the Pre-Cambrian rocks cannot be drawn accurately. Some small, isolated masses of granite are found several chains west of the edge of the continuously outcropping granite. These may be outcrops, and may be boulders. Granite fragments are found in a well, 20 feet deep, 200 yards W.N.W. of the Mountain Quarry, far from any granite outcrop and 100 yards west of the nearest quartz outcrop. Near the Seaforth Home, a quartz mass extends far west of other outcrops. But in spite of these irregularities, and other irregularities due to laterite in the south, the boundary runs fairly straight in a north-south direction.

Outcrops of the Cardup series are very discontinuous. They are found next at Kelmscott, 3½ miles farther south (Honman, 1912, p. 63). They may exist, however, under the laterite rubble which is so common in the south of the Gosnells area.

Tertiary beds, found in bores near Perth, are probably developed west of the Pre-Cambrian rocks. A sub-artesian bore (depth 172 feet) was put down near Gosnells in 1872 Its exact location cannot be ascertained—it is mentioned by Brown (1873, p. 10), who stated that (among other things) fragments of lignite had been reported from the bore. Evidently the bore was put down entirely in the younger rocks west of the Pre-Cambrian: Simpson (1916, p. 173) called them "Mesozoic sandstones and shales."

G. *Laterite.*

As the laterite has been studied mainly in the field, it is best to discuss it at length now. There are two distinct types: high- and low-level laterite.

1. *High-Level Laterite.*

The edge of this capping lies at a height of between 700 and 850 feet above sea level. Although in places it is marked by a "breakaway"—a scarp (up to 30 feet high) topped by a few feet of solid pisolitic laterite,—more often the edge of the laterite is covered by a few feet of sand and rubble so that it cannot be mapped with certainty. Furthermore, laterite is found in places at a level below that of the breakaway only a short distance away. North of stream A, there is a small outcrop, 30 feet below the scarp, and north of Wright Brook, a ridge about 50 feet below the breakaway, projects for ¼ mile. These outcrops are separated from the main plateau by rubble which in other places extends for 200 feet below the breakaway. Detritus obscures most granitic outcrops over the whole scarp east of the Seaforth Home, but it is now being cut through by a stream.

A pit has been dug a chain away from and a few feet above the edge of the laterite outcrop, east of the White Rock Quarry. It passes through about 30 feet of laterite, underlain by pink and white clay. Laterite must therefore extend below the level of the breakaway, and, as has just been mentioned, its boundary is likely to be obscure, especially where there is no breakaway.

As the laterite capping formed (Woolnough, 1918) on the surface of the peneplain, differences of laterite level are due to initial relief of the peneplain. The thickness of the capping probably rarely exceeds the 30 feet found in the pit (above). In places, it is much thinner, for epidiorite fragments have been found well above the base of the laterite.

2. *Low-Level Laterite.*

Near the foot of the Darling scarp, laterite crops out in places, west of all outcrops of Pre-Cambrian rocks. In a gravelpit just west of the Mountain Quarry, the deposit grades from ill consolidated detrital material mixed with large quartz boulders to more homogeneous laterite. Small "breakaways" in laterite have been noted (e.g., at a height of 300 feet near the south-west corner of the area, and at a height of 180 feet, west of the White Rock Quarry). The laterite may not be all detrital in origin.

Near Ellis Brook, just west of the porphyritic epidiorite, is a red, clayey deposit with incipient pisolitic structure—perhaps a partially formed laterite. The heavy minerals of this clay and of the porphyritic epidiorite were almost exclusively magnetite, so it may be suggested that here the porphyritic epidiorite (or some other rock of favourable composition and texture) is being laterised *in situ*. But all that can definitely be asserted is that, near Gosnells at least, the low-level laterite is too discontinuous to mark the position of a step-faulted block, as suggested by Woolnough (1919, p. 16).

H. *Later Superficial Deposits.*

These include silt, sand and talus slopes. A little silt has been deposited in the valleys of the larger streams, but it is not shown on the map. Sand occurs over the laterite on the gently-sloping plateau and over low-level laterite near the plain. Except for the lateritic rubble which covers such a lot of the area, talus slopes are small.

IV. PETROLOGY.

A. *Xenoliths.*

Although in the field these are much darker, some contain only a little more biotite than does the surrounding granite, so that the two rock-types are very similar in section.

Usually, the biotite is a green variety (X = light yellow Y = Z = dark green) with inclusions of opaque magnetite (?) aligned parallel to c. In particularly biotitic rocks, recognisable felspar crystals are rare, their place being taken by masses of finely granular epidote. Epidote may be found, too, as coarse, turbid and red stained granules associated with biotite aggregates. Quartz is subordinate to biotite and epidote. Sphene (in the form of scattered granules) and apatite are rare. Most of the xenoliths are these biotitic rocks more or less digested by the plagioclase- and quartz-rich granite.

Potash felspar is found in very few of the xenoliths. Plagioclase is saussuritised and sericitised to a varying extent; and some individuals contain small columnar crystals of zoisite. Extinction angles measured on albite twin lamellae indicate that the felspar averages Ab_{93}, with a range in composition from Ab_{86} to Ab_{98}. In rocks containing heavily sericitised felspar, the biotite has recrystallised to coarser green flakes. Sometimes, this process is incomplete and leaves the biotite intergrown with muscovite or with colourless chlorite (?).

Occasional specimens contain a brown biotite (X = light yellow, Y = Z = deep copper-brown). Such a rock (with granular epidote marking the place of felspar) is found at Statham's. Clarke and Williams (1926, p. 169) noted that such "biotitic segregations" exist, but they did not describe them.

The Gosnells xenoliths resemble the hornblende-biotite-zoisite hornfels xenoliths found at Armadale (Prider, 1941). They are, however, much more digested by the granite magma. Hornblende has disappeared, and apatite is much rarer. Quartz (and plagioclase in the more assimilated rocks) have been introduced, and epidote has recrystallised to coarser granules.

A rather different type of material is the chloritic schist, which resembles one, but only one xenolith, near the foot of the scarp north of Ellis Brook. The former is green, fine-grained and finely banded (about 15 bands to the centimetre). The constituent minerals found in thin section are quartz, chlorite, magnetite, muscovite, and a little epidote and apatite. Alternate bands are rich in quartz and in chlorite and magnetite, and the minerals are usually elongated parallel to the banding. The quartz veinlets seen in the field are found, on a small scale, in a thin section. As a result of weathering, hematite has been formed from the magnetite and has discoloured the rock, and consequently it was impossible to compare specimens of the schist from both sides of stream A.

An epidiorite dyke alongside the schist contains abundant green chlorite, but the schist resembles most closely a dark, massive xenolith found near Ellis Brook. The xenolith is made up magnetite, biotite, apatite, sericitised felspar and muscovite; a higher grade assemblage than occurs in the schist. Sericite is abundant in the schist, to the exclusion of felspar, of which it is the alteration product: apatite is less common; biotite has been converted to chlorite and quartz has been introduced as bands and veinlets. In both rocks, the sericite has been partially recrystallised to small flakes of muscovite.

From its field occurrence the schist is considered to be a xenolith, permeated by siliceous solutions derived at a late stage of cooling of the granite. Near quartz veins in the area, granite is generally altered to a schistose aggregate of low-grade minerals: similar changes in a xenolith have produced the schist.

B. *Granite.*

A hand-specimen of this rock is medium, even-grained and either light coloured, or tinted red by weathering. The minerals recognisable are limpid quartz; pink, greenish or white felspar and flakes of biotite.

The texture is allotriomorphic granular (or occasionally poikilitic) and the minerals found in thin sections are quartz, a plagioclase near albite and some microcline with dark minerals (biotite, chlorite and epidote) very subordinate. Table I. shows the range of mineralogical composition of the granite.

Plagioclase in all the rocks sectioned is of positive optical character, and in most of them the maximum extinction angle on the albite twin lamellae is 12° to 15°, indicating a composition between $Ab_{[illegible]}$ and $Ab_{[illegible]}$. The average composition is then the same as that of plagioclase in the xenoliths, but its range is narrower.

The plagioclase in some of the granites is saussuritised. In most, however, it is sericitised, and it has been found in all stages of alteration from being perfectly fresh to being completely replaced by sericite. These alterations must be primary: they are too widespread and independent of jointing and other means of ingress of water to be regarded as due to weathering. Plagioclase in the pegmatite and aplite dykes is remarkably fresh. In a few granites, too, plagioclase is only slightly sericitised, and in these rocks as much saussuritisation has taken place as sericitisation. These rocks are rich in microcline, and under the microscope several of them shown signs of crushing and even of faulting of small displacement.

TABLE I.

Micrometric Analyses of Gosnells Granites.

(Figures are volume percentages.)

	1.	2.	3.	4.
Quartz	37·9	35·1	34·6	37·4
Plagioclase	47·7	46·7	37·8	19·7
Microcline	10·4	13·1	24·4	38·7
Muscovite	1·6	1·8	...	0·1
Biotite	1·6	0·2	0·5	2·8
Chlorite	0·8	1·2	2·6	...
Apatite	0·1	...	...	...
Epidote	...	1·7	...	1·0

1. Granite containing sericitised plagioclase. Road Board Quarry (for analysis *see* Table II., column 1) specimen 20,696*.

2. Granite containing saussuritised and sericitised plagioclase. Specimen 20,709.

3. Granite containing clear felspar and a crush breccia. The analysis is of the uncrushed part. The crush breccia occupies 14 per cent. of the section. Specimen 20,706.

4. Granite: gneissic with slightly turbid but unsericitised plagioclase. Specimen 20,704.

* The numbers refer to catalogued specimens in the General Collection at the Geology Department, University of Western Australia.

TABLE II.

Analyses of Darling Range Granites and of Certain "Average" Types.

	1.	2.	3.	4.	5.
SiO_2	75·01	73·19	73·36	73·30	75·99
TiO_2	0·20	0·14	0·04	0·11	0·09
Al_2O_3	13·14	14·24	13·88	12·33	13·14
Fe_2O_3	1·08	0·88	0·81	2·58	0·93
FeO	1·39	0·92	0·93	1·28	0·24
MnO	0·01	tr.	0·15	0·02	...
MgO	0·02	0·43	0·51	0·26	0·08
CaO	0·26	1·84	1·69	0·46	0·62
Na_2O	3·96	3·86	3·22	4·55	3·92
K_2O	4·00	3·42	5·07	4·20	4·70
H_2O+	0·28	0·55	0·18 }	0·86 {	0·27
H_2O-	0·30	0·08	0·11 }		0·08
CO_2	...	0·07	...	...	...
P_2O_5	0·07	0·01	0·07	0·05	...
BaO	0·08	0·07	0·09	...	0·03
FeS_2	...	0·01	0·05	...	...
	99·80	100·01	100·19	100·00	100·09

The alkalis were determined in a granite from Statham's by C. R. Le Mesurier in 1929: giving Na_2O 4·25: K_2O 2·31 per cent.*

1. Granite: Road Board Quarry, Gosnells. Analyst: C. E. S. Davis.
2. Granite: Government Quarry, Boya. Analyst: J. N. A. Grace.*
3. Granite: Mahogany Creek. Analyst: A. J. Robertson (Simpson, 1916, p. 18).
4. Alkaline Granite: Average of 10 analyses (Daly, 1933, p. 10).
5. Kalialaskite: Average of six analyses (Johannsen, 1932, p. 49).

