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PART 1 (No. 419)

(Issued 31st December, 1969)

(Presidential Address and Papers read March–April, 1969)

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(Issued 1st June, 1970)

(Papers read June–July, 1969)

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PART 3 (No. 421)

(Issued 28th September, 1970)

(Papers read September–November, 1969)

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ANNUAL GENERAL MEETING

26th MARCH, 1969

The Ninety-fourth Annual General Meeting was held in the Society's Rooms, Science House, 157 Gloucester Street, Sydney, on Wednesday, 26th March, 1969 at 7.30 p.m.

Professor T. G. Vallance, President, occupied the chair.

The minutes of the Ninety-third Annual General Meeting (27th March, 1968) were read and confirmed.

REPORT ON THE AFFAIRS OF THE SOCIETY FOR THE YEAR

The Society's Proceedings for 1967, Vol. 92, Part 3 and for 1968, Vol 93, Part 1, were published on 6th May and 19th November, 1968, respectively. There have been increases in printing costs as from 1st September, 1968, and in block-making costs as from 1st October, 1968. A donation of $100 was made towards the printing of one paper in the Proceedings.

During the year 16 new members were admitted to the Society, one died, five resigned and six were removed from the list of members. The numerical strength of the Society at 1st March, 1969, was: Ordinary Members, 279; Life Members, 31; Corresponding Member, 1; total 311.

Papers read at Ordinary General Meetings totalled 27. Lecturettes were given at the following meetings: April, Fishes and Corals—ecological results of a study on One Tree Island Reef, Great Barrier Reef, by Dr. F. H. Talbot; June, Star fishes of the Fiji reefs, by Miss Elizabeth C. Pope; September, Some new aspects of Crustacean development, by Dr. D. T. Anderson; October, Some local Charophytes, by Dr. A. T. Hotchkiss. The Sixth Sir William Macleay Memorial Lecture, 1968, was delivered by Dr. H. J. Frith, Chief, Division of Wildlife Research, C.S.I.R.O., on 31st July, 1968, the subject being "Wildlife Conservation". Interesting notes and exhibits were given at the June and November meetings. No meetings were held in May or August. We are indebted to all who contributed in these various ways to the interest of the meetings.

Library accessions from scientific institutions and societies on the exchange list amounted to 1,959 for 1968. The total number of borrowings of books and periodicals from the library by members and institutions for the year was 302. Members and others continued to consult publications in the Society's rooms, and books and periodicals were made available for photographic copying. Copying of articles for institutions is now done for the Society by the Australian Museum instead of the Fisher Library, University of Sydney and our thanks are due to the Director for making this service available. Two books, "A Treasury of Australian Wildlife", edited by Dr. D. F. McMichael and "Flowers and Plants of Victoria" by Cochrane, Furher, Rotherham and Willis were purchased by the Society and "Festskrift til Hans Laurits Jensen, 27/6/1898–27/6/1968" presented to the library. During the year a request from Staatsinstitut für Allgemeine Botanik und Botanischer Garten, Hamburg, for exchange of the Proceedings for Mitteilungen, was granted and it was decided to send the Abstract of Proceedings to the College of Guam, Agana, Guam. The exchange of publications with the Royal Society of London was discontinued, at the request of the Royal Society, as from 1st January, 1969. Certain periodicals in the library have been bound.

Dr. F. H. Talbot, Director, Australian Museum, Sydney, was elected a member of Council in place of Professor J. M. Vincent, who resigned.

Congratulations were extended to Professor R. N. Robertson on the award in the Queen's Birthday Honours of the C.M.G.; to Professor Beryl Nashar on her appointment as Dean of the Faculty of Science, Newcastle University, and to Mr. Abdul Khan on his appointment to a lectureship at the new University at Lahore, Pakistan.

The net return to the Society from Science House was $4,859.67 for the year.

The Society responded to an appeal by the Linnean Society of London for funds for the proper care and maintenance of the collections, including those of Linnaeus, held by that Society.

A brochure on the history, aims and objects of the Society has been revised and is being reprinted.

The Furnishing Committee, appointed by Council with the object of improving the appearance and comfort of the Meeting Room, made certain recommendations which were adopted. These included the purchase of new chairs, the re-upholstering and polishing of the benches and the reduction in size of the Council table. A Leitz Prado projector, a typist's table and addresser were also purchased. The old items of furniture were disposed of at a satisfactory price.

The Society has lent its support to the following matters: Dee Why Lagoon, Norfolk Island, Australian Conservation Foundation, Nature Conservation Council of N.S.W., and "Save Colong".

Linnean Macleay Fellowship

In November, 1968, Miss Alison K. Dandie, B.Sc.(Hons.), was re-appointed to a Linnean Macleay Fellowship in Botany for one year from 1st January, 1969. Miss Dandie has continued her research on the occurrence and importance of mycorrhizae in New South Wales. This included experiments on the utilization of nitrogen by mycorrhizal and non-mycorrhizal plants and experiments to assess the effect of mycorrhiza on the uptake of phosphorus. Studies were made on the germination of *Endogone*-type spores and on the dimension and size range of these. A paper is in preparation on the occurrence of various types of mycorrhizae in New South Wales.

Linnean Macleay Lectureship in Microbiology

Dr. Y. T. Tchan, Reader in Agricultural Microbiology and Linnean Macleay Lecturer in Microbiology, University of Sydney, was appointed to the Chair of Microbiology, University of Sydney, from 1st July, 1968. As from 1st January, 1969, Dr. K. Y. Cho was appointed to the Linnean Macleay Lectureship in Microbiology. Dr. Cho is 34 years of age, and graduated Bachelor of Science with Honours II (Division 1) in Biochemistry at the University of New South Wales, 1964, and Doctor of Philosophy at the Australian National University in 1968. Prior to graduating from the University of New South Wales in 1964, Dr. Cho held appointments as Technical Assistant with the Division of Food Preservation and Transport of the C.S.I.R.O., at Ryde, New South Wales (1957–59), as a Laboratory Assistant with the Institute of Clinical Pathology and Medical Research, Lidcombe, New South Wales (1959-61), and as Microbiologist in the Department of Virology at this Institute (1962-63). From 1964-65, he was a Research Assistant in the Department of Microbiology at the University of New South Wales, and from 1965-66 he was a Research Scholar in the Department, under a grant from the National Health and Medical Research Council. This grant was subsequently transferred to the Australian National University, where he continued as a Research Scholar during 1967. In 1968 he held an appointment as a Tutor-Demonstrator in the Department of Biochemistry at the University of Sydney. He has published four joint papers. We wish Dr. Cho every success.

In the absence of the Honorary Treasurer (Dr. A. B. Walkom) the balance sheets for the year ending 28th February, 1969, duly signed by the Auditor, Mr. S. J. Rayment, F.C.A., were presented. On the motion of the Honorary Secretary it was resolved that they be received and adopted.

Presidential Address

Spilites again: some consequences of the degradation of basalts

Rock fabrics, bulk chemistry and the evidence of clino-pyroxenes indicate a close relation between spilites and basalts. Replacement textures show that the relation is, in fact, one of solid basalt and spilite. Primary magmatic models for the origin of spilites encounter formidable difficulties; a secondary status is required.

Secondary alteration of solid rock material can be effected at relatively low temperatures in various environments ranging from local hydrothermal to regional diagenetic/burial metamorphic types. The significant control in spilite genesis is reaction of solid basalt in aqueous media, the water being volcanic or perhaps more commonly meteoric or oceanic, according to the particular situation.

An analogy between chlorite-rich spilites and palagonites is suggested, the differences being related to contrasts in water chemistry and environment. Redistribution of basalt components is effected in response to mainly hydrolytic reaction. Common spilites are seen as simply one type of degraded basalt (low-grade metamorphic), namely, that resulting from reaction in alkaline media containing or acquiring sufficient SiO_2 in solution to stabilize albite, localization of which is related to the distribution of pre-existing feldspar sites. Quite different materials would be derived from basalts in acid waters within the same temperature range.

There is no justification from nature for restricting the term spilite to albite-rich basic rocks. Albite-rich and albite-poor variants are commonly associated. Spilite as a petrographic name has value only in a general sense encompassing the variety of materials formed together: Albite spilite, chlorite spilite, chlorite-epidote spilite, epidote spilite, etc. Those materials, mineralogically and chemically similar but formed or affected by structurally penetrative metamorphism, should be excluded.

The extent of compositional changes produced in hydrous degradation of basalt has obvious consequences in the study of subsequent higher-grade metamorphism. Some basic (or mafic) rocks interpreted as products of higher-grade metasomatic metamorphism may, in fact, be essentially isochemical materials.

No nominations of other candidates having been received, the Chairman declared the following elections for the ensuing year to be duly made:

President: Professor F. V. Mercer, B.Sc., Ph.D.

Members of Council: D. T. Anderson, D.Sc.; L. A. S. Johnson, B.Sc.; E. Shipp, Ph.D.; N. G. Stephenson, M.Sc., Ph.D.; F. H. Talbot, M.Sc., Ph.D., F.L.S.; and A. B. Walkom, D.Sc.

Auditor: S. J. Rayment, F.C.A.

The Chairman then installed Professor F. V. Mercer as President.

A cordial vote of thanks to the retiring President was carried by acclamation.

OBITUARY NOTICE

Harold George Raggatt

Sir Harold George Raggatt, K.B.E., D.Sc., F.A.A., who died on 2nd November, 1968, had been a member of the Society since 1929. He was a distinguished geologist, founder-director of the Bureau of Mineral Resources, then secretary of the Department of National Development from 1951 until his retirement in 1964. He saw Australia as "a land of mountains of ore, a land of promise", and played a major role in realizing that promise. He was born at North Sydney on 25th January, 1900, and educated at Sydney Technical High School and the University of Sydney. In 1922, having served in World War I, he joined the N.S.W. Geological Survey where he worked until 1940. The University of Sydney awarded him the D.Sc. degree in 1939 for his studies on the Sydney Basin. Between 1940 and 1942 he was Commonwealth Geologist and was appointed to the World War II mineral research survey. At the end of the war the Commonwealth decided to make the survey unit more permanent and, acting on a joint report by Raggatt and Rayner, established the Bureau of Mineral Resources, with Raggatt as director. He was author of many geological reports and his recent book "Mountains of Ore" gives an excellent summary of Australia's mineral wealth. He was Clarke Memorial Lecturer of the Royal Society of New South Wales in 1943, was elected to Fellowship of the Australian Academy of Science in 1954, and had been twice president of Section C of A.N.Z.A.A.S. (Perth 1947 and Adelaide 1958). He contributed two papers to the Society's Proceedings in 1929.

Sheet at 28th February, 1969.

LIABILITIES.	$	$
Accumulated Funds—		
Amount received from Sir William Macleay during his lifetime	28,000.00	
Further sum bequeathed by his will	12,000.00	
		40,000.00
Contingencies Reserve		47,344.13
Current Liabilities—		
Bookbinding Account	1,283.16	
Income Account	26,313.26	
Suspense	16.43	
		27,612.85
		$114,956.98

ASSETS.	$	$
Fixed Assets—		
Commonwealth Loans, at Cost	30,097.00	
Debentures :		
Metropolitan Water, Sewerage and Drainage Board, at Cost	41,688.75	
Sydney County Council	6,000.00	
Science House (one-third), at Cost	31,470.43	
		109.256.18
Current Assets—		
Cash in Hand	40.00	
Commercial Banking Company of Sydney, Ltd.	5,660.80	
		5,700.80
		$114,956.98

INCOME ACCOUNT. Year Ended 28th February, 1969.

	$	$	$
To Honorarium and Salary		4,102.04	
,, Printing *Proceedings*		3,449.88	
,, Reprints		1,087.80	
,, Illustrations		1,389.28	
,, Insurance		31.13	
,, Postage	303.73		
,, Petty Cash	77.42		
		381.15	
,, Expenses :			
,, Audit	105.00		
,, Printing and Stationery	229.55		
,, Expenses	154.57		
,, Cleaning	154.40		
,, Freight	57.24		
,, Furniture	1,315.46		
,, Epidiascope	178.56		
,, Addresser	271.00		
,, Sir William Macleay Lecture	115.03		
		2,580.81	
,, Science House Rent		3,556.00	
,, Library		225.73	
Expenditure for Year			16,803.82
Balance to 1969–70			26,313.26
			$43,117.08

	$	$	$
By Balance from 1967–68			20.117.10
,, Subscriptions :			
1968–69	1.586.20		
Arrears	119.00		
Advance	42.00		
		1,747.20	
,, Interest		4,071.80	
,, Science House		9,415.67	
,, Rent		43.50	
,, Sales		1,991.31	
,, N.S.W. Government Grant		800.00	
,, Fellowships Account (surplus income at 28th February, 1969, transferred)		3,193.61	
,, Sale of Reprints		887.86	
,, Printing Donation		100.00	
,, Surplus Furniture Sale		174.00	
,, Epidiascope Sale		60.00	
,, Library : Sale of Surplus Periodicals		515.03	
Receipts for Year			22,999.98
			$43,117.08

AUDITOR'S REPORT TO MEMBERS.

I have examined the books of account and vouchers of the Linnean Society of New South Wales for the year ended 28th February, 1969, and certify that the above Balance Sheet and accompanying Income Account are correct, and in accordance therewith, and in my opinion present the true state of the Society's affairs at 28th February, 1969, as shown by the books. Certificates of the investments have been inspected.

S. J. Rayment, F.C.A.,
Chartered Accountant, Auditor.
Registered under the Public Accountants Registration Act, 1945,
as amended.

Sydney, 11th March, 1969.

4th March, 1969.

A. B. Walkom,
Hon. Treasurer.

LINNEAN SOCIETY OF NEW SOUTH WALES.

LINNEAN MACLEAY FELLOWSHIPS ACCOUNT.

Balance Sheet at 28th February, 1969.

LIABILITIES.	$	ASSETS.	$	$
Accumulated Funds—		Fixed Assets—		
Amount bequeathed by Sir William Macleay	70,000.00	Commonwealth Loans, at Cost	60.885.50	
Surplus Income Capitalized	50,939.66	Debentures :		
		Metropolitan Water, Sewerage and Drainage Board, at Cost	41,196.98	
		Rural Bank of N.S.W., at Cost	1,745.50	
		State Electricity Commission	5,000.00	
				108,827.98
		Current Assets—		
		Commercial Banking Company of Sydney, Ltd.		12,111.68
	$120,939.66			$120,939.66

INCOME ACCOUNT. Year Ended 28th February, 1969.

	$		$
To Salary of Linnean Macleay Fellow	3,200.00	By Interest	6 404.11
,, Legal Expenses	10.50		
,, Balance, being Surplus Income transferred to General Account	3,193.61		
	$6,404.11		$6,404.11

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Sydney, 11th March, 1969.

A. B. Walkom.
Hon. Treasurer.

4th March, 1969.

LINNEAN SOCIETY OF NEW SOUTH WALES.

BACTERIOLOGY ACCOUNT.

Balance Sheet at 28th February, 1969.

LIABILITIES.	$	$	ASSETS.	$	$
Accumulated Funds—			Fixed Assets—		
Amount bequeathed by Sir William Macleay	24,000.00		Commonwealth Loans, at Cost	30,636.25	
Accumulated Income Capitalized	12,620.00		Debentures:		
Research Fund	20.00		Metropolitan Water, Sewerage and Drainage Board, at Cost	1,600.00	
		36,640 00	Loan on Mortgage	4,200.00	
Current Liability—					36,436.25
Income Account at 28th February, 1969		577.51	Current Assets—		
			Commercial Banking Company of Sydney, Ltd.		781.26
		$37,217.51			$37,217.51

INCOME ACCOUNT. Year Ended 28th February, 1969.

	$		$
To University of Sydney (towards salary of Lecturer)	1,900.00	By Balance from 1967–68	566.65
,, Balance to 1969–70	577.51	,, Interest	1,910.86
	$2,477.51		$2,477.51

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as amended

Sydney, 11th March, 1969.

A. B. Walkom.
Hon. Treasurer.

4th March, 1969.

PRESIDENTIAL ADDRESS

SPILITES AGAIN: SOME CONSEQUENCES OF THE DEGRADATION OF BASALTS

T. G. VALLANCE

(PLATES I-II)

[Delivered 26th March, 1969]

Synopsis

Rock fabrics, bulk chemistry and the evidence of clino-pyroxenes indicate a close relation between spilites and basalts. Replacement textures show that the relation is, in fact, one of solid basalt and spilite. Primary magmatic models for the origin of spilites encounter formidable difficulties; a secondary status is required.

Secondary alteration of solid rock material can be effected at relatively low temperatures in various environments ranging from local hydrothermal to regional diagenetic/burial metamorphic types. The significant control in spilite genesis is reaction of solid basalt in aqueous media, the water being volcanic or perhaps more commonly meteoric or oceanic, according to the particular situation.

An analogy between chlorite-rich spilites and palagonites is suggested, the differences being related to contrasts in water chemistry and environment. Redistribution of basalt components is effected in response to mainly hydrolytic reaction. Common spilites are seen as simply one type of degraded basalt (low-grade metamorphic), namely, that resulting from reaction in alkaline media containing or acquiring sufficient SiO_2 in solution to stabilize albite, localization of which is related to the distribution of pre-existing feldspar sites. Quite different materials would be derived from basalts in acid waters within the same temperature range.

There is no justification from nature for restricting the term spilite to albite-rich basic rocks. Albite-rich and albite-poor variants are commonly associated. Spilite as a petrographic name has value only in a general sense encompassing the variety of materials formed together: Albite spilite, chlorite spilite, chlorite-epidote spilite, epidote spilite, etc. Those materials, mineralogically and chemically similar but formed or affected by structurally penetrative metamorphism, should be excluded.

The extent of compositional changes produced in hydrous degradation of basalt has obvious consequences in the study of subsequent higher-grade metamorphism. Some basic (or mafic) rocks interpreted as products of higher-grade metasomatic metamorphism may, in fact, be essentially isochemical materials.

Before our thoughts turn to Cook and Banks and Botany Bay, I draw your attention to another, humbler, anniversary. This year, as far as we know, marks the sesquicentenary of spilite. The notion that this single rock type (or group of rocks) is sufficiently distinctive to merit a place in the taxonomy of petrology has been remarkably resilient and adaptable. It has been roundly condemned and as confidently endorsed. Now 150 years old, spilite literature is growing as never before. Perhaps that should be reason enough to desist, but having earlier outlined something of the development of geological opinion on the spilite concept I should like, with your indulgence, to continue the story with a more idiosyncratic view.

Like many of our problems, that of spilites is to a large extent man-made. What one person may call a spilite another would reject. Some claim they are igneous rocks some say they are metamorphic and some do not believe in their separate existence. Having decided to talk about spilites we may excuse the latter. Definition is no stranger in debate and the numerous proposals to account for the origin of spilites read like a potted history of petrogenetic thought (Amstutz, 1968; Vallance, 1960). Mineralogy, fabric, chemical composition, field occurrence or geological age and, more commonly, these in various particular combinations have all been taken as definitive criteria. The presence of albite as the typical feldspar of spilites is one of the more widely-accepted attributes. Further, as albite is the chief repository of soda here various attempts have been made to define spilites in terms of limiting soda contents. Such exactness may be splendid for a petrographic table; it is far less certain to have any necessary connection with nature.

Spilites and Basalts

Spilitic rocks occur as bodies having broadly the characters of basic volcanic masses. Field evidence points to many being truly extrusive; others form relatively shallow intrusions. Our knowledge of natural volcanic materials and processes has been influenced to a large degree by study of presently-active volcanic regions. Solid basalt, andesite, rhyolite and so on are all observable during formation from materials of appropriate compositions at elevated temperatures. Examples of these rocks from earlier parts of the geological record are interpreted in the light of contemporary operations. Yet no rocks diagnosed as spilites have been reported among the products of recent volcanism.