* Published by kind permission of the Government Mineralogist and Analyst.

Potash felspar is always much fresher than the plagioclase, and any alteration is by kaolinisation, not sericitisation. As it always shows grid-iron twinning, it has been described as microcline. No orthoclase was recognised in any section of a granite. Occasionally, thin strings of clear quartz thread the potash felspar, forming an injection micropegmatite.

Quartz is found as clear grains which always show wavy extinction. Next to felspar, it is the dominant mineral.

Biotite has the pleochroic scheme X = light yellow, Y = Z = deep brown, but in many rocks it has changed to the green variety which may be interlaminated with colourless chlorite (?) and muscovite. The green biotite, too, may be replaced and pseudomorphed by weakly birefringent green chlorite.

Epidote, if present, usually forms coarse turbid granules associated with biotite, as it does in the xenoliths. Rocks containing this type of epidote are, then, slightly hybridised. Epidote in the veins emanating from the epidiorites is colourless to canary yellow and clear.

Short stumps of apatite are rare constituents of the granite. They are larger and more prominent in completely sericitised rocks.

Occasionally sericite has partially recrystallised to muscovite, which is developed both as anhedra within the parent plagioclase and as laths between the plagioclase grains.

An analysis was made of an albite-rich granite in which the albite was moderately sericitised (it is estimated that about 20 per cent. of the albite has been replaced by sericite). The result is shown in Table II. in which it is compared with other granites analysed from the Darling Ranges near Perth, and with two "average" types.

The main point of difference between the Gosnells granite and the other two granites near Perth which have been analysed is its extreme poorness in magnesia and lime. It is slightly poorer in alumina, and slightly richer in silica, titania and both iron oxides. The total alkalis in all three rocks are fairly constant, although there is considerable variation in the relative proportions of potash and soda.

Of Daly's average rock types (1933, p. 9) the Gosnells granite resembles most closely the alkaline granite (Table II., column 4), but is decidedly low in ferric oxide, a little low in magnesia, lime and the alkalis; but richer in silica and alumina. Johannsen's "kalialaskite" (Table II., column 5) has, like the Gosnells rock, a low magnesia and lime content.

From the mode of the Gosnells granite (Table I., column 1), its alkali content can be calculated to be Na_2O 5.6% K_2O 2.0%. The excess potash found in the analysis must be due to the sericite flakes, and to a little potash-felspar in solid solution in the plagioclase.

The plagioclase of the granite probably crystallised as a solid solution containing up to 30% of potash felspar. The solubility of the two diminishes rapidly with fall in temperature (Johannsen, 1932, p. 141), and the excess potash-felspar normally separates as antiperthite. In the Gosnells granite, sericite is found instead of perthitic intergrowths: the potash-content of the plagioclase separated as sericite, which is stable at a low temperature and (especially) under conditions of stress. Some rocks contain unsericitised plagioclase and much potash-felspar, and many of these microcline-rich rocks show signs of crushing. The plagioclase probably recrystallised under the stress, and later, smaller stresses produced the faulting now visible. In pegmatite and aplite dykes, which crystallise at a lower temperature than the parent granite, original plagioclase was comparatively free from potash-felspar, and little sericite has since formed.

C. *Acid Intrusives.*

1. *Pegmatite and Aplite.*

These two types are often associated, and in such instances the pegmatite occupies the border and aplite irregular patches in the centre of the intrusion. Coarse crystals scattered near the edge of an aplite dyke are seen in section to be resorbed. Emmons (1940, pp. 5-6) points out that the outstanding difference between pegmatite and aplite is textural: if the volatile constituents escape from a liquid which is crystallising as a pegmatite, the residuum will solidify as a fine-grained aplite.

The pegmatites consist of plagioclase, microcline, microperthite or graphic intergrowth of quartz and microcline, together with quartz and small books of muscovite. The grain size of the pegmatite is up to 10 cm., but that of the aplites is only 0.3 mm.

The plagioclase in both types of rock, as mentioned previously, has been remarkably little sericitised. Microcline is usually subordinate to plagioclase. Quartz, though fairly common, is not as abundant as it is in the granite. One aplite contained a few rods of muscovite and a few laths of tourmaline (pleochroic scheme X = deep blue, Z = colourless) but no dark minerals.

2. *Quartz Masses.*

As described in the section on their field characters, quartz masses may be from an inch to over 20 chains wide. In spite of this tremendous difference in their size, all such masses appear to be of similar character.

The central parts consist mainly of fine-grained massive white quartz. In thin section, they are made up of irregular interlocking grains of quartz of very uneven texture (in one section the grain size varied from 0.03 mm. to 0.5 mm. and in another from 0.2 mm. to 1 mm.) Undulose extinction is very common, and is especially noticeable in the larger grains.

Some of the quartz from near the centre of the "blow" is friable and "sugary" and contains numerous small flakes of sericite. This sericite content increases towards the edge of the mass, but nowhere has much sericite recrystallised to muscovite. On the west side of the Mountain Quarry, sericitic and quartzose bands are interleaved. In other places near the edge of its outcrop, the quartz "blow" is made up of a stockwork of tiny quartz veins (about 1 cm. wide) in a micaceous matrix. This is especially clear on weathered surfaces. "Shaly bands" noted in weathered rock near the edge of the "blow" consist entirely of an aggregate of small flakes of sericite.

The granite is generally weathered away for some 50 yards from the edge of the quartz outcrops. Where granite does outcrop in the immediate vicinity of the larger quartz masses, it contains stockworks of quartz, flanked by crushed and silicified granite containing bands rich in sericite. Most of the thinner quartz veins are surrounded by flaky, dark, weathered rock.

Sericite and subordinate green biotite have been introduced in cracks through the original felspars in apparently massive granite threaded by quartz veinlets. Occasionally the twin lamellae of the felspars are bent; otherwise they are not altered. Quartz, as it is not unduly strained, must have been introduced after the stresses operated to deform the felspar. Other specimens of granite, which can be seen in hand-specimen to be altered, contain felspar in various stages of replacement by sericite. So rock types are known, in the wall-rocks and in the quartz masses, which are transitional between granite and pure massive quartz.

It has been held that the quartz "blow" is merely recrystallised quartzite xenolithic in the granite. But there is no trace of bedding in the "blow" (except possibly the sericitic bands found in the Mountain Quarry). It is unlikely that such a large scale structure would be obliterated elsewhere. Recrystallisation, too, should produce a mass of even-grained quartz and muscovite, and no stockworks of quartz threading the surrounding granite.

Thin sections from the "blow" and from narrow quartz veins resemble one another. Both contain evidence of replacement, and because so many transitional rocks are found, it is concluded that all these masses (including the wide "blow") were formed by hydrothermal replacement.

Similar quartz veins (both in width and nature) occur near the Great Bear Lake, Canada. The wall-rock (a granodiorite) is altered for distances of up to 100 feet from the edge of the quartz veins. Such alteration (Furnival 1935, p. 855) consists of the replacement of felspar by secondary minerals (chiefly sericite), followed by replacement of original and secondary minerals by quartz. Furnival concludes (p. 859) that the hydrothermal solutions passed along faults of great persistence and displacement along which the rocks were severely fractured over widths of up to 1,000 feet. Similar faulting in the massive granite near Gosnells, although it cannot yet be proved, is nevertheless possible. The quartz was probably derived from end-stage solutions from the granite, as no other acid igneous rock has been found in the district.

The long quartz vein north of stream A contains small scattered crystals of pyrite which weather easily to make the rock appear vughy and to stain it reddish-brown, green and yellow. Iron oxide has been deposited by percolating water in many places in the adit, which cuts through the vein 90 feet below the surface.

Veins 1 cm. wide, rich in blue-grey tourmaline, cut the quartz of the White Rock and Mountain Quarries. The quartz of these veins is colourless, limpid and coarse-grained (the grain size is up to 1 cm.) but excessively strained. The tourmaline is in the form of wisps or rods, aggregating to an irregular fibrous mass with pleochroic scheme X = deep blue, Z = pale brown. The refractive index $\epsilon = 1.628 \pm 0.003$ indicating a tourmaline about midway between dravite and schorlite (Winchell, 1927, p. 246). Simpson (1931, p. 141) describes the occurrence of dravite in many places near Perth, and mentions that "In addition schorl has been detected in small quantities at Gosnells and Cardup."

D. *Cardup Series.*

1. *Arkose and Slate.*

Being intimately associated in the field, the two are discussed together.

Arkosic bands and lenses in the slate contain pebbles of quartz up to 5 cm. long, set in a mass of smaller grains of rounded quartz, more turbid felspar and (in weathered specimens) white kaolinite (?). Some slaty material is found in the arkosic patches.

The constituents present in sections are subangular quartz (grain size 0.1 mm. to 2 mm.), subordinate fresh microcline and a little slightly sericitised plagioclase, and rare aggregates of a flaky mineral of low birefringence which may be kaolinite, all set in a sericite cement. In weathered specimens, plagioclase and sericite are absent, but the clay constituent (a turbid, earthy mass) is abundant.

The slate is a fine-grained finely bedded micaceous rock. Fresh specimens are grey, and slightly weathered ones stained pink. It consists of sericite and oval shaped quartz grains about 0.05 mm. long, and a few small, rod-like idioblasts of tourmaline in various stages of development (the largest noted was 0.3 mm. by 0.1 mm.). The pleochroic scheme of the tourmaline is X = deep blue-green, Z = very pale blue.

Bedding of the slate is conspicuous and marked by orientation of the sericite and by iron-staining. Although hand specimens of weathered slate and of "shaly bands" from near the edge of the quartz "blow" resemble each other, they are very different in section. "Bedding" is irregular in the "shaly bands," the sericite is haphazardly oriented and not associated with rounded quartz grains, and quartz occurs only in veins composed of interlocking angular grains.

2. *Sandstone.*

Rocks classed as "sandstones" grade from sandy slates to porous quartzose grits resembling the arkoses. Bedding, though clear in the finer grained rocks, may not be noticed in the coarser ones.

The dominant constituent is quartz, in rounded grains up to 5 mm. long with wavy extinction. Sericite, present in small quantities as a cement in all the sandstones, is as common as quartz in the sandy shales. Felspar and tourmaline are rare, but rounded zircon plentiful.