At the present time, basic melts in volcanic situations cool to form basalts of one sort or another. Depending on the manner and rate of cooling, the resultant solid basalt may be largely glass, a mixture of crystalline phases and glass, or essentially crystallized. The common crystalline phases thus produced are Ca-plagioclase about labradorite, pyroxene(s) and opaque minerals. Many basalts contain olivine. Glass, if present, has a composition related to original melt composition and the stage at which final consolidation occurred. These phases are arranged in various but highly characteristic patterns that have received particular textural names too well-known to need enumeration here. Grosser geometrical arrangements due to flow layers, ropy, blocky, or scoriaceous surfaces, pillows, jointing, vesicles, brecciated zones and so forth also contribute to what are called simply "basaltic" fabrics.

If we except those rocks called spilites that bear the imprint of deformative metamorphism we find, quite generally, a marked similarity in fabric between spilites and basalts. Fabric analogies between spilites and basalts or basaltic-andesites exist, in fact, on all scales (cf. Amstutz, 1968, p. 743). The analogies are closest for those basalts, such as subaqueous types, with heterogeneous fabrics related to locally variable cooling rates. Such basalts may be fragmented at their margins and tend to be there richer in glass than well inside. Many spilitic rocks, inferred from their mode of occurrence to have been originally connected with underwater environments, also show increasing development of the analogues of crystallized basalt textures away from what appear to have been their initial cooling surfaces. However, regardless of their fabrics, all these rocks described as spilites are observed to be crystalline.

Despite the fabric analogies, the mineral phases of spilites stand in marked contrast to those of basalts. The common associations in spilites have been listed previously (Vallance, 1960, p. 31); there is no need to repeat them. What one wants to emphasize here is that textural positions of Ca-plagioclase in basalt are occupied, as a rule, by low-temperature albite in spilite and those of glass by crystalline aggregates commonly rich in chlorite or chlorite plus a hydrous Ca-Al-silicate like epidote. Olivine is never seen in spilites though apparently pseudomorphous patches of chlorite or carbonate suggest its former presence in some cases. The prior existence of pyroxenes is likewise indicated by such textural relations and the evidence can be more direct here. A significant number of spilites contain fresh-looking clinopyroxene, occupying those sites one associates with the pyroxene of basalts. Apart from this pyroxene, formation of all the characteristic phases found in spilites requires conditions lower in temperature and presumably richer in fluids than those prevailing during development of the normal phases of basalt. If reliance can be placed on the fabric analogies one is drawn either to expect a genetic relation between spilite and basalt or to postulate a parental material for spilite, intrinsically different from basalt or at least different in its cooling history from anything known by observation of modern volcanic phenomena yet capable of producing "basaltic" fabrics on cooling. One admits a preference for a working scheme involving relation to something known or at least identifiable. *Entia non sunt multiplicanda praetor necessitatem.*

Bulk Chemical Relations. In view of the obvious contrasts in their mineralogy it is to chemical features we must turn in seeking to develop and identify a possible connection of spilites to basalts. The topic has been examined before (Vallance, 1960; 1965) but recently the store of data has grown considerably. Comparison of basalt and spilite compositions is facilitated now by Manson's (1968) invaluable compilation of chemical data for nearly 2000 rocks of basaltic composition. Manson's data and those for a much smaller set of rocks called spilites (225) are used in Table 1 and Figure 1.

A few points seem worthy of special comment. With regard to silica, arithmetic means and modes for both the basalts and spilites are remarkably close, despite the conscious limitation of silica in the case of basalts. Arithmetic means for Al_2O_3, MnO, and P_2O_5 in both are also close. Note also the tendency in many spilites for restriction of Al_2O_3 to the range 14·5–15·5 (Figure 1). Hidden within the notably higher mean values for H_2O+ and CO_2 in spilites we find considerable variations (for H_2O+ 0·4–9·4%, for CO_2 0·0–15·5%). Obvious contrasts exist for Na_2O and CaO between the basalts and spilites; not only do Na_2O values tend to be higher and CaO lower in spilites but each oxide shows wide spread and much lower percent frequencies at the modes. For CaO in the spilites the maximum frequency (9%) stands between 5·5% and 6·0% (wt.), well below the mean value. The absence of a single frequency peak for Na_2O in the spilites is clear. It should also be noted that some 19% of the total spilite sample have 3% or less Na_2O. For FeO and MgO frequency maxima are of the same order in both basalts and spilites but for each oxide higher populations are displaced to lower wt. percent classes in the spilites.

The tendency for spilites to have more Na_2O, H_2O+ and CO_2 and less CaO than basalts is one of the more widely-accepted spilitic attributes. The data presented also reinforce a point made earlier (Vallance, 1960), that the elements of spilites may be present in highly variable amounts. Clearly

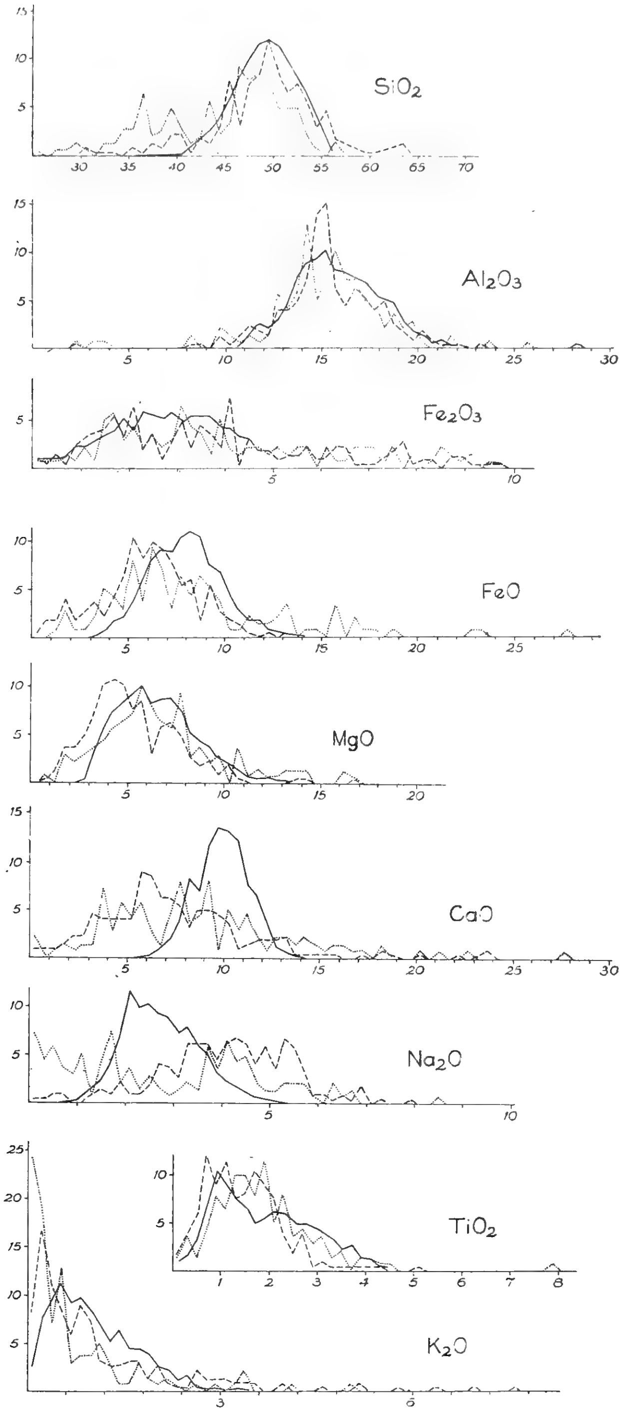

Fig. 1. Frequency distribution curves (percent frequency as ordinate; percent wt. abscissa) for basalts (full lines), spilites (dashed lines) and spilitic pillows (dotted lines) for selected major oxides. Sources of data: basalts—Manson (1968), for spilites and pillows see Appendix here.

a sizeable proportion of these 225 rocks identified as spilites by their investigators would be ineligible for the name if, for instance, a lower limit of 4 or 5% Na_2O were accepted as definitive. Yet we should be careful before rejecting the defaulters. Amstutz (1958) deserves credit as the first author to recognize clearly the problems involved in sampling spilitic rocks. One of the most characteristic internal features of spilites is their heterogeneity both in fabric and mineral constitution. The latter has an obvious influence on local variations in chemical composition; both Amstutz (1968) and Vallance (1960) have discussed some of the consequences. In view of this common heterogeneity, it is highly probable the set of 225 individual analyses, mainly from different localities, represents a partial sampling. I have therefore reserved a second, differently based, set of spilite data for an independent comparison.

TABLE 1

Mean Compositions—Basalts and Spilites

	Rocks of Basaltic Compositions (Manson, 1968)	Rocks described as Spilites	(Spilitic) Pillows—cores and selvedges	Cores of (Spilitic) Pillows (col. 3)	Holomineralic Spilite (Amstutz, 1968)
Number in sample ..	1,996	225	140	58	—
SiO_2	49·2	49·0	44·3	49·1	48
Al_2O_3	15·8	15·4	15·2	15·1	15
Fe_2O_3	3·0	4·1	4·7	3·9	10
FeO	8·0	6·1	8·3	6·6	
MnO	0·17	0·18*	0·16	0·14	—
MgO	6·6	5·3	6·8	5·6	6
CaO	10·0	7·6	8·7	8·2	8
Na_2O	2·7	4·1	2·8	4·3	5
K_2O	1·0	1·1	0·7	0·5	1
H_2O+ ..	0·9	3·2*	4·3	2·9	5
CO_2	—	2·4*	1·3	1·2	
TiO_2	1·9	1·5	1·9	1·7	2
P_2O_5	0·33	0·30*	0·33	0·33	—

* Mean based on fewer data than total sample.