A few veins, consisting entirely of an interlocking mosaic of quartz, thread the lower sandstone. Their grain size varies from about 0.1 to 0.5 mm. and in one specimen the grains of the vein quartz were noted to be larger than those of the surrounding sandstone. Strain shadows may be noticed in the larger grains. Cherty lenses in the middle sandstone band have a conchoidal fracture and consist of fine (0.05 mm.) interlocking grains of quartz.

As the lower sandstone is very vughy also, it appears that material has been dissolved out of the rock to leave the vughs and has been redeposited elsewhere in the same bed as veins. The vughs (which are up to 3 cm. in diameter) are lined with a thin layer of quartz, and within the vughs there are well developed crystals of barite up to 1 cm. long. A little barite is scattered through the sandstone, but no barite veins have been seen in this bed. However, in a cherty lens of the upper sandstone, there are barite veins.

The nearby intrusion of porphyritic epidiorite, which contains a segregation of barite, is probably the source of the barite found in the sandstone. It is suggested that barite-rich solutions dissolved some material out of the sandstone, forming the vughs which they later incrusted with quartz and barite; this suggestion may be tested by finding out (at Armadale and southwards) whether the vughy sandstone is always baritic.

3. *Metamorphism.*

Metamorphic effects in the Gosnells sediments are very slight. Tourmaline has developed in the slates, and sericite may be recrystallised. In the sandstones, a little quartz recrystallised at some stage as cherty lenses and as quartz veins. But hematite has not been changed to magnetite, and no biotite has developed. Only slight jointing has been produced. Argillaceous sediments are very readily affected by rise of temperature, and the very slight metamorphism of these rocks indicates that they were deposited after the granite had cooled.

E. *Basic Intrusives.*

1. *Uralitised Quartz Dolerite (Epidiorite).*

Hand specimens of this rock are grey to greenish-black in colour and are fine-grained near the edge of the dykes, but medium-grained near the centre. They consist of white felspar set in a darker matte of amphibole. Essential minerals present in thin section are felspar, amphibole, epidote and ilmenite. Most of the amphibole is a pale variety consisting of flaky aggregates or irregular plates, and is evidently a secondary mineral. It is referred to as "uralite." A little primary brown amphibole is present in most rocks, and bluish, more euhedral amphibole is produced by recrystallisation of the uralite. Both these latter types of amphibole are referred to as "hornblende."

In similar basic dykes north of Gosnells (e.g., in the Lower Chittering area (Miles, 1938, p. 29)), uralite is derived from pyroxene. The author has seen a section of a dyke near Darlington in which pyroxene has partly altered to a pale green uralitic aggregate which farther from the parent mineral, has recrystallised to a blue-green type of hornblende. Although no relics of the primary, high-grade parent mineral of the uralite have been found in the Gosnells area, it is believed that this uralite, too, is derived from pyroxene.

Holmes (1928, p. 92) defines "epidiorite" as "A doleritic or basaltic rock in which the augite has suffered alteration to hornblende so that the rock (mineralogically) approaches the composition of a diorite." The writer has added the word mineralogically as, chemically, such alteration does not produce a more acid rock.

Basic dykes near Perth with pyroxene entirely replaced by hornblende have been described in previous literature as "epidiorite." This has, however, become a field- and a sack-name and moreover has often been altered to "diorite," even in geological publications. It is best, therefore, to give to the rocks a name indicating their genetic relationships, and they are here termed uralitised quartz dolerites. Uralitisation must have been deuteric, for the Cardup sediments are so very low-grade that there could have been no regional metamorphism to effect the change.

Fresh primary felspars are clouded and coloured brown, but this colouration is far less marked than it is in dolerites from Darlington and Lower Chittering. MacGregor (1931) suggested that, were a basic intrusive heated at some period after its consolidation, minute traces of impurities, of which iron oxide is the commonest, would separate, resulting in grey- and brown-clouding. He contends (p. 537) that:—

> "it seems necessary to prove that (any igneous rock with clouded felspars) . . . can never have been subjected to regional- or contact-thermal metamorphism before the clouding can be regarded either as an original feature of the felspar or as a deuteric effect that arose at a late stage in the consolidation period."

In the Gosnells area, there are no later intrusions to effect contact metamorphism and, as has just been shown, no regional metamorphism can have taken place. Clouding, then, was produced either at a primary or at a deuteric stage. Recrystallised epidiorites from Gosnells contain unclouded felspar, and felspars in Gosnells epidiorites are far less clouded than those from basic dykes farther north. In the Lower Chittering, Miles (1938, p. 31) notes that clouding was especially marked in the unaltered dolerites. It appears that clouding is best developed in the rocks which have undergone least deuteric alteration, and is therefore an original feature of the felspars.

The least recrystallised dolerite from Gosnells contains abundant uralite as irregular fibrous aggregates or irregular plates with the following optical properties: pleochroism X = very pale green, Y = pale green, Z = pale brown; extinction $Z \wedge c = 22°$ and (—) 2V large. Along edges adjacent to felspar, part of the uralite has recrystallised to blue-green hornblende (pleochroic scheme X = pale green, Y = grass-green, Z = blue-green, $Z \wedge c = 23°$). There are occasional crystals of euhedral primary brown hornblende (X = light yellow-brown, Y = deep green, Z = deep green-brown).

The plagioclase is generally fresh with a slight brownish smoky coloration, and has a maximum extinction angle of 32° in sections cut normal to the albite twin lamellae, indicating a composition of about Ab_{45}. In some rocks, however, plagioclase has been entirely replaced by an aggregate of turbid, colourless epidote, and epidote has elsewhere gathered into a mass of clearer laths and granules. Other constituents of the rock are leucoxene (with a small core of ilmenite), laths of apatite and a little interstitial micropegmatite. The ophitic texture of dolerites has been well preserved.

A similar dyke from the Bickley Brook Reservoir Quarry, one mile north of the area, has been analysed (Clarke and Williams, 1926, p. 173). It contains more blue-green hornblende, and a little brown hornblende in the central parts. Some of the felspar has been converted into a mass of epidote, but other crystals are brown and smoky.

In some rocks, the felspar is always replaced by a turbid mass of epidote and the ophitic texture lost. Hornblende in this type of rock (a lighter blue-green variety) forms crystals with very irregular borders. Quartz and micropegmatite are common, and, in certain segregations, dominant. The felspar of the micropegmatite is extensively sericitised.

Nodules and veins of epidote are scattered through the dykes exposed in the quarries in the Gosnells area. The dolerite surrounding a nodule, spherulitic in structure, was totally recrystallised to a non-porphyritic medium-grained (grain size 2 mm.) ophitic intergrowth of clear albite felspar and pale green hornblende. The albite contains a few pale green inclusions and both albite and hornblende are very similar in this rock and in a fresh porphyritic epidiorite (4. below) from farther south. The pleochroic scheme of the hornblende is X = pale yellow; Y = Z = pale green, and its refractive index β is 1.641, compared with 1.657 in primary brown hornblende from the Bickley Brook Reservoir Quarry.

A little of this hornblende has been converted to biotite. However, another recrystallised specimen (about three feet from the edge of a dyke) contains much biotite so that it resembles biotite epidiorites, described in the next section.

A few veins of calcite, up to 3 cm. wide, occupy prominent joint cracks in the dykes. Some pyrite, too, has crystallised with the calcite in and near the veins. The rock surrounding calcite veins is very low grade: it consists of pale green chlorite, quartz and turbid patches of calcite.

Occurrence of Galena.—The author has seen two loose specimens of galena from Gosnells, but, in spite of a long search, none in situ. One, from a dump at the Blue Rock Quarry, contains a mass of galena about 1 cm. in diameter, set in coarse, strained and slightly granulated milky quartz. According to quarrymen, it came from a mass of quartz adhering to the granite at the dyke contact on the west wall of the north quarry, but no galena-bearing quartz could be found in situ.

The other specimen, from the White Rock Quarry, was collected by S. E. Terrill early in 1935. Now that so much further quarrying has been carried out, it was impossible to recognise the dyke from which it came. His specimen is a fine-grained, rather schistose, dark rock, with fine disseminated grains of galena and pyrite. It contains a little residual green hornblende and biotite, but the main ferro-magnesian is chlorite. Other minerals present are clear recrystallised albite, very subordinate epidote and a quartz vein containing some calcite.

This occurrence of galena at Gosnells, although on a very small scale, is interesting because the galena is definitely associated with the uralitised quartz dolerite or one of its derivatives. It throws light on the genesis of the galena-sphalerite-quartz veins of Armadale (Prider, 1941, p. 51) and silver-lead deposits at Mundijong (Esson, 1927), and confirms Prider's suggestion that they are genetically related to the basic rather than to the granitic magma.

2. *Biotite Epidiorite.*

A dyke, 10 feet wide, exposed only in the southern corner of the White Rock Quarry, is the sole rock found of this type. It contains many calcite veins and numerous small brown rounded biotitic patches. A section cut from the centre of the dyke shows that the pale blue-green hornblende has been largely altered to brown biotite—the brown patches consist of a decussate aggregate of biotite flakes. Recrystallised albite is common. Near its edges, the dyke consists of a fine-grained mass of green biotite with subordinate epidote and leucoxene, and clear felspar is rare.

These rocks are similar to those described by Prider (1941, p. 46) from Armadale which, being chemically very rich in potash and poor in lime, resemble the chlorite-albite epidiorite and, probably, the porphyritic epidiorite (4. below). But the Gosnells rock seems to be a derivative of the uralitised quartz dolerites, altered by end-phase potassic solutions.

A narrow epidotic biotite epidiorite dyke (five inches wide) in the White Rock Quarry is firmly welded to the granite. It consists of epidote and (especially near its margin) of green-brown biotite. Microscopic veins of biotite and chlorite penetrate the granite for at least ½ cm. both between and through its constituent crystals, and cause a bending of the albite twin lamellae of the felspar. In composition, this dyke is intermediate between the biotite epidiorites and the biotite-epidote veins.

3. *Biotite-Epidote Veins.*

These thin veins (maximum width two feet) are, unlike the dykes, irregular and not persistent.

The vein material is aphanitic, green or black and flaky, evidently containing abundant biotite. Indeed, it consists of green biotite (largely converted to chlorite) and very pale green epidote. Granite inclusions in the vein are cut by stringers of biotite and epidote. Albite twin lamellae of the felspar in the xenolithic rock are bent and fractured, but the felspar is clear and unsericitised and may have recrystallised before these deforming movements took place.

4. *Porphyritic Epidiorite.*

This type is found only near Ellis Brook, where it intrudes the Cardup sediments. Porphyritic epidiorites occur at various places (Wongong, Cardup, Mundijong) farther south, and a similar non-porphyritic rock at Armadale (Prider, 1941, p. 43).