This second set offers an initial advantage in that each occurrence involved is represented by at least two compositions of adjacent parts. All these data relate to pillow lavas. Both basalts and spilitic bodies may display pillow structure and in basalts, at least, the feature is usually related to differential cooling of silicate melt against water or wet sediment. The more rapidly chilled margin of a basalt pillow is far richer in glass than the relatively insulated core material. Sampling of glass-rich selvedges and adjacent less-glassy cores of basaltic pillows or chilled fragments demonstrates the common chemical uniformity in individual bodies (Vuagnat, 1959; Nicholls, 1965). Analogous pillow bodies in spilitic associations are marked not by glassy margins but by fine crystalline aggregates. These marginal aggregates consist of phases such as chlorite in far greater amount than is present in the core. Fabrics analogous to those of more crystallized basalts are found only in spilitic pillow cores. Table 2 provides a summary of observed patterns of variability in these pillows.

The spilitic pillow set comprises 140 analyses derived from 52 pillows. Although smaller than the first set, it does represent a wide sampling of localities and mineral associations. None of the pillow analyses is included in the first set. Only examples offering data for at least selvedge/matrix and adjacent core have been used. The cores (and, indeed, the selvedges too) of some pillows are obviously zoned, hence the number of core analyses reported in Table 1 exceeds the total number of pillows.

TABLE 2

Variability in Spilitic Pillows

Selvedge/Matrix		Core	
Chemical features	Typical phases (usually + chlorite)	Chemical features	Typical phases
(1) Fe^{2+}Mg-rich, low Ca, Si, Na	Chlorite	"Spilitic", i.e. albite spilite compositions	Albite-chlorite Albite-chlorite-carbonate
(2) Rich in non-carbonate Ca, low Si, Na			
(*a*) Fe^{3+}(Al)-rich ..	Epidote Pumpellyite Prehnite Hydrogarnet		Albite-chlorite Albite-chlorite-epidote Albite-chlorite—other CaAl(OH) silicates
(*b*) Ti-rich	"Sphene"		
(3) Ca, CO_2-rich, low Si, Al, Na	Carbonates		Albite-chlorite Albite-chlorite-carbonate
(3*a*) Ca-rich, considerable FeMg, diminished Al, low Na, (Si)	Tremolite/actinolite		Albite-amphibole-chlorite
(4) Fe^{3+}-rich, low Ca, Si, Na	Haematite		Albite-chlorite-(haematite)

Referring to Figure 1 it will be apparent that the distribution of silica in the pillow group has a crudely bimodal character with a minor frequency peak at 36–37% (wt.); the major grouping for pillows falls in the range 46–49%, slightly away from those of the other sets. Again, for Na_2O there is a suggestion of bimodal distribution; an even greater number fall in the low soda range than was found in the 225 spilites. Low values for K_2O in the pillows produce a marked frequency peak. Apart from these the major elements in pillows appear to be distributed in much the same way as in the other spilites, their distribution curves not uncommonly falling between those for spilites and those for basalts. Scatter of wt. percent values recorded is at least as great as, and for some oxides greater than, that seen in the 225 set. The broadly consistent distribution patterns for Al_2O_3 and TiO_2 in both spilite groups and in basalts deserve special mention.

Evidence of chemical diversity within pillows emerges clearly if we extract data relating to one particular portion. In Table 1 mean values of oxide abundances in the total pillow sample appear beside those for pillow cores only. Whereas the average core closely resembles the 225 spilite mean, the total pillow mean, apart from its greater H_2O+ and CO_2, is nearer a basaltic composition.

Spilitic pillow cores share their chemical characters with the majority of rocks called spilites (cf. Vallance, 1965). Selvedges, on the other hand, are manifestly diverse from one place to another though all display a common tendency to contain less Na_2O and SiO_2 than adjacent cores (Table 3). The immediate sources of these contrasts are not hard to find. The phases most abundant in selvedges (Table 2) are characterized by relatively low silica

TABLE 3

Representative Spilitic Pillows

	Mullion Id., Cornwall		Port Vad, Ayrshire		Porth yr Halen, Anglesey		Nundle, N.S.W.		Rudha Cuillin, Argyllshire	
	Core	Selv.	Core	Selv.	Core	Selv.	Core	Selv.	Core	Selv.
Major elements (wt. %)										
SiO_2	51·82	32·08	50·48	35·12	51·00	36·12	50·00	34·68	53·84	40·85
Al_2O_3	14·29	16·36	14·72	14·75	17·82	20·29	16·69	17·52	18·81	12·80
Fe_2O_3	2·51	5·76	2·59	3·52	1·73	9·15	1·97	8·47	4·01	1·10
FeO	6·32	13·34	4·20	13·00	6·28	5·81	9·20	8·56	6·18	4·28
MnO	0·14	0·22	0·09	0·15	0·11	0·12	0·26	0·47	0·17	0·07
MgO	4·93	14·29	3·91	13·71	5·72	5·08	5·04	4·52	2·38	1·86
CaO	8·79	3·89	8·40	3·63	4·80	16·44	7·22	16·00	2·17	13·80
Na_2O	4·82	0·56	6·38	1·45	5·64	0·48	3·74	0·64	6·70	4·58
K_2O	0·18	0·72	0·35	0·46	0·28	0·15	1·10	0·55	0·78	0·96
H_2O+	2·29	9·01	2·10	8·36	3·62	4·06	3·25	4·39	1·62	1·96
H_2O-	0·62	1·30	0·80	3·02	0·38	0·40	0·14	0·29	0·19	0·13
TiO_2	1·39	2·44	2·36	2·70	1·90	2·10	1·68	4·08	1·74	15·78
P_2O_5	0·02	0·01	0·52	0·36	0·33	0·22	0·21	0·26	0·14	1·47
CO_2	1·82	0·05	3·28	0·31	0·40	0·32	0·00	0·00	1·44	0·33
Total	99·94	100·03	100·18	100·54	100·01	100·74	100·50	100·43	100·17	99·97
Trace elements (p.p.m.)										
Ga	10	10	22	10	22	28	15	45	22	22
Cr	125	220	100	125	320	270	26	100	32	180
V	180	220	250	250	250	420	220	520	150	420
Li	24	14	6	32	22	18	17	17	13	13
Ni	40	40	46	40	46	46	22	47	21	21
Co	40	40	26	40	32	26	28	51	40	18
Sc	45	45	26	35	46	46	26	100	22	46
Zr	140	270	120	270	56	70	40	175	150	1200
Y	22	15	22	22	21	21	12	55	22	125
La	—	—	—	—	—	—	—	—	170	465
Sr	180	—	180	40	80	200	260	260	350	350
Ba	5	5	8	5	8	22	550	60	350	220
Rb	—	12	—	—	—	—	45	—	—	—
Norms										
Q	1·79	—	—	—	—	—	—	—	5·52	—
or	1·06	4·26	2·07	2·72	1·65	0·09	6·50	—	4·61	5·67
ab	40·79	4·74	53·99	12·27	47·73	—	31·65	—	56·70	38·76
an	16·83	18·92	10·49	13·70	19·13	52·77	25·51	43·31	0·75	11·53
lc	—	—	—	—	—	0·62	—	2·55	—	—
ne	—	—	—	—	—	2·20	—	2·93	—	—
C	—	7·73	—	6·85	1·23	—	—	—	6·67	—
di	12·34	—	5·59	—	—	19·72	7·14	21·46	—	5·57
hy	13·76	12·91	6·52	18·03	10·76	—	13·44	—	11·41	2·05
ol	—	28·05	1·72	23·83	7·72	2·46	6·23	2·52	—	—
cs	—	—	—	—	—	—	—	1·85	—	—
hm	—	—	—	—	—	0·16	—	—	—	1·10
mt	3·64	8·35	3·76	5·10	2·51	13·03	2·86	12·28	5·81	—
il	2·64	4·63	4·48	5·13	3·61	3·99	3·19	7·75	3·30	9·19
tn	—	—	—	—	—	—	—	—	—	4·03
pf	—	—	—	—	—	—	—	—	—	15·83
ap	0·05	0·02	1·20	0·83	0·76	0·51	0·60	1·09	0·32	3·40
cc	4·14	0·11	7·46	0·71	0·91	0·73	—	—	3·27	·75

Major-element data quoted from Vallance (1960, 1965).

(wt.%) contents; the high FeO and MgO contents of chlorites and CaO of epidote, pumpellyite, calcite, etc., serve to compensate in the total pillow means for deficiencies in the core means. Again, as albite is the commonest, and indeed is usually the sole, sodic phase in spilitic rocks, the distribution of Na_2O is related to distribution of albite. In turn, distribution of albite (with up to 68·7% SiO_2) has an obvious bearing on dispersal of silica.

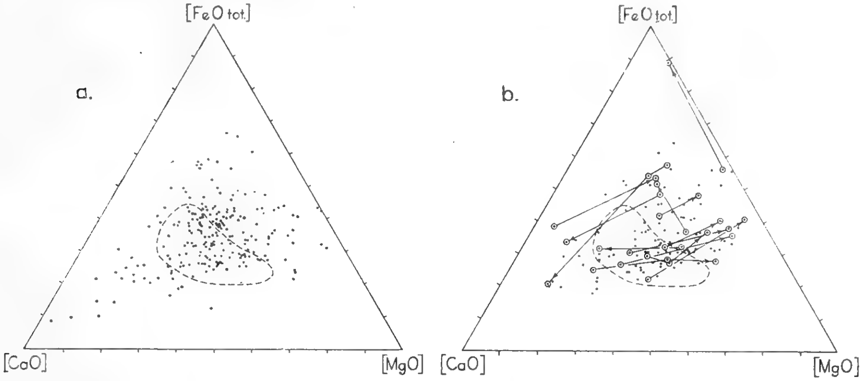

Fig. 2. Plots of total iron oxides as FeO: MgO: CaO (molecular proportions). The dashed field encloses plots for 350 Quaternary—Tertiary basaltic rocks. (a) Spilites. (*b*) Spilitic pillows. Plots of the different parts of selected pillows are joined by full lines, in each case the arrow points towards selvedge or matrix.

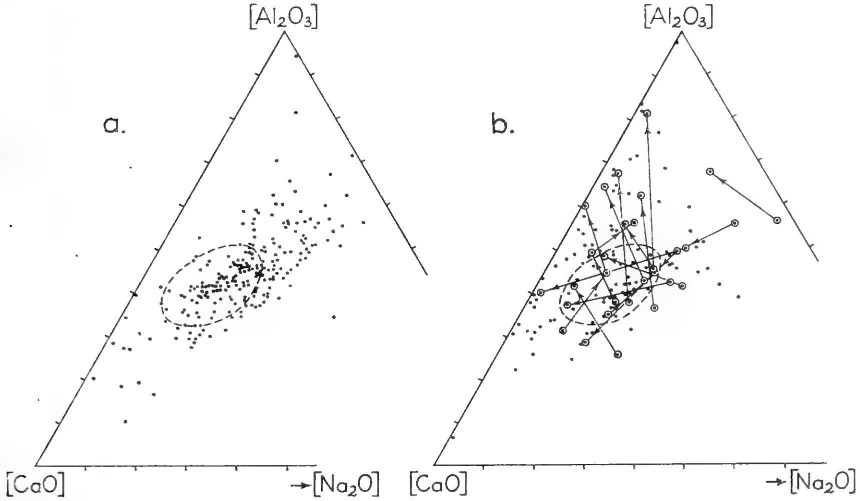

Fig. 3. Plots of Al_2O_3: Na_2O: CaO (mol. props.). The dashed field is that of 350 basalts. (*a*) Spilites. (*b*) Spilitic pillows. See note for Fig. 2.

Petrographic examination confirms that those volumes richest in albite occur typically in the cores of pillows. The close spatial relation of volumes with contrasted compositions and the essentially complementary arrangement of oxides between the contrasted parts render a causal connection highly probable. The existence of similar diverse compositions in the set of 225 spilites points to a wider relevance for contrasts of the types observed in spilitic pillows. Would all spilitic bodies, if adequately sampled, be found to have bulk compositions far closer to those of basalts?

Unfortunately, there are few instances of detailed studies of non-pillowy spilites. Many investigators have remarked on the presence in massive spilites of patches marked by mineral content in distinct contrast with that of their surroundings. Such heterogeneities appear to be especially common near margins, joints or within brecciated zones. The splendid work of R. E. Smith (1968) on a single outcrop of Ordovician spilitic lava at Cliefden, N.S.W., provides the only well-documented case available. Smith's petrographic and chemical data define a scheme of diversity and complementary distribution of oxides similar to those found in pillows with parts rich in hydrous Ca-Al-silicates. In fact, some measure of this may be judged from Figure 4 where data for a pillow in the same Ordovician formation but from a locality some miles away from Cliefden are plotted with Smith's data (cf. also Figures 2 and 3). Chemical variety in this pillow from near Woodstock falls within the considerable range discovered by Smith; he found, for instance, Na_2O contents from 0·03% to 6·55% (wt.) and SiO_2 from 38·17% to 65·31% in different parts of the Cliefden outcrop. The weighted bulk composition calculated by Smith approaches that of a basaltic andesite plus water. High silica content is not exclusively related to high Na_2O at Cliefden and, in fact, the presence of a silica phase, with or without albite, appears to be fairly common in veins and patches associated with brecciated basic rocks.

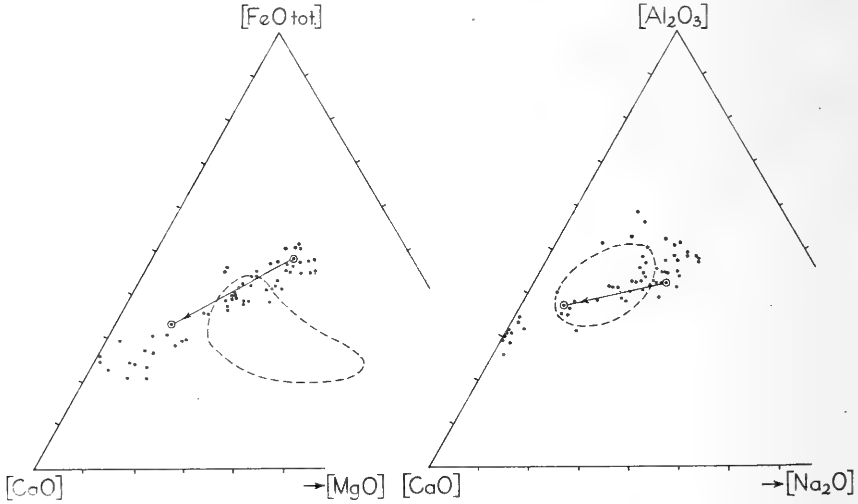

Fig. 4. Plots of FeO (tot.): MgO: CaO and Al_2O_3: Na_2O: CaO (both mol. props.) for analysed samples from the Cliefden outcrop (Smith, 1968). The two points joined by an arrow represent a pillow from Woodstock, in the same district (Vallance, unpubl. data). Fields of basalts indicated as in Figures 2 and 3.

At Yalwal, N.S.W., silica becomes locally abundant as a matrix to chlorite-rich fragments in basic breccia (Vallance, 1967*a*, Table 1). Considerable silica also occurs locally with epidote and pumpellyite in breccias near Pambula, N.S.W. These Devonian breccias at Yalwal and Pambula are associated with basaltic rocks retaining Ca-plagioclase though albite is the common feldspar in the breccia fragments. A dark patch which "basaltic" texture and surrounded by an epidote-quartz zone in breccia at Cusack's Creek (Pambula district) carries some 7% Na_2O—present in albite mainly on original sites. Samples of more normal basalt in the area contain Na_2O in the range 2·2% to 2·9% (Brown, 1931; unpublished data).

Much more detailed study of massive spilites and breccias is clearly required. Adequate sampling becomes a far more complex task with such material than it is with pillows but Smith's work has pointed the way. At least we can say that contrasted compositions are not confined to spilitic pillows. Patterns similar in both style and degree exist also in massive bodies. Among the latter this tendency to contrasted compositions may be manifested in material with fabrics akin to those of reasonably crystallized basalts. Some examples of almost monomineralic patches retaining "basaltic" fabrics are illustrated in Plates I and II. Chlorite, epidote, pumpellyite, hydrogarnet, quartz, and carbonates have all been observed in such situations which, apart possibly from that for chlorite, seem commonest near veins containing the same phase. Eskola (1934) has described what appears to be a similar case involving prehnite. Though Eskola's samples were pebbles (from the Baltic Sea) he recognized a likely connection with a spilitic association.

Detailed study of both spilitic pillows and patchy spilites leads to the same conclusion, that compositions of spilitic bodies where adequately sampled are found to approach those of basalts plus water (and CO_2). Such a conclusion adds point to the observed fabric analogies. It also leaves little room for doubt that all the contrasted fractions are essential parts of the whole. To dismiss some of these as eccentric or insignificant and to select others as characteristic is unacceptable. The Na_2O-poor volumes are as much part of the whole as the Na_2O-rich. The wide range of compositions represented in the 225 spilites reflects in some measure the diverse decisions made by various investigators. Some have taken a comprehensive view; many others have been more restrictive in their definitions. The latter impose on nature.

You will have noticed I claim no more than *an approach to basaltic compositions* for bulk spilites. Detailed comparison of the data in Table 1 for the total pillow sample and for basalts discloses, in fact, much closer agreement for some oxides than others. I leave aside here H_2O+, CO_2, and Fe_2O_3; the latter is so greatly influenced by one single haematite-rich selvedge containing almost 50% (wt.) Fe_2O_3. Of the other oxides, SiO_2 and CaO appear to be less abundant in the pillows than in basalts. It is necessary, however, to add that no attempt was made to adjust the total pillow means in terms of relative volume contributions of the various parts. Some pillows have thicker selvedges than others but rarely, if ever, would the volume of selvedge reach that of core. A probability of prejudice towards selvedge compositions is therefore hidden in the means. Such prejudice could affect mean SiO_2 and Na_2O and the large number of pillows with chloritic selvedges must influence mean CaO. But where bulk compositions can be calculated in terms of relative volume proportions of the different parts, mean values for some oxides still remain out of accord with those for basalts.

The adjusted bulk of a spilitic pillow from Nundle (Vallance, 1960, Table 3), for instance, does not invite ready matching with any specific and common basalt composition though it is generally basaltic in character. One would expect a rather different pattern of oxide abundances in a basalt with less than 45% SiO_2. Likewise, Smith's (1968) adjusted bulk for the Cliefden body is not exactly typical of either common basalts or basaltic andesites.