It is a dark, weathered rock made up of laths of felspar, up to 5 mm. long, set in a fine-grained ground. From a section, it is seen that felspar is developed as stout prisms (of all sizes from ½ mm. to 5 mm.) which form a coarse network. The felspar is near albite, contains abundant chloritic inclusions and is little altered except for slight kaolinisation. The ferromagnesian constituent is now green to brown biotite, forming decussate aggregates, filling the interstices between the network of albite prisms. Magnetite is fairly common.

Small lumps of barite have been found near a pit in the porphyritic epidiorite. The mineral is associated with veins of strained quartz, and is largely massive (grain size 0.3 mm.), but is also developed as tabular crystals up to 5 cm. long. As this is the sole occurrence of barite in association with any igneous rock in the area, the porphyritic epidiorite is probably the source of the barite in the Cardup sandstones at Gosnells.

V. GEOLOGICAL HISTORY.

There is no record in this area of any event prior to the emplacement of a granite batholith in middle Proterozoic time (Clarke, 1930, p. 160), although a little to the south large masses of earlier, more basic rocks are preserved (Prider, 1941). These have been largely digested by the granite at Gosnells, and only a very small quantity of them is found as xenoliths.

End-liquids circulating in joints formed in the cooling mass crystallised as dykes of pegmatite and aplite. Stresses at a later stage fractured the granite over a wide zone, and quartz was deposited from hydrothermal solutions over this zone and in many smaller fractures.

There followed a period of erosion and deposition of a normal sequence of sediments (the Cardup series) which have undergone very little anamorphism. Although only a small thickness of sediments is exposed at Gosnells, several hundred feet are exposed farther south, and a considerable thickness may underly the surface rubble even at Gosnells.

All pre-existing rocks were invaded by basic dykes of (Clarke, 1930, table p. 187) late pre-Cambrian age. These dykes now contain the lower-grade mineral hornblende instead of pyroxene. In a porphyritic basic dyke, a segregation of barite was formed. At the same time, probably, baritic solutions entered the more porous basal beds of the Cardup series.

Since pre-Cambrian times, a great thickness of sediments has been laid down in the trough west of the Gosnells area. In the Tertiary (Woolnough, 1918) a laterite capping was developed over the peneplained surface of the pre-Cambrian rocks. The peneplain was uplifted (in at least two stages) and a small amount of subsequent erosion produced the present topography.

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VII. BIBLIOGRAPHY.

Balk, R., 1937: "The Structural Interpretation of Igneous Rocks." *Geol. Soc. Am. Memoir* 6.

Brown, H. Y. L., 1873: "General Report on a Geological Exploration of that Portion of the Colony of Western Australia lying Southward of the Murchison River and Westward of Esperance Bay." Paper No. 1, Votes and Proceedings, Legislative Council, W.A., for 1873, pp. 1-20.

Clarke, E. de C., 1930: "The Pre-Cambrian Succession in some parts of Western Australia." *Report A.N.Z.A.A. Sc.* for 1930, pp. 155-192; and Williams, F. A., 1926: "The Geology and Physiography of parts of the Darling Range near Perth." *Jour. Roy. Soc. W.A.*, XII., pp. 161-178.

Daly, R. A., 1933: "Igneous Rocks and the Depths of the Earth." New York.

Emmons, R. C., 1940: "The Contribution of Differential Pressures to Magmatic Differentiation." *Amer. Jour. Sci.*, Vol. 238, pp. 1-21.

Esson, A. D. G., 1927: "The Silver-lead Deposits at Mundijong." *Geol. Surv. W.A. Ann. Rept.* for 1926, pp. 4-9.

Furnival, G. M., 1935: "The Large Quartz Veins of Great Bear Lake, Canada." *Ec. Geol.*, XXXI., pp. 843-859.

Holmes, A., 1928: "The Nomenclature of Petrology." London.

Honman, C. S., 1912: "The Extension of the Kelmscott Clay Deposit." *Geol. Surv. W.A., Bull.* 48, pp. 63-65.

Johannsen, A., 1932: "Petrography, Volume II." Chicago.

Jutson, J. T., 1934: "The Physiography (Geomorphology) of Western Australia." *Geol. Surv. W.A., Bull* 95.

MacGregor, A. G., 1931: "Clouded Felspars and Thermal Metamorphism." *Min. Mag.* XXII., pp. 524-538.

Miles, Keith R., 1938: "The Geology and Physiography of the Lower Chittering Area." *Jour. Roy. Soc. W.A.*, XXIV., pp. 13-41.

Montgomery, A., 1910: "Report on a Quartz Reef in the Darling Range near Gosnells." *Ann. Rept. Dept. Mines for* 1909, pp. 123-125.

Prider, Rex T., 1941: "The Contact between the Granitic Rocks and the Cardup Series at Armadale." *Jour. Roy. Soc. W.A.*, XXVII., pp. 27-55.

Simpson, E. S.—

1916: "Analyses of Western Australian Rocks, Meteorites and Natural Waters." *Geol. Surv. W.A., Bull.* 67.

1931: "Contributions to the Mineralogy of Western Australia—Series VI.—(4) Dravite, Darling Ranges, S.W. Division." *Jour. Roy. Soc. W.A.*, XVII., pp. 141-143.

Thomson, B. P., 1941: "The Geology and Physiography of the Wongong-Cardup Area." *Jour. Roy. Soc. W.A.*, XXVII. pp. 265-283.

Winchell, A. N., 1927: "Elements of Optical Mineralogy," Volume II., New York.

Woolnough, W. G.—

1918: "The Darling Peneplain of Western Australia." *Jour. Roy. Soc. N.S.W., LII.*, pp. 385-396.

1919: "The Physiographic Elements of the Swan Coastal Plain." *Jour. Roy. Soc. W.A.*, V., pp. 15-19.

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19.—THE GEOLOGY AND PHYSIOGRAPHY OF THE WONGONG-CARDUP AREA

By

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CONTENTS.

I. INTRODUCTION.

The Wongong-Cardup area lies about 20 miles south-south-east of Perth. It extends for four and a half miles along the Darling Scarp, which forms the western edge of the Darling Peneplain (Jutson, 1934, p. 84), from Cardup Brook in the south, to half a mile north of Wongong Brook and it covers about six square miles.

The rocks, bounded on the west by the sedimentary Cardup series, consist mainly of granites and gneisses of the Pre-Cambrian Darling Complex (Clarke, 1938, p. 21). These rocks are all intruded by later greenstone dykes. The geology generally is similar to that of the Armadale area (Prider, 1941). The examination of the area was conducted to determine whether the features of this small closely mapped Armadale area were maintained to the south, and to obtain further data regarding the extent of the Cardup series and its relation to the granitic rocks. Good exposures of the Cardup sediments have been made at Byford and Cardup where the slates are quarried for the manufacture of pressed bricks.

Published information regarding the geology of the area is as follows:—

Honman (1912) traced outcrops of the Cardup sediments at many points along the front of the scarp.

Esson (1922) examined the rocks of the Wongong dam site several miles east of the area, and in 1926 he reported on the silver lead deposit at Mundijong, several miles to the south, where part of the country in the vicinity of the deposit is made up of the Cardup series.

Clarke (1930) mentioned the Cardup series and published a map of Cardup.

Forman (1937, p. xxiv) considered that the Cardup series conformed to the local structure in the gneisses, which he suggested were derived from the sediments by granitisation.

Both Clarke and Forman correlated the Cardup series with the Jimperding series of Yilgarn age, but Prider (1941) at Armadale has advanced strong evidence indicating that the Cardup series is younger than the granite and gneiss.

The structure and relations of the gneisses to the Cardup series in the Wongong-Cardup area confirm the conclusions reached by Prider.

The area was mapped during 1940 by the author working alone. It has been well subdivided by the Lands and Surveys Department, thus enabling detailed mapping to be done by pace and compass traverses. Form lines were drawn from spot heights obtained by aneroid barometer, with frequent checking on Byford Railway Station and Wongong Siding.

II. PHYSIOGRAPHY.

A. *General Relief.*

The area may be considered to be made up of four physiographic units.

1. The partly dissected and eroded block of the uplifted Darling Peneplain (elevation 750 feet to 950 feet). This is mostly covered with laterite above the 800 feet level.

2. The scarp front (elevation 400 feet to 750 feet) which is considerably indented and modified by the drainage system.

3. The subdued "foothill" zone (elevation 250 feet to 400 feet), partly underlain by the Cardup series. This zone is discontinuous and it merges into the fourth unit.

4. The sandy plain (elevation 200 feet to 250 feet) which slopes very gently to the west and forms the eastern border of the Swan Coastal Plain.

This subdivision agrees closely with that given by Woolnough (1918, p. 19), except in the treatment of the foothill zone. Woolnough's Ridge Hill shelf at 200 feet elevation is not represented, except possibly by the small areas of low level laterite near the Beenyup and Cardup Brooks.

B. *Drainage.*

The Wongong, Beenyup and Cardup Brooks (the main streams in the area, see Plate 1) are perennial. Features in common to these streams are:—the westerly direction of flow; the young valleys; the west-north-west trend in the foothill zone.

1. *The Wongong Brook.*—This is the major stream. The U-shaped bend in the Wongong after it enters the area suggests the larger feature observed in the Canning River (Clarke and Williams, 1926, p. 161) and likewise may be a relic of an old north-south drainage channel. This is suggested by the alignment of tributaries with the straight eastern side of the bend and with the early-mature valley of a south-flowing tributary of the Beenyup Brook, a little over a mile to the south. West of this bend, the Wongong flows for a quarter of a mile in a very juvenile valley with walls rising steeply to 500 feet above the stream. Here the tributaries are short, steep and insequent. Downstream the brook swings west-north-west into a broader valley; at the bend, a short channel has been abandoned. The course is gently winding and contains a little alluvium; it receives several tributaries and then passes through the foothill zone onto the plain.

2. *The Beenyup and Cardup Brooks.* These have young valleys which lack the gorge-like characteristics of the Wongong and possess steeper grades. These differences may be explained by considering the upper portion of the Wongong, east of the area. This can be regarded, like the upper Helena and Canning Rivers, as another example of a consequent south-easterly flowing stream which developed after the uplift of the Darling Peneplain, and was captured and reversed by a more active westward flowing consequent stream (Jutson, 1934, p. 169). Probably the three brooks were developed equally as westward flowing consequents, but the young Wongong, because it had a shorter distance to advance by headward erosion, reached the south-east stream. This led to augmented flow and deepening of the valley. Meanwhile the Beenyup and Cardup Brooks developed tributaries, but retained relatively steep grades.

3. *Minor tributaries to the main stream.*—These comprise:

(a) Uncertain relics of a mature north-south system.

(b) Short steep-graded minor streams which generally enter at right angles to the main stream.

(c) Larger tributaries which tend to be developed near the scarp; the valleys are youthful, but some broaden in the upper parts. Small waterfalls often occur at an elevation of 400 to 450 feet.

4. *Independent scarp streams.*—These have steep grades and flow west. Examples are the two creeks north of the Byford Brickworks Quarry.

5. *Adjustment of topography to geology.*—Adjustment of the drainage to the major rock structure is not apparent. The courses of the three main brooks form arcs, slightly concave to the north which cut across the strike of the gneiss and the sediments. Two tributaries of the Beenyup Brook appear to have been influenced by quartz blows trending north-west.

Between the Wongong and Beenyup Brooks, streams have deeply embayed the laterite capping by headward erosion, leaving a number of large spurs, some overlying large epidiorite dykes. These spurs represent the most westerly extension of the high level laterite. The sharp edge of the laterite disappears where the mature heads of the creeks approach it and laterite pebbles and sand slope gently up to the laterite level. In such places soaks may develop, the water apparently coming from under the laterite capping.

III. STRUCTURAL GEOLOGY AND FIELD DISTRIBUTION OF THE ROCKS (see Plate I.).

A. *Granite and Gneiss.*

1. *Field Occurrence.*—Aplogranite and gneiss are intimately associated, as at Armadale, hence mapping of them separately was not attempted. Also no persistent type corresponding to the fine banded gneiss of Armadale (Prider, 1941) could be found differing in strike from the hybrid gneiss.

Aplogranite tends to outcrop predominantly in the western part of the area. Here near the Wongong the gneissic foliation is usually vague although a few outcrops contain typical hybrid gneiss (Prider, 1941) with basic xenoliths. Farther south from the Rifle Range to the Brickworks Quarry, the gneissic structure is fairly well maintained and basic xenoliths are common. Again in the south-west of the area, between the Cardup and Beenyup Brooks, aplogranite predominates.

The eastern part of the area exposed in the Wongong Brook consists almost entirely of well-banded gneiss which is cut in places by aplite veins. Xenoliths are rare or absent, although biotitic clots and streaks in the gneiss appear to correspond to the basic xenoliths found elsewhere in the area and at Armadale (Prider, 1941).

2. *Structure of the granite gneiss area and the occurrence of Quartz Veins.*—Dips and strikes of the gneiss foliation were mapped, with the knowledge derived from Armadale that the readings in the hybrid gneiss may be unreliable for detailed interpretation. Such local reversals of dip and overturned structures as observed at Armadale by Prider (1941) were found in the western part of the granite gneiss area, but as mapping progressed it was seen that order was maintained in the strike and in a more general way in the dip of the gneiss throughout the entire area. The gneiss in the western part within half a mile of its contact with the Cardup series strikes north-west to north-north-west, hence the contact instead of being parallel to the strike of the gneiss foliation as at Armadale, truncates it obliquely. The series of quartz blows which outcrops "en echelon" across the Beenyup Brook in a north-westerly direction, appears to be related to the structure of the gneiss in the western strip. For three miles north of these blows the general dip is east. South of the blows the gneiss dips steeply to the west. All this evidence indicates that the structure of the gneiss in the western strips bears no relation to the structure of the Cardup series. The gneiss appears to form a major anticlinal structure, cored by quartz blows (steep dip inferred), which may have formed in either a sheared zone or in tension openings along the crest. This anticlinal interpretation is supported by the majority of the dragfolds which also suggest that the anticline pitches gently to the north-north-west.

The gneiss in the eastern part of the Wongong Brook area dips without exception to the west. Dragfolds are rare and they indicate an east limb of a normal syncline. No structural break has been observed between this gneiss and that to the west. On the south side of the Wongong Brook at one point near the broad laterite spur, the foliation is flat-lying, which suggests that the axis of the syncline passes beneath the spur. North of Wongong Brook the strike of the east limb swings north-north-east possibly because of cross-folding. The synclinal structure may extend to Armadale, the axis of the syncline lying east of the area examined by Prider.

The southern extension of this structure is unknown, although it is significant that four miles south, on the north bank of the Cardup Brook the gneiss foliation strikes north-north-east and dips west.

South of Wongong Brook there is considerable reversal of dip on the west limb of the syncline. These westerly dips may be due to either to dragfolding (as illustrated in Plate 2, Section A-B) or to intrusions of aplo-granite. The interpretation of this structure as a syncline is confirmed in the distribution of the quartz veins. The N.W. trending veins are the best developed in the area and are most abundant in the vicinity of the Beenyup Brook at the crest of the anticlinal structure. The absence of such large quartz veins in the Wongong valley may be explained by the general synclinal structure of that part of the area.

The "blows" outcrop "en echelon" and do not pass through the contact of the granite gneiss and the Cardup series. A similar relationship has been observed in the quartz blows at Armadale (Prider, 1941). The small north-south blow which disappears under the laterite south of Beenyup Brook represents the north-south type which occurs at Armadale. Weathered sericitic bands in the outcrop suggest replacement by quartz in a zone of sheared granite and gneiss.

B. *Cardup Series.*

The contact of the series with the granite gneiss is nowhere exposed, but it can be fixed within half a chain in many places by means of slate fragments in the soil and outcrops of the basal sandy beds. Outcrops of these sediments are found along the foot of the scarp, except between the Brickworks Quarry and the Rifle Range, where laterite pebbles and sand obscure the geology. From north of the Wongong Brook to the Armadale area the series is either absent or completely obscured. To the south it appears to persist at least as far as Mundijong (Honman, 1912, p. 63).

The strike of the contact is 356° which conforms with the observed strikes of the series near the contact, where the average dip is 50° to 60° to the west. Small outcrops of epidotic quartzite occur at wide intervals along the contact, these outcrops are resistant to weathering and dip steeply west.

At the State Brickworks Quarry the exposed series has the same succession as at Armadale, thus:—

Upper (4) *Epidiorite* (?)—A sill-like body of red weathered rock.

(3) *Banded White Slate.*

(2) *Black Carbonaceous Slate*—Exhibits features indicating upthrust of the series from the west (Prider, 1941). These are: dragfolds pitching north at 45°: small reverse faults dipping steeply west.

Lower (1) *Grits and Sandstone*—In bands up to 18 inches thick (some are baritic) which alternate with *Sandy Shale* over several chains. Graded bedding in the sandy bands indicates that the beds are normal and not over-turned. These beds lie unconformably on the hybrid gneiss.

South of Beenyup Brook the Cardup series is exposed over a wider area. On the Cardup Brook, white slate outcrops half a mile west of the granite gneiss-Cardup series contact.

In the adit of the barite workings near the contact the same succession of beds as occurs at the Brickworks Quarry is found dipping west at 65°. In the Cardup Quarry at least three epidiorite dykes intrude the slates, which appear to dip almost vertically. The bedding of the slates is obscured by closely spaced fracture planes, caused probably by the intrusion of the epidiorite dykes, because 5 chains west of the large dyke on the west side of the Cardup Quarry the dip of the slate returns to the normal 60° west.

The wider exposures of slate in the southern parts of the area may best be explained as a more complete sequence of the Cardup Series which has been protected from erosion by quartz blows and basic dykes. Isoclinal folding may be advanced as an alternative explanation but no evidence of repetition of the black slates or the basal sandy beds has been obtained and dragfolding, which may have yielded some information in this connection, has been obscured by weathering.

The quartz blows interleave the slates and outcrop "en echelon" as north-south ridges. In the section exposed in the Cardup Quarry the blow quartz forms lenses up to 6 feet wide. Other quartz veins occur in the series; these will be described later in the petrography section.

C. *Basic Intrusives.*

These are epidiorites, the main types are:—

1. Uralitised quartz dolerites.
2. Porphyritic chlorite-albite epidiorite.

All the dykes in the granite gneiss are of uralitised quartz dolerite. In the north of the area the large dykes have a dominant east-west trend, narrower dykes strike north to north-north-west. Hence the dyke pattern in the north corresponds to that of Armadale (Prider, 1941). In the central part of the area the dykes strike mainly north-west. In the south there are very few dykes the trend of these being north-east.

Dykes intrude the Cardup series at several places at the contact of the series with the granite gneiss. At Cardup several dykes occur completely in the slates and being roughly parallel to their strike, may be sill-like bodies.

The porphyrite chlorite-albite epidiorite (the albite porphyrite of Esson, 1926), is found only as scattered boulders on the north bank of Wongong Brook and to the south of Cardup Brook. This epidiorite outcrops south of the area, at Whitby Falls and Mundijong (Esson, 1926).

No reliable field evidence can be obtained in the Wongong-Cardup area concerning the relationship between this porphyritic epidiorite and the uralitised quartz dolerite.

D. *Later Rocks.*

The later rocks are:—

(1) *Laterite.*—This forms a capping over most of the area above 800 feet elevation. Laterite boulders and pebbles occur on the lower levels at the foot of the scarp.

(2) *Alluvial deposits.*—These occur along the courses of Wongong and Cardup Brooks. Silt and sand cover much of the plain (sege pae 266) lying west of the scarp.

(3) *Talus slopes.*—These are formed on the steeper sides of the valleys, and are composed of aplogranite, gneiss and dolerite.

IV. PETROGRAPHY.

A. *Aplogranites, Gneisses and Associated Basic Xenoliths.*

The basic xenoliths include hybridised varieties of the biotite-hornblende hornfels found at Armadale (Prider, 1941) and hornblende schist xenoliths.

1. *Biotite-hornblende Hornfelses.*—Xenoliths of these rocks are common in the hybrid gneiss. They form rounded masses up to four feet long. In the granitic phases of the gneiss the xenoliths form narrow sheets intercalated "lit-par-lit" with fine-grained granite.

The rocks are dark grey to black in colour, and generally have a fine even-grained hornfelsic texture.

In thin section, clots of decussate greenish biotite are associated with saussuritised plagioclase. Subhedral hornblende may be present with synantectic reaction rims of biotite or chlorite. Quartz is rare as small clear interstitial areas. Apatite prisms and euhedral sphene, as crystals up to 1 mm. long, are characteristic accessories together with pyrite and magnetite and more rarely, pink euhedral zircon up to 0.5 mm. long.

The felspar crystals are crowded with epidote grains and small clinozoisite prisms. Lamellar twinning is common and extinction angles indicate albite-oligoclase.

Biotite varies from a brownish variety with X = pale yellow to colourless ; Y = Z = yellow-brown ; $X < Y = Z$, to a greenish chloritised variety with X = pale green-yellow ; Y = Z = yellow-brown ; $X < Y = Z$.

The hornblende has the pleochroic scheme :—

X = light brown-green ; Y = dark green ; Z = dark bluish-green ; $X < Y \geqq Z$; $Z \wedge c = 17°$.