In Table 4 data for three spilitic pillows (see also Table 3) are compared with basalt compositions on an equal-volume basis. While fabric analogies between spilites and basalts give some support to this method there must be doubt about strict equivalence in volume between basalt glass and the crystalline material of a pillow selvedge. However, for the present

TABLE 4

Basalt and Spilite Compositions (as gm/100 cm³)

	Basalt as glass; assumed D=2·77		Spilitic pillow selvedges			Basalt; assumed D=2·90		Spilitic pillow cores		
	Average tholeiite (Nockolds, 1954)	Margin of tholeiite fragment (Nicholls, 1965)	Mullion Island	Port Vad	Porth yr Halen	Average tholeiite (Nockolds, 1954)	Core of tholeiite fragment (Nicholls, 1965)	Mullion Island	Port Vad	Porth yr Halen
SiO_2	141	140	94	103	120	147	147	147	141	152
Al_2O_3	39	44	48	43	67	41	46	41	41	53
Fe_2O_3	8	3	17	10	30	8	3	7	7	5
FeO	25	22	39	38	19	26	23	18	12	19
MnO	0·5	0·4	0·6	0·4	0·4	0·5	0·4	0·4	0·3	0·3
MgO	18	24	42	40	17	18	26	14	11	17
CaO	29	32	11	11	54	30	33	25	23	14
Na_2O	6	7	2	4	2	7	8	14	18	17
K_2O	2	0·3	2	1	0·5	2	0·3	0·5	1	0·8
H_2O+	3	2	26	25	13	3	0·7	7	6	11
TiO_2	6	3	7	8	7	6	3	4	7	6
P_2O_5	0·6	0·3	0·1	1	0·7	0·7	0·4	0·1	1	1
CO_2	—	—	0·2	1	1	—	—	5	9	·1

Calculated compositions of spheres with selvedges 0·5 cm thick and total diameter 13·5 cm. i.e. approximating dimensions of the three pillows

A series of rocks from the Carlsberg Ridge, Indian Ocean "illustrating the course of spilitization" (Cann and Vine, 1966)

	Average basalts (Nockolds, 1954)		Pillows			Fresh basalt	Slightly altered basalt	Incompletely spilitized dolerite	Spilite after variolitic basalt
	Tholeiite	Alkali* basalt	Mullion Island	Port Vad	Porth yr Halen				
SiO_2	146	134	136	133	145	138	139	138	140
Al_2O_3	40	43	42	42	56	44	45	43	40
Fe_2O_3	8	9	9	8	10	10	12	7	5
FeO	26	26	22	17	19	21	17	20	21
MnO	0·5	0·6	0·4	0·3	0·3	0·6	0·6	0·7	0·7
MgO	18	27	20	17	17	20	19	26	22
CaO	30	31	22	21	23	30	30	22	19
Na_2O	6	8	11	15	14	9	10	13	14
K_2O	2	3	1	1	0·8	0·8	0·1	0·2	0·1
H_2O+	3	2	11	10	11	2	6	10	9
TiO_2	6	8	5	7	6	6	5	5	5
P_2O_5	0·7	1	0·5	1	0·9	0·2	0·4	0·2	0·1
CO_2	—	—	4	8	1	ol-hy normative		ne normative	

let us assume equal volumes. The three pillows selected are all of much the same size and bear rather thin selvedges. Their roughly adjusted bulk compositions reflect the greater contribution of core material. Complementary distribution of oxides between cores and selvedges, mentioned before, is also apparent. Thus the adjusted bulk for the pillow from Porth yr Halen, Anglesey, the selvedge of which is epidote-rich, has no more CaO than the two pillows with chloritic selvedges. Omitting H_2O+ and CO_2, the most obvious differences between the adjusted pillows and average basalts lie in lower CaO and higher Na_2O in the spilites. These individual examples, representing two distinct types of spilitic materials, add a degree of conviction to the notion that chemically the basalt/spilite relation cannot be a simple one: basalt + H_2O + (CO_2) = spilite.

Here I draw your attention to a group of samples taken from the submarine Carlsberg Ridge in the Indian Ocean. Of course in such a situation exact details of association are unknown but in material raised from a given locality Cann (Cann and Vine, 1966) recognizes a series from basalt to albite-rich spilite. Cann's data appear in Table 4. His inferred series includes contrasts between basalt and spilite similar to those just quoted. The basaltic members of Cann's series are *ol-hy* normative; the spilites are *ne* normative. Generally, in terms of basalt normative compositions, norms of spilites are extremely variable (cf. Table 3). Yoder (1967) has also remarked on this.

Pyroxenes. Recently, it was suggested (Vallance, 1969) that study of pyroxenes in spilitic rocks may afford a means of identifying the connection between spilites and basalts. The common occurrence of fresh-looking clinopyroxene related subophitically to albite has been recognized in the spilites at Nundle since the work of Benson (1915*a*). Benson, indeed, argued that the particular textural relation together with the clarity of the mineral indicate a primary (magmatic) origin for albite. The evidence of geometry would require crystallization of albite before proxene and, in turn, presumably a lower temperature separation of pyroxene than is normal in basalts. One would therefore expect spilitic pyroxenes thus formed to be different from those of basalts or to be at least distinctive. Meriläinen (1961), in fact, has analysed an aegirine-augite from an albite diabase in Finland but study of the pyroxenes from both fine-grained spilites and the chemically similar but coarser albite dolerites at Nundle shows clearly these pyroxenes are of basaltic types. Chemical data are now available for 12 samples: none departs far from the average position Ca 41·7, Mg 39·2, ΣFe 19·1 (atomic percent). No evident relation exists between the present Na_2O content and the character of the pyroxene (Table 5). One sample (13242) retaining Ca-plagioclase has a pyroxene that clearly belongs with the rest. These Nundle pyroxenes

TABLE 5

Spilitic Rocks and Pyroxenes, Nundle, N.S.W.

Sample*		13242	13237	13240	41106	23062	13236	23014
Rock	Na_2O	3·02	3·06	3·80	4·48	4·70	4·98	5·51
(wt. %)	SiO_2	49·38	47·36	49·68	52·96	54·20	49·28	52·48
cpx.	Ca	41·4	45·0	40·4	40·2	41·9	44·0	38·6
(at. %)	Mg	41·6	34·6	42·5	39·2	38·3	36·2	41·8
	ΣFe	17·0	20·4	17·1	20·6	19·8	19·8	19·6

* University of Sydney collection. 13242 contains Ca-plagioclase relics.

are mainly *hy* normative types with a minor group having some *ne* in the norm. Despite some distinctive features that must be considered in detail elsewhere, these pyroxenes are broadly what we should expect in a series of olivine tholeiitic to transitional alkali basalts (Vallance, 1969). Comparable results have emerged from less extensive studies of spilitic pyroxenes from the United Kingdom and Australia. I shall mention only one other case, now being studied in collaboration with Professor R. N. Sukheswala of Bombay. Sukheswala and Poldervaart (1958) demonstrated the occurrence of albite-rich basalt or spilite within a clearly tholeiitic flow in the Bombay area. Pyroxenes from both spilites and tholeiite there appear to be closely similar—in each subcalcic augite to augite.

The Basalt-Spilite Relation. We should now take stock. We have seen, first, the close fabric analogies between basalts and spilites, second, that spilites where adequately sampled have bulk compositions approaching those of basalts, third, that despite this approach agreement of bulk spilite is incomplete, deviations, however, being confined mainly to CaO and Na_2O, and last, that pyroxenes where present in spilites tend to be normal basaltic types. There can be little doubt of a genetic relation between the two rock types. Only one matter remains before we start asking why spilites differ from basalts. That is the final question what is the nature of the relation. The basaltic-type pyroxenes in spilites surely point to their having crystallized under "basaltic" conditions, that is, by separation from basalt melts at elevated temperatures.

In some spilites unequivocal evidence of secondary mineral generation is not hard to find. The examples of patches illustrated in Plates I and II should make that clear. Outlines of feldspar laths (taking the basalt analogy) remain though the place of feldspar is taken by the phase dominating the patch. Interstitial groundmass material is also replaced; a good example is the quartz-rich patch (Plate II) where the boundaries of secondary quartz intersect feldspar-groundmass interfaces. Such neat examples are less common in spilitic pillows but cracks, similar in style to perlitic cracks in altered acid glass, have been observed in a number of chloritic selvedges (Vallance, 1965). These and the colloform arrangements found in some selvedges suggest a process of glass-decomposition and that spilitic pillows once had glassy selvedges. In that case the analogy with basaltic pillows would be complete.

The weight of observational evidence leads to the basalt/spilite relation being generally solid basalt/spilite and not basalt melt/spilite. In other words, we can expect spilitic rocks to have been derived from cooled, consolidated basalts. Spilites normally must be products of the degradation of solid basalt to low temperature, hydrous conditions. No particular restriction as to the type of basalt involved appears to be required. Both alkali basalts or tholeiites can serve as parental materials.

Having reached this conclusion with its implication of a metamorphic status for spilites, it is only fair to point out the conflict with a widely-held view that spilites are primary igneous rocks. Before getting too tendentious, one must take another look at the alternative models though in doing so there must be some repetition of things already said (Vallance, 1960; 1965).

SPILITE GENESIS

Amstutz (1968) has conveniently tabulated the various proposals advanced to account for the origin of spilitic rocks They can be simplified into two broad groups: (1) spilites are primary basic igneous rocks resulting from direct crystallization during magmatic cooling, and (2) spilites owe their present characters to secondary, generally post-magmatic alteration of solid basic igneous rocks. Amstutz clearly favours the primary model.

Some authors have talked of spilitic magma but their meaning is too often ambiguous. One suspects that usually they imply no more than parent magma for an observed rock having what is deemed spilitic character and not a magma with specifically spilitic characters (whatever they might be). For this latter nature supplies no direct evidence though we can recognize among contemporary volcanic products the equivalents of other volcanic materials from the geological past.

The commoner and less ambiguous primary spilite model involves derivation from basaltic magma under particular conditions of cooling—conditions one may add not manifest now. The primary model must supply a cause for initial separation from melt of phases like low albite and chlorite. For this recourse is usually had to basalt consolidation under extremely hydrous conditions—the so-called hydromagmatic theory. The theory has some formidable problems with which to contend.

That variant of the theory proposed by Rittmann (1958) whereby considerable superincumbent water loads might suppress the temperature-range of freezing to one in which primary albite and chlorite appear is refuted by the normal and even glassy basalts collected from the floors of the deep oceans. Despite Yoder's (1967, p. 276) claim, there is not even clear evidence of any enhanced H_2O content in deep submarine glasses (cf. Nicholls, 1965).

There are other objections to hydromagmatic crystallization in lava bodies. For example. retention and accumulation of magmatic volatiles are essential to the scheme yet spilites have closest fabric analogy with basalts that have chilled rapidly. Also the occurrence of amygdales in spilites corresponds with the unfilled vesicles of modern basalts; there can hardly be much doubt the cavities form through loss of volatiles from cooling melt. Relatively rapid loss of heat and magmatic volatiles are scarcely desirable for hydromagmatic operations.

Experimental laboratory results are no more encouraging. From their work in the system basalt-water, Yoder and Tilley (1962, p. 459) conclude "all major basalt compositions crystallized on cooling in the presence of water as hornblende gabbro". Yoder (1967, pp. 278-9) has shown that even spilite + water gives amphibole-bearing assemblages over the temperature range from 600°C to the beginning of melting at water pressures 2–10 Kb. Spilite assemblages according to Yoder are most likely confined to the solidus region below 600°C at these pressures. Yoder also remarks that clinopyroxene appears before feldspar in the system albite—diopside—H_2O under both hydrous and anhydrous conditions, a relation contrary to that observed in spilitic rocks. In conjunction with the nature of the pyroxenes discussed earlier, this experimental evidence gives no support to the primary spilite model.

Lehmann (1965) saw support for primary magmatic separation of spilitic chlorites in textural relations and the established stability of Mg chlorites to temperatures of the order 700°C. However, the upper stability of chlorites is limited by pressure-sensitive dehydration reactions within the solidus field. Experimental results (Fawcett and Yoder, 1966; Yoder, 1967) do not imply direct separation of chlorite from melt and while chlorite may certainly form as a non-replacement phase in veins and cavities its occurrence elsewhere is more often secondary. Even chlorite in cavities must be interpreted carefully in view of observations like those of Smith (1967) who records instances of silicate melt having invaded vesicles and chilled mainly to glass.

One encounters difficulty also if attempt is made to reconcile the contrasted compositions, such as exist in spilitic pillows, to known schemes of magmatic consolidation. Amstutz (1968) refers to the contrasted materials as differentiates but that cannot be assumed to imply *magmatic* differentiates. By analogy with modern pillows we expect the margins of spilitic pillows to have consolidated originally before their cores. There is only limited evidence of magmatic differentiation effects in basalt pillows and it is usually confined to larger bodies. Marked chemical contrasts occur within spilitic pillows of all sizes. Further, reference to Table 3 and the earlier discussion makes it clear if we follow normal petrographic criteria the situation arises that materials of extraordinarily different types (as seen in pillow selvedges where one expects initial chilling) must lead by rather slower cooling to the formation of strikingly convergent core compositions. For this we have no parallel in the whole range of igneous petrology. In sum, I believe the case for extensive primary separation of spilitic phases from basaltic melts must be abandoned. Which brings us to secondary operations.

Secondary Processes. Secondary adjustment of igneous rocks may result from operations in many different types of environment. Recognition of the particular controls in a given case must depend largely on local evidence. All share one thing, the essential role of water. The following tabulation may serve to outline the variety of situations envisaged:

(1) *Hydrothermal alteration* (Mainly local)
  (*a*) *autometamorphism*—action of connate (volcanic) fluids during late-magmatic cooling stage.
    ? grading to:
  (*b*) *volcanic hydrothermal metamorphism*—post-eruptive action of fluids ranging in origin from largely connate to largely extraneous (meteoric).
    grading to:
  (*c*) *post-volcanic hydrothermal metamorphism*—action of fluids unrelated in origin to the solid volcanic material.
      (Hot-spring activity in (*b*) and (*c*)).
    ? grading through more spatially extensive geothermal activity to:
(2) *Regional alteration*
  (*a*) *burial metamorphism, diagenesis*—action involving pore fluids in a regionally-controlled "hydrostatic" environment.
  (*b*) *low-grade metamorphism*—involving formation of penetrative fabrics.

The witness of schistose fabric elements is sufficient to isolate products of structurally penetrative metamorphism from the others.

At least since the time of Dewey and Flett (1911), autometamorphic alteration has proved attractive to many students of spilites. Such alteration, in fact, is linked by some to a primary magmatic history for these rocks (Amstutz, 1968). That magmatic volatiles may be retained and enriched in late fractions of a cooling melt system is established beyond reasonable doubt as is the tendency for the late fractions to react with earlier-formed crystalline phases. In a body like the differentiated Prospect Intrusion (Wilshire, 1967), the action of late-magmatic fluids resulted in extensive autometamorphic or deuteric alteration. The secondary products at Prospect, mainly Na-rich zeolites, prehnite, clay minerals and carbonates, are typical of this sort of adjustment. Now this intrusion is some 400 feet thick, has distinct chilled zones top and bottom of the order 15–20 feet thick, and consolidated under at least a few hundred feet of shale—clearly effective conditions for prolonged cooling and internal concentration of volatiles. A few spilites are reported from basic intrusions apparently unrelated to surface volcanism (see Vallance, 1960). It may not be difficult to envisage some late-magmatic adjustment in such cases.

The situation in an effusive body is likely to be very different, especially where loss of heat to the surroundings is assisted by boiling-off volatiles. The likelihood of truly autometamorphic conditions being achieved in flows other than very thick ones seems much lower than in intrusions. Despite this, there is still a widespread dedication to belief in late-magmatic agencies as responsible for alteration in flow basalts. Fawcett (1965), for instance, argues thus in his discussion of basalt alteration on Mull. These basalts may be as old as Eocene and Fawcett's samples, taken near sea level, appear to be well down in a thick volcanic pile. Arguments for late-magmatic adjustment would be more convincing if similar alteration features were to be found in present-day basalt flows. For those common spilitic masses in which fabric evidence suggests fairly rapid cooling, the autometamorphic model seems inappropriate. Yoder (1967, p. 275) evidently favours an autometamorphic origin for spilites though the basis for his conclusion is not indicated. The only alternative he recognizes, metamorphism at depth, is "not believed to be common" but, again, no reason is given.

One may envisage gradations in nature from autometamorphic situations obtaining before complete magmatic consolidation to hydrothermal environments in which solidified volcanic materials are affected by fluids at first perhaps mainly volcanic in origin. The existence and activity of thermal springs in volcanic regions are well known. Some thermal waters are considered to be volcanic, many others, perhaps most (White, 1957*a, b*) appear to be largely of surface provenance. Study of hydrogen and oxygen isotope abundances in many thermal waters reveals close correspondence with abundances in meteoric waters (cf. Ellis and Mahon, 1964).

Secondary Processes—Post-Magmatic. As Naboko (1963*a*, pp. 11–12) remarks (in translation) of the Tertiary-Quaternary volcanic field in the Kurile Islands, "hydrothermal metamorphism in volcanic regions proceeds continuously over long periods but, judging by the volcanoes Sheveluch, Ebeko and others, eruptive acts are relatively short-lived. The products of their eruptions, *after complete cooling*,* are predominantly fresh, unaltered rocks". She points to the absence in this area of any clear spatial relation between hydrothermal and actual eruptive centres. At Ebeko one of the more extensively studied hydrothermal areas, solid andesites have been and are still being converted to silica rocks and silica-alunite rocks under the influence of ultra-acid waters (Naboko, 1963*a*; Zelenov *et al.*, 1965). As an instance of the acidity of these thermal waters, a small pool was observed in 1959 to contain little beside a 2N HCl solution at 98°C.(Zelenov *et al.*, 1965, p. 145). Judging from the data presented, however, it would seem that SO_4^{2-} usually exceeds Cl^- in the waters (common pH range 0–3) and some are almost chloride-free. Massive andesites are most severely affected in the vicinity of fractures through which the thermal waters pass. Gradations from fresh andesite to extreme hydrothermal products exist in both horizontal and vertical senses. The common sequence of progressive alteration as

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* my italics.

recognized by Naboko (1963*a*, p. 26) is from fresh andesite, through weakly altered ("propylitized") andesite containing secondary hydrothermal chlorite, pyrite, quartz, hydromica and calcite, to quartz-sericite rocks, then quartz-alunite or quartz-dickite rocks and finally to porous quartz rocks in the most altered zone. The similarity to wall-rock alteration in acid media as recognized by economic geologists should be obvious. The final quartzites at Ebeko are evidently residual materials and, indeed, some retain relict igneous textures. In contemporaneous alteration areas the end result is opal rock or opalite; in the older occurrences the material is quartzite—but quartzite with relict andesite texture. Along with SiO_2, titania is the only major oxide persisting in the residua. Evidently in the acid media all the other metals are leached and removed as cations in solution. In addition to pH, redox potential plays a significant part. Relative removal of aluminium and iron is apparently linked to local oxidizing or reducing conditions (Zelenov *et al.,* 1965, p. 149).

The influence of such hydrothermal metamorphism reaches beyond the vicinity of the altered rocks. The Yuriev River, draining part of the Ebeko field, runs a distance of some 3 Km to the Sea of Okhotsk without receiving any major tributary. Near its mouth the flow has been measured at 1·8 m^3./sec. and its pH at 1·72; some 440 mg./litre of Al and 220 mg./litre Fe are carried in solution (Zelenov *et al.,* 1965, p. 162). Simple arithmetic will reveal the immense quantities of these two elements alone carried each day to the sea. On meeting the oceanic water the pH rises sharply and precipitation of Al and Fe as hydroxides follows directly. Zelenov *et al.* have calculated the total volume of altered rocks at Ebeko as 3×10^9 cubic metres and taking present rates of acid generation give a period from 36×10^3 to 50×10^3 years as that necessary to effect neutralization by hydrothermal reactions.

This case has been discussed in some detail not because it is unique (valuable work has also been done on hydrothermal areas in New Zealand and North America) but because it is well-documented and perhaps unfamiliar to many. The particular interest of these hydrothermal studies in the present context is that they afford observable natural mechanisms clearly capable of inducing extreme secondary response in solidified igneous rocks. Furthermore these operations can persist for considerable periods of time and thus provide greater scope for completion of sluggish low-temperature reactions. The Kurilean examples are extreme cases involving ultra-acid waters. Natural thermal waters, indeed, natural waters in general, include not only acid sulphate-chloride types but neutral types rich in alkali chlorides and alkaline solutions with pH 10 or higher containing alkali carbonates, etc. Taken with the obvious variety of sources (connate, meteoric, oceanic, etc waters) the range of possible natural hydrothermal environments is considerable. It is only reasonable, however, to repeat Naboko's (1963*b*) observation that basalt volcanism is not, as a rule, accompanied by such intense gas-hydrothermal activity as is found in andesite terrains. Nonetheless thermal waters are known in basalt fields and those basalts cooled under water in sedimentary environments already exist in hydrous systems. The significant point is that solid basalt material will be as clearly out of equilibrium with natural waters of various types as the andesites mentioned above. In cold water the reactions simply take longer.