The xenoliths are distinguished from the hybrid gneiss by the absence of microcline. Apparently, all the potash which was introduced during granitisation, reacted with the hornblende of the xenolith to form biotite instead of crystallizing as microcline.

TABLE I.

Analysis of Biotitic Xenolithic Material.

	1.	2.	3.
SiO_2	44·95	40·09	66·52
Al_2O_3	17·70	14·01	13·22
Fe_2O_3	3·12	6·05	4·99
FeO	11·32	14·42	3·29
MgO	6·08	4·34	0·58
CaO	3·08	9·89	2·84
Na_2O	3·03	0·46	3·45
K_2O	6·38	3·78	2·95
H_2O+	1·41	1·97	0·50
H_2O-	0·12	0·07	Nil.
CO_2	...	0·08	0·03
TiO_2	1·36	2·76	0·66
P_2O_5	0·95	1·24	0·10
MnO	0·14	0·38	0·15
BaO	...	Nil.	0·53
FeS_2	...	0·77	0·07
$Fe\,S_4$	...	0·02	Nil.
V_2O_3	...	0·03	0·04
	99·64	100·36	99·92

1. Fine-grained biotitic hornfels xenolith, Cardup (Analyst, B. P. Thomson).
2. Hornblende–epidote–biotite–hornfels xenolith, Roads Board Quarry, Armadale (Prider, 1941, p. 36).
3. Hybrid Gneiss, Roads Board Quarry, Armadale (Prider, 1941, p. 36).

Analysis I. indicates that the Cardup xenolith is rich in iron and potash like the Armadale hornfels, and is likewise the result of the action of potassic solutions on original basic material. A feature of the analysis is the high alumina content.

This hybridisation (which is essentially a granitisation process involving the addition of K_2O, Al_2O_3 and SiO_2 to the original basic xenolith), was effected during an early period of granite intrusion (Prider, 1941).

2. *Hornblende-schist xenoliths.*—These are not widely distributed like the hornfelses. They occur as angular blocks, up to five feet long, which appear to be part of a larger mass which is cut by narrow veins of aplogranite. They are best developed on the south side of the Wongong gorge, but have also been found in gneiss a quarter of a mile south-east of the Brick Works Quarry and on the south side of Cardup Brook.

The hornblende-schists are black, medium to even-grained and have a schistose structure which may not be apparent in the hand specimen, but is obvious in larger masses. When felspar is present a gneissose structure may develop.

The rock is composed mainly of subhedral hornblende crystals, for which—

X = light yellow-brown; Y = dark brown-green; Z = dark blue-green; $X < Y \lessdot Z$ and $Z \wedge c = 18°$.

A small amount of biotite occurs either as plates or decussate clots. The biotite has X = yellow; Y = Z = dark brown and (—) 2V small. Quartz forms small clear angular inclusions in the hornblende. Saussuritised plagioclase is found as subhedral crystals in the slightly hybridised types. Accessories are pyrite and magnetite and rare prisms of apatite and epidote.

The relation between these two main types of xenolith is not visible in the field. The biotite-hornblende hornfels xenoliths represent hybridised rocks, probably of original gabbroic composition. The hornblende-schist xenoliths appear to represent amphibolite which has escaped intense hybridisation.

3. *Hybrid Gneiss.*—This rock is identical with the Armadale type. The foliation is well-marked by biotitic clots and streaks. Light-coloured bands contain pale microcline phenocrysts, greenish saussuritised felspar and quartz. The more porphyritic types have augen of microcline which are developed with vitreous quartz in a black biotitic ground-mass.

The dark bands are similar to the associated biotitic xenoliths and are composed of decussate clots of biotite containing euhedral apatite, sphene, and accessory magnetite and pyrite. Euhedral zircons up to 0.4 mm. long, occur rarely.

The leucocratic bands contain plagioclase (albite-oligoclase) as subhedral crystals which are invariably saussuritised and often sericitised. Occasionally, clear irregular areas of oligoclase occur in the cloudy plagioclase. The twin lamellae are continuous in the clear and cloudy areas, but the extinction angles of the lamellae differ. This may be a replacement structure.

Microcline forms large clear crystals, often with a microperthitic structure. "Phantom Twinning" is present in the central parts of some crystals, indicating that some orthoclase is present, partly inverted to microcline (Alling 1923, pp. 283-305.)

4. *Aplogranite.*—This rock type is the same as the Armadale aplogranite. A typical aplogranite is a medium-grained leucocratic rock, containing albitic plagioclase, quartz and microcline. The texture is allotriomorphic granular. The plagioclase is albite-oligoclase, slightly clouded with kaolin and partly spangled with sericite flakes.

Microcline is microperthitic and slightly kaolinised.

Quartz forms clear allotriomorphic crystals with undulose extinction. Blebs of quartz are also common in the microcline, with which they form myrmekitic structures.

Rare chlorite wisps are the only ferromagnesians present.

A characteristic of the aplogranite is the domination of sericitisation over saussuritisation. Otherwise, the plagioclases in the aplogranite and the gneiss show no marked differences: both are albite-oligoclase, although the abundance of epidote and clinozoisite in the plagioclase crystals of the gneiss suggests that in these the original felspar was more calcic.

5. *Pegmatite and Aplite.*—No coarse-textured pegmatite dykes or veins were found, but the gneiss may be locally pegmatitic and contain microcline crystals up to 2 inches long. Whether this pegmatitic phase is derived from the early granite magma that formed the hybrid gneisses or from the latter aplogranite magma, cannot at present be stated.

Garnet-Muscovite Aplite.—A vein of this rock 13 inches wide occurs in the gneiss in the extreme east of the area near the Wongong Brook.

The aplite is pale pink in colour and varies in grain from a fine-grained saccharoidal to a more pegmatitic phase with small microcline phenocrysts and muscovite plates up to 12 mm. across.

The texture in thin section is allotriomorphic. The minerals present are fresh albite, unstrained quartz allotriomorphs, perthitic microcline, rare large muscovite flakes and garnets.

The garnets form small pale pink euhedra up to 0.5 mm. diam. Accessories are a little chlorite and epidote.

Somewhat similar garnet aplites occur at Jimperding (Prider, 1934, p. 10) and Malkup (Cole and Gloe, 1940, p. 160), where they are related to granite intrusions of post-gneiss age.

The origin of this garnet-muscovite aplite is not certain, but because of its remarkable freedom from alteration, it is most probably a phase of the aplogranite.

6. *Relation between the Aplogranite and Hybrid Gneiss.*—In the Wongong-Cardup Area no evidence was found of two types of gneiss striking discordantly to each other, as do the fine-banded and hybrid gneisses at Armadale (Prider, 1941).

Prider considers that there are two periods of granite intrusion.

(1) An early period that led to the formation of the hybrid gneiss.

(2) A later period, represented by the aplogranite. In the Wongong-Cardup Area, two periods of granite intrusion are indicated by—

(a) Angular xenoliths of gneiss in aplogranite, best exposed on the south side of the Wongong Brook gorge.

(b) The truncation of gneissic banding by masses of aplogranite.

B. *Cardup Series.*

The series may be subdivided into

1. Basal sandy beds.
2. Slates.

1. The basal sandy beds comprise sandstone, epidotic quartzite, and interbedded sandy slates.

(a) *Sandstone.*—This may vary considerably in grain size. The coarser types, which can be classed as grits, contain sub-rounded quartz grains up to 15 mm. long. The matrix is often argillaceous and the quartz grains show imperfect graded bedding.

In finer-grained sandstone on the western side of the Brickworks Quarry, ripple-marking appears to be present.

Vughs, which may have originated by the leaching out of calcite, are common in the grits. These vughs are lined with small quartz crystals, and some contain white or colourless barite. At Cardup a small amount of purple fluorite is associated with the barite, a little pyrite and chalcopyrite are also present. White calcite occurs in some unweathered specimens.

In thin section:—

The typical sandstone contains rounded to sub-angular quartz grains interlocking loosely in a ground mass of micro-crystalline quartz and sericite. The quartz shows undulose extinction. Rounded pink zircons occur sparsely, but are rarely absent. In one section several small idioblastic crystals of tourmaline were found.

The baritic sandstone has a granular structure which is obscured by a mosaic of later vein-quartz. Angular cloudy felspar fragments (mostly microcline) are common. Barite forms irregular grains and strings. Calcite and rounded pink zircons are present.

(b) *Epidotic Quartzite.*—This rock has been shown by Prider (1941, p. 40) to be sandstone which has undergone contact metamorphism, due to the intrusion of epidiorite. This is supported south of Wongong Brook, where an outcrop of the quartzite grades into sandstone and is associated with fine-grained epidiorite.

The quartzite varies from a grey-green even-grained rock with a conchoidal fracture to a banded rock in which sandy and cherty bands alternate. Some of the sandy bands show graded bedding. Pyrite and marcasite are present in small amounts.

In thin section clear rounded quartz grains are seen to be rimmed with a plexus of small pale green needles of an optically negative biaxial mineral with oblique extinction (probably actinolite).

The quartz is strained. Epidote is present as small interstitial grains or as yellow-green clots. The felspar forms slightly clouded subhedral crystals, either of microcline or plagioclase.

Small rounded zircons are common.

The cherty bands contain microcrystalline quartz which is streaked with nearly isotropic white material and is spotted with epidote grains.

2. Slates:—

Black and white slates, similar to those found at Armadale, are exposed at the Brickworks Quarry and at Cardup. On the north bank of the Wongong Brook, white and grey sandy slate outcrop, but no black slate is exposed.

(i) *"Black" Slate.*—This is a black to dark-grey coloured rock, in which close bedding planes are well developed and marked by alternating light and dark bands.

Barite occurs on the joint planes of the black slate in the Brickworks Quarry.

In thin section:—Minute sericite plates and microcrystalline quartz form the ground mass which is banded with graphitic material. Light brown-green idioblastic tourmaline prisms are scattered with random orientation throughout the rock.

(ii) *"White" Slate.*—This variety of slate has a white to light grey colour. The light grey type is compact and hard and corresponds to the slate interbedded with the sandstones. Such slate shows a greater development of microcrystalline quartz, under the microscope, than do the lighter types.

In thin section the white slate is seen to consist of minute sericite flakes and a smaller amount of microcrystalline quartz, which may be intermixed with or may form lenticles in the sericitic groundmass. Later veinlets of strained quartz cut the bedding.

In the Cardup quarry, pale green chlorite is developed in the "white" slate near the contact with an epidiorite dyke.

The small tourmaline prisms are distributed sparsely throughout all the slates, and do not decrease in quantity, even half a mile west of the Cardup Series-granite gneiss contact at Cardup. This supports Prider's suggestion (1941, p. 41) that the tourmaline was derived from the crystallisation of the original constituents of the argillaceous sediments rather than from material introduced by an intrusive granite.

C. *Basic Intrusives of Post-Cardup Age.*

The following types are recognised:—

1. *Uralitised quartz dolerite.*
2. *Biotitic epidiorite.*
3. *Porphyritic chlorite-albite epidiorite.*

1. *Uralitised quartz dolerite.*—As at Armadale, most of the dykes are of this dominant type.

A typical specimen is dark grey-green in colour, with fine to medium grain. The texture is ophitic to subophitic and is obscured by the formation of uralite and epidote.

Uralitic amphibole is the dominant mineral. Plagioclase occurs, almost entirely replaced by granular epidote and zoisite.

The mesostasis is clear quartz, often in micrographic and rarely granophyric intergrowth with the epidotised felspar. The quartz encloses apatite prisms. Brownish hornblende, biotite and chlorite may be associated with the uralite. Leucoxene is abundant as large skeletal plates replacing ilmenite. Some leucoxene has also recrystallised to granular sphene.

The uralite is often developed in large crystals with good cleavage and simple twinning. The colour is rather variable in intensity, a typical pleochroism is X = very pale yellow-green; Y = pale olive-green; Z = pale greenish-blue; $X < Y \ll Z$, $Z \wedge c = 20°$, (−) 2V is large.

Closely related to the ordinary uralitised quartz dolerite is the variety in which the felspar is tinted by pale-brown smoky clouding. Only one dyke has been found to contain felspar in this condition. None have been found at Armadale, but they occur farther north at Gosnells, Lower Chittering and Malkup.

According to MacGregor (1931), such features are due to reheating of the rock after consolidation.

The felspar varies from fresh labradorite, with the characteristic brown tint, to intensely saussuritised felspar and is in ophitic relation to the uralite plates.

The uralite develops blue-green resorption borders in contact with the felspar and in places appears to grade into brownish hornblende.

Unstrained quartz forms a mesostasis and skeletal ilmenite, rimmed with leucoxene, is common.

Associated Veinlets.—In the uralitised quartz dolerite, veinlets of epidote or quartz are found up to two inches wide.

2. *Biotitic epidiorite.*—This Armadale type has been found only near the prospecting shaft, north of Wongong Brook.

Its field relations are not known: it probably represents a phase of the uralitised quartz dolerite.

Megascopically it resembles a hornfels, being black and fine-grained.

The thin section reveals an allotriomorphic granular aggregate of greenish-brown biotite, small plagioclase laths (which are almost completely converted to epidote), uralite, leucoxene, quartz and sparse pyrite.

The biotite has the pleochroic scheme:—

X = pale yellow-green; $Y = Z$ = brown-green $X < Y = Z$.

Uralite forms sparse patches with biotite which is apparently derived from it.

3. *Porphyritic chlorite-albite epidiorite.*—Mineralogically, this rock corresponds to the albite epidiorite of Armadale (Prider, 1941).

Hand specimens show yellow subhedral albite phenocrysts (up to 3 cm. long), in a dark fine-grained ground mass. In the Cardup specimens the phenocrysts are grouped radially, forming "rosettes" up to 5 cm. in diameter.

In thin section, albite phenocrysts are set in a ground mass of albite laths, uralite, biotite and chlorite with a little interstitial quartz and leucoxene.

The albite is cloudy and contains epidote. The phenocrysts are rimmed and penetrated by the chloritic ground mass.

Uralite is rare and is a soda-rich variety with $X < Y \ll Z$, X = pale yellow; Y = pale olive-green; Z = bright green-blue, $Z \wedge c = 17°$.

In the ground mass are found aggregates of deep-green chlorite or decussate brown biotite, each containing several euhedral epidote crystals.

D. *Quartz Veins and Barite.*

The quartz veins may be subdivided into—

1. Quartz veins in the granite gneiss.
2. Quartz veins in the Cardup Series.

1. Quartz veins in the granite gneiss. There are two types:—

(a) The small north-south striking vein south of Beenyup Brook. The vein averages five feet in width and is identical with the corresponding type of "blow" at Armadale. It contains sericitic bands, and in thin section shows cataclastic structures and recrystallised sericite. This suggests a replacement by quartz along a shear zone.

(b) The north-west striking blows, which cross the Beenyup Brook. These are, on the average, 4 feet wide and may be traced continuously for distances up to 10 chains or more. No sericite bands are observed in these. Fresh specimens of the quartz are greenish-grey, massive and frequently contain later quartz veinlets and pyrite. On joint surfaces which have been bleached by weathering, angular fragments of quartz up to 4 inches long are seen to be set in a fine-grained cherty matrix. Thin veinlets of later quartz traverse both the fragments and the matrix.

The quartz in the angular fragments shows strain and cataclastic structures. A small amount of felspar is present. The crystals are probably of microcline, they are allotriomorphic and slightly rounded.

The ground mass is fine grained quartz, through which, in the unweathered rock, shreds of chlorite and biotite are distributed.

This evidence suggests that these blows are not simple replacement bodies formed along shear zones. They may represent quartz reefs, which after their formation, have been sheared and then partly replaced by later quartz.

2. Quartz veins in the Cardup Series. These are:—

(a) Quartz Blows in the slates at Cardup.

There appears to be two parallel series of quartz blows, striking north and south in the slates at Cardup:—

(i) The westerly series which is the more strongly developed. These average 5 feet in width and outcrop continuously for distances of more than 10 chains. A section of one of the blows of this series is to be seen in the east wall of the main Cardup quarry and it appears to be made up of bulbous quartz lenses up to 4 feet wide, dipping at 85° to the west. These lenses appear to conform (in strike and dip) to the slate which has been distorted, so that the bedding now follows around the edge of the quartz lenses.

(ii) The easterly series which outcrops in a north striking zone some 5 or 6 chains to the east of (i). These veins are lenticular and the lenses are more elongated than in (i). They conform to the dip and strike of the slate.

Under the microscope, the quartz in (i) and (ii) is practically identical as regards intensity of shearing. Weathered outcrops may be massive or show a pseudo gneissic structure caused by fine ferruginous streaks. This structure is cut by later quartz veinlets, up to one inch wide, in which vughs occur.

The quartz is intensely sheared and large crystals (including those of later veinlets) show slicing and granulation.

Thin shreds of greenish pleochroic chlorite (?) are arranged parallel to the lines of granulation. Twisted plates of muscovite occur sparsely and iron ore in subhedral grains is common.

(b) "Contact" Quartz Veins. These occur at several places on the granite-gneiss-Cardup Series contact. One is well developed south of the Brickworks Quarry and it closely resembles the north-south type of blow of Armadale. It contains sericite bands and the quartz shows cataclastic structures.

(c) Vein quartz in the baritic sandstone. "The quartz-barite vein" (Clarke, 1930, p. 166) at Cardup is sandstone which is veined and partly replaced by later quartz and barite.

In thin section the veinlets are seen to consist of clear quartz forming a mozaic of slightly strained crystals.

(d) Narrow veins of vitreous quartz, up to one inch wide, occur in the black slate of the Brickworks Quarry. The quartz is limpid and shows undulose extinction.

3. *Origin of the quartz veins in the Cardup Series*:—In the light of other evidence, indicating that the Cardup Series is post granite in age, it is suggested that these veins are the result of a period of vein formation that followed the intrusion of the epidiorite. The veins are possibly the result of differentiation of the basic magma.

Coulson (1933, p. 114) suggests such an origin for the quartz reefs associated with certain Indian barite deposits. Although the age relationship between the epidiorite and quartz veins in the Cardup Series has not been determined in the Wongong-Cardup area, post-epidiorite quartz veins are known to occur at localities near the area.

Prider (1941, p. 42) mentions that at Armadale, in the tunnel west of the slate quarry, vein-like bodies of quartz that show pronounced cataclastic structures occur in uralitised quartz dolerite.

Esson (1926, p. 7) states that quartz reefs of the silver lead deposits at Mundijong occur in the epidiorites which intrude the slate of the Cardup Series.

4. *Origin of the barite.*—The minerals associated with the barite in the sandstone are quartz, pyrite, chalcopyrite, calcite, and purple fluorite. These minerals, except possibly the calcite, appear to be the result of one period of mineralisation.

Because of the irregular distribution and the absence of banded veins, the paragenesis cannot be worked out. Nevertheless, such an association of minerals indicates a hydrothermal origin for the barite (Laurence, 1939, pp. 190-200).

Prider (1941) suggested that the silver-lead bearing veins of Mundijong and the barite and fluorite are both related to the albite epidiorite magma. Coulson (1933, p. 115) considers that the barite of certain Indian deposits are derived from a somewhat similar basic magma.

Whatever their source, the hot barytic solutions appear to have ascended into the porous basal sandy beds of the Cardup Series in many places. Solutions containing barium ions have also migrated along the fracture planes of the slates, where barite has been deposited (p. 275).

E. *Later Rocks.*

1. *Laterite.*—The distribution of this rock has been described (p. 270).

The high level laterite is the common pisolitic variety, and it does not appear to vary markedly in composition, whether developed over epidiorite dykes or granite gneiss.

On the slopes below the laterite, fragments of a dark-red fine-grained limonite rock are found in a few restricted areas. Thin section reveals a fine-grained matrix of limonite with a small amount of interstitial quartz. This rock may be equivalent to the ferruginous grit found below the laterite of other Darling Range areas (Miles, 1938, p. 32).

On the lower levels laterite occurs as boulders of the pisolitic variety or as unconsolidated deposits of limonite pebbles with sand or ferruginous clay.

2. *Alluvium.*—The alluvium in the Wongong Brook is sandy. At the bend west of the gorge, large boulders of conglomeratic rock lie in the abandoned stream bed. This rock contains pebbles and boulders of granite and gneiss which have been cemented by clay, in the banks of the stream.

V. CONCLUSIONS.

A. *Age of the Cardup Series and its relation to the granitic rocks.*

The structure of the gneiss can be broadly interpreted as due to folding which took place before the formation of the Cardup Series. Further facts similar to those recorded by Prider (1941) support the conclusion that the gneiss and granite are older than the Cardup Series. They are:—

(i) No quartz or pegmatite veins have been observed to pass from the granite and gneiss into the Cardup Series.

(ii) The Cardup Series maintains a normal erosion sequence and the basal beds must rest upon the eroded granite gneisses which strike obliquely to the Cardup Series.

(iii) Xenoliths of the sediments are absent from the gneiss.

(iv) The gneiss does not vary in character across the strike and therefore does not appear to be a granitised phase of the Cardup Series.

(v) Contact metamorphic effects in the sediments are slight and are due to basic intrusions.

(vi) The widespread occurrence of small idioblastic crystals of tourmaline in the slates can be readily attributed to original boron in the sediments rather than to pneumatolytic effects of a granite intrusion.

(vii) Rounded zircons are found in the basal sandy beds of the sediments, whereas mineralogically similar zircons occurring in the gneiss and basic xenoliths are unrounded. This points to the possible derivation of the Cardup Series (in part at least) from the gneiss.

(viii) Detrital microcline, most reasonably regarded as derived from the aplogranites and gneisses, occurs in the Cardup sediments.

B. *Darling Scarp.*

Prider, (1941), considered that the Darling Scarp was produced by the differential erosion of a monoclinal fold, and was not primarily a fault structure as has been suggested by most geologists (Jutson, 1934, p. 87). He based his conclusions on the minor structures in the slates at Armadale, which indicate an upthrust from the west, the result of a downwarp of sediments to the west of the area. In the Wongong-Cardup area, similar structures are found in the slates of the State Brickworks Quarry. It is true that at Cardup, slate further west of the granite gneiss Cardup Series contact dips almost vertically which is hard to reconcile with the upthrust, but this steepening of dip may be attributed to the deformation produced by the nearby basic dykes.

The "foothill zone" (p. 266), which is partly underlain by the Cardup Series, can be attributed to the effect of differential erosion between the sediments and the granite gneiss.

C. *Comparison of the Wongong-Cardup, Armadale and Gosnells Areas.**

All three areas are situated on the Darling Scarp, on an igneous metamorphic complex, flanked on the west by the Cardup sedimentary series which strikes almost due north and dips steeply to the west.

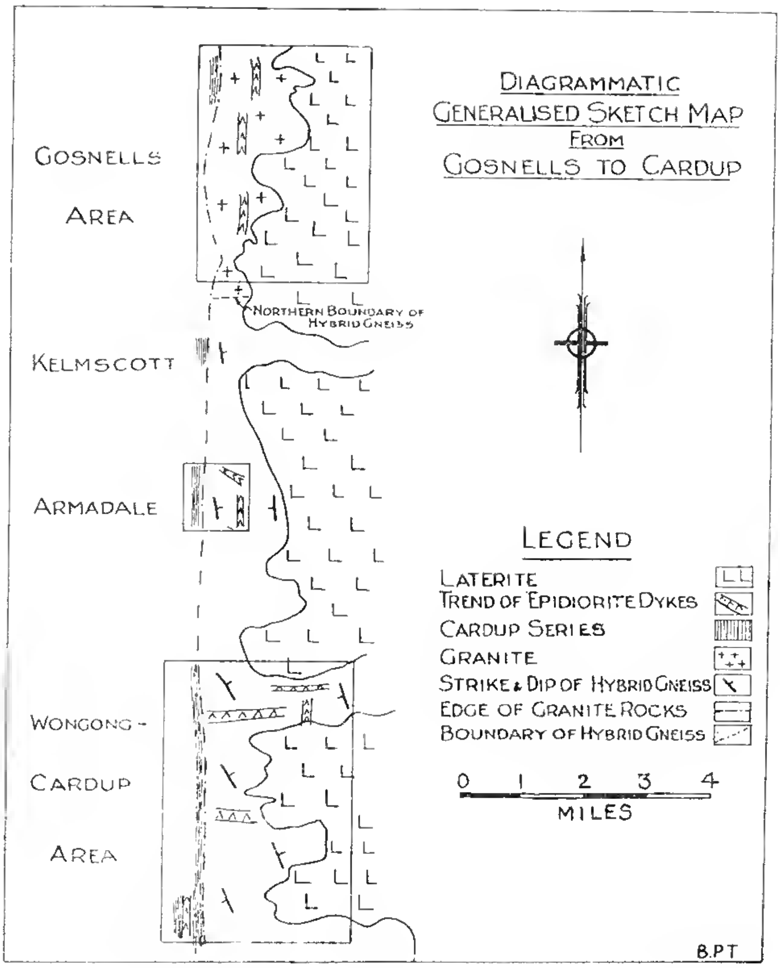

Fig. 1.

There are as yet insufficient data to give a complete structural picture of the igneous-metamorphic complex. The known facts from the three areas examined (which are illustrated in fig. 1) are:—

(1) The predominant rock in the areas examined is a hybridised gneiss which is best developed in the Wongong-Cardup and Armadale areas. In the Wongong-Cardup area the gneiss is considerably folded and the strike varies from N.W. to N.N.E. while in the Armadale area the general strike is almost due north. At Gosnells the granitic rocks are generally massive without any gneissic structures. Post-gneiss massive granites occur at both Armadale and Wongong-Cardup where they form only a minor part of the complex—these granitic rocks (aplogranites) may possibly be offshoots from the main Darling Range massive granite which lies to the north of Gosnells.

*This section was written in collaboration with Dr. R. T. Prider and Mr. C. E. S Davis.

(2) Quartz veins are developed in all three areas, the trend being N.N.W. at Cardup, W.N.W. at Armadale, and N.E. at Gosnells. In none of the areas have quartz veins been observed to pass from the granitic rocks into the Cardup Series (although many were traced to the boundary between these two formations) and this is the main evidence for regarding the granitic gneiss complex as pre-Cardup in age. Quartz veins occur in the slates at Cardup but these are of a different type and probably genetically related to the younger basic intrusives.

(3) Basic dykes are common to all three areas but a marked variation in trend is noticeable. In the Wongong-Cardup area and at Armadale the general trend is E.-W. with a few N.-S. dykes whereas at Gosnells the general trend is in a N.-S. direction. The basic intrusions are all of post-Cardup age.

The Cardup Series is developed in all three areas and the succession, lithology, grade of metamorphism and relation of the Series to the granitic rocks and to the later basic intrusives are similar throughout .

Post-Cardup basic intrusives belong to two main types, (i) albite epidiorite and (ii) uralitised quartz dolerites, both of which are developed in all three areas. They have been assigned to two ages—the earlier albite epidiorites having accommodated themselves to the earth movements affecting the Cardup Series, while the later quartz dolerites have been comparatively little altered.

Although the significance of the various structural patterns of these three areas (as seen in the general trend of the gneissic structures, quartz veins and basic dykes) is not as yet completely understood, it is the authors' opinion that the Darling Range complex consists of an older hybridised granitic gneiss intruded by a later batholithic granite extending over the area between Gosnells (on the south) and Lower Chittering (on the north). Offshoots (aplogranite) from this granite mass have penetrated the older hybridised gneisses lying to the south of Gosnells. The Cardup sedimentary Series is definitely of later age than the granitic rocks and the various basic intrusions are younger still.

VI. GEOLOGICAL HISTORY OF THE AREA.

(1) Period of granitisation, during which the hybrid gneisses were formed from older basic rocks.

(2) Folding of the hybrid gneiss (by pressures directed from the N.N.W. and S.S.E.), probably closely followed by, or contemporaneous with, (3).

(3) Aplogranite intrusions.

(4) Earth movements, forming shear zones and joints in the gneiss, followed by the formation of quartz veins, which may represent the end-phase of the aplogranite magma.

(5) Erosion of the granite and gneiss and deposition of the Cardup Series.

(6) Downwarp to the west of the area, causing upthrust of the Cardup Series towards the east over the granite gneiss.

(7) Intrusion of the epidiorites.

(8) Formation of post-Cardup quartz veins and the introduction of barytic solutions. Both of these are the end-phases of the epidiorites.

End of the Pre-Cambrian.

(9) Deposition of sediments west of the area, leading to further downwarping which may have produced strain effects in the quartz veins in the slates.

(10) Continued erosion leading to peneplanation and laterite formation (Woolnough, 1918, p. 385).

(11) Uplift of the peneplain in late Miocene times (Jutson, 1934, page 205). and probable formation of the Darling Fault.

(12) Further erosion, producing the present topography.

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VIII. LIST OF REFERENCES.

Alling, H. L., 1923: "The Mineralogy of the Feldspars. Part II." *Jour. Geol.*, Vol. XXXI., pp. 283-305, and pp. 353-375.

Clarke, E. de C., and Williams, F. A., 1926: "The Geology and Physiography of Parts of the Darling Range near Perth." *Jour. Roy. Soc. W.A.*, Vol XII., pp. 161-178.

Clarke, E. de C., 1930: "The Pre-Cambrian Succession in some parts of Western Australia." *Repl. Aust. and N.Z. Assoc. Adv. Sci.*, 1930, pp. 155-192.

Clarke, E. de C., 1938: "Middle and West Australia." *Regionale Geologie der Erde*, VII., Leipzig, pp. 1-58.

Cole, W. F., and Gloe, C. S., 1940: "The Geology and Physiography of the Malkup Area." *Jour. Roy. Soc. W.A.*, Vol. XXVI., pp. 139-171.

Coulson, A. L., 1933: "Barytes in the ceded districts of the Madras Presidency, with notes on its occurrence in other parts of India." *Mem. Geol. Surv. Ind.* Vol. LXIV., Pt. I., 1933, p. 114.

Esson, A. G. D., 1922: "The Basic Rocks of the Wongong Dam-Site." *Geol. Surv. W.A. Ann. Report*, 1922.

Esson, A. G. D., 1926: "The Silver-Lead Deposits at Mundijong. *Geol. Surv. W.A. Ann. Report*, 1926, pp. 4-9.

Forman, F. G., 1937: "A Contribution to our Knowledge of the Pre-Cambrian Succession in some Parts of Western Australia." *Jour. Roy. Soc., W.A.*, Vol. XXIII, p. xxiv.

Honman, C. S., 1912: "The Extension of the Kelmscott Clay Deposit." *Geol. Surv. W.A. Bull. No.* 48, p. 63.

Jutson, J. T., 1934: "The Physiography (Geomorphology) of Western Australia." *Geol. Surv. W.A. Bull.* 95.

Laurence, R. A., 1939: "The Origin of the Sweetwater, Tennessee, Barite Deposits." *Econ. Geol.*, Vol. XXXIV., pp. 190-200.

Miles, K. R., 1938: "The Geology and Physiography of the Lower Chittering Area." *Jour. Roy. Soc. W.A.*, Vol. XXIV, pp. 13-41.

MacGregor, A. G., 1931: "Clouded Felspars and Thermal Metamorphism," *Min. Mag.*, Vol. XXII., p. 528.

Prider, R. T., 1934: "The Geology and Physiography of the Jimperding Area." *Jour. Roy. Soc. W.A.*, Vol. XX, pp. 1-16.

Prider, R. T., 1941: "The Cardup Series—Granite Contact at Armadale." *Jour. Roy. Soc. W.A.*, Vol XXVII., pp. 27-55.

Woolnough, W. G., 1918: "The Physiographic Elements of the Swan Coastal Plain." *Jour. Roy. Soc. W.A.*, Vol. V., pp. 15-19.

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