One obvious example of basalt-water reaction at low temperatures is that leading to formation of palagonite from basalt glass. The process involves response of solid rock to an aqueous environment in which the controls of solution chemistry apply. These must also extend to conditions of burial metamorphism where temperature and pressure controls on both rock and pore water are related to regional thermal gradients and superincumbent loads. Distinction between burial metamorphism and more restricted hydrothermal metamorphism will be made on the basis of particular field relations. By its nature burial metamorphism will have pervasive effects. Materials closely associated spatially in a geosynclinal pile will all tend to show evidence of adjustment to locally-prevailing conditions.

Thus sedimentary rocks containing abundant local igneous detritus acquire authigenic phases in accord with those produced in the associated igneous bodies (Vallance, 1965). R. E. Smith has recognized such authigenic relations in lavas and sediments at Cliefden. Donnelly (1966) in his account of a spilite-bearing geosynclinal pile in the Virgin Islands indicates the presence of similar authigenic phases in both sediments and spilites. He has proposed an autometamorphic origin for the spilites but from his own account some regional control such as burial metamorphism seems far more probable. Consistent zonal patterns of regional extent are to be expected from burial metamorphism and, in fact, since Coombs' (1954) pioneering work in New Zealand these have recognized across the world.

Hydrous Degradation of Basalt. Secondary adjustment of solid basalt involves production of hydrous phases in place of the original high-temperature phases but it should be apparent that minerals like chlorite, epidote, pumpellyite and so on, are not simple hydration-equivalents of primary igneous materials. Take the case of a pillow selvedge now consisting largely of chlorite. There is, I believe, a high probability this chlorite replaced glass and, further, that this glass was originally basaltic. The reaction basalt glass → chlorite cannot be a simple case of devitrification-hydration for the operation requires removal of components like CaO, Na_2O, TiO_2, etc., as well as a significant amount of SiO_2 (Vallance, 1965). The decomposition reaction involves hydrolysis, H^+ being received from the available fluid phase and cations, chemically equivalent in amount, going into solution (Hemley and Jones, 1964). These authors propose the name hydrogen ion metasomatism to cover this type of process. In cases of hydrolysis we can distinguish a relatively insoluble hydrolysed residue from solutions enriched in displaced ions. During hydrolysis silicates bearing a number of different cations will normally yield these to solution at different rates. A general result of silicate hydrolysis will be a decrease in the acidity (or increase in pH) of the solution simply because the common silicates are, in effect salts of strong bases and weak ("silicic") acids. Keller and Reesman's (1963) experiments on abrasion of basalt in distilled water gave pH results to 9·5.

Although admittedly a gross over-simplification of natural conditions, a plot such as that in Figure 5 has some value to our present discussion. These data are, strictly, applicable only to cases where Al, Fe, or Mg exist in simple hydrous solution at equilibrium with their respective hydroxides at 25°C. No account is taken of the effects of additional materials, either solid or in solution. The broad pattern nevertheless is useful as a guide. We see, for instance, the basis for the efficiency of the ultra-acid waters at Ebeko. Divalent iron and magnesium may be expected to be reasonably soluble in all but rather alkaline media. Very little Al exists in solution at equilibrium with its hydroxide over an appreciable intermediate pH range and this accords with inferred immobility of Al in many hydrous systems. The relevance of redox potential should be apparent in the contrasts between the behaviour of iron at equilibrium with, respectively, its divalent and trivalent hydroxides. The other major elements of basaltic rocks are not plotted; several of them (Na, K, Ca) form relatively highly dissociated hydroxides in low temperature aqueous solutions.

Qualitative extrapolation to the response of igneous silicate phases in aqueous media leads to expected variety related to the availability of hydrogen ions. Patterns of cation loss from solid phases in alkaline media will be very different from those in acid media. Under alkaline conditions, for instance, cation loss may be confined largely to Ca and the alkali metals. With redox control as well as pH, possibilities exist for natural separation of magnesium from iron, two elements so closely identified in high-temperature ferromagnesian phases of basalt.

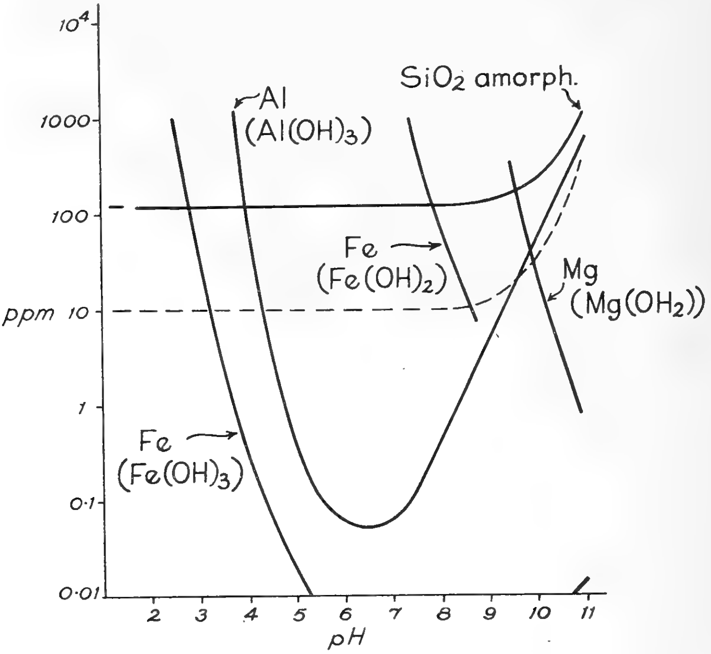

Fig. 5. Plots of total dissolved Al (in parts per million) in equilibrium with $Al(OH)_3$, Fe with amorphous $Fe(OH)_3$, Fe with $Fe(OH)_2$, and Mg with $Mg(OH)_2$, as functions of pH at 25°C. The dashed line indicates dissolved SiO_2 with quartz. Based on data from Krauskopf (1967).

Nature is not quite so delightfully simple. Redox potential and pH are both temperature-influenced and, as well, they can be restricted by buffer reactions. The predominating anions present in solutions and possible complex-formation will also contribute to particular patterns of solution and distribution of components in aqueous environments. Based on both theoretical and experimental studies (e.g. Garrels and Christ, 1965), this field of solution geochemistry has expanded rapidly in recent years. As yet, the major applications have been with sedimentary materials, low-temperature syngenetic ore deposition and problems of wall-rock alteration (Lovering, 1950; Hemley and Jones, 1964). Its extension to the study of basic rock alteration, though logical, is presently hampered by the few data available to complement petrographic observations. A wider recognition of the significance of solution geochemistry in petrological studies is greatly needed.

Aware, at least, of the broad possibilities offered by adjustment of solids in aqueous media let us return to basic rocks. Degradation of basalt to clays through atmospheric humid weathering needs no particular emphasis though we can learn much of value because the operation is observable. Basalts do not alter to spilites at the surface or, at least, the process is not operative now. Of volcanic materials glass is the most obviously unstable at low temperatures. The particular instability of glass is manifested in its spontaneous tendency to crystallize. Availability of water first serves to promote the adjustment by breaking Si-O-Si bridges in the glass. Basaltic glasses have relatively fewer such network-forming bonds than acid glasses and hence may be expected to be especially responsive to hydrous conditions (Marshall, 1961).

The best known instances of basic glass adjustments are those by which palagonite is formed. Such conversion of basalt glass has been reported from the deep oceans and from nearer surface occurrences, as for instance in Iceland (Tyrrell and Peacock, 1926) where palagonite may be associated with hot-spring activity. In all cases palagonitization of glass appears to be entirely a post-eruptive process. Some of the Iceland palagonite is perfectly isotropic structureless material ("gel-palagonite"), some is obscurely fibrous; the final product according to Peacock is a chlorite-zeolite mixture.

Recently, Hay and Iijima (1968) have provided valuable data on palagonite derived from basalt glass in tuffs on Oahu, Hawaiian Islands. Even their isotropic, gel-palagonite gives weak X-ray diffractometer peaks for poorly crystalline montmorillonite; the common authigenic phases throughout the tuffs include zeolites, opal, calcite and montmorillonite. Despite this authigenic mineral generation, original crystalline phases (olivine, pyroxene, Ca-plagioclase) tend to remain unaltered.

Recent work on hydrothermal aging of aluminosilicate gels indicates preferential stabilization of four-fold co-ordinated Al atoms under alkaline conditions (de Kimpe, 1967). The genesis of palagonite seems to confirm this in the formation of montmorillonite and zeolites. Hay and Iijima point to the marked response of natural glass to water at pH 9 or higher. As hydrolysis proceeds, both pH and salinity of water tend to rise to a critical level for rapid reaction, most of the SiO_2, Al_2O_3, K_2O and much of the CaO and Na_2O released from the glass being precipitated nearby to form zeolitic cement. The particular zeolite formed at a given time and position will be determined by such factors as the thermodynamic concentrations (activities) of the various ions and SiO_2 in solution.

Palagonitization then leads to formation of a montmorillonitic residuum, the leached cations being precipitated locally (and forming in some cases other montmorillonites) or lost into the circulating water. Montmorillonites of the beidellite, nontronite and saponite series have all been recognized in altered basic rocks both as residue materials and as precipitates. The high ferric content of some palagonites lends support to the idea of nontronite being present and indeed this clay has been identified in many cases. Oxidation of iron is readily achieved in alkaline media and this can lead to residual iron-enrichment and perhaps some Mg loss to solution. The magnesian montmorillonite saponite may also occur as residue but is perhaps more common as precipitate. Miyamoto (1957) reports an iron-bearing saponite as both cavity-filling and as a direct replacement of glass in altered basalt and tuff.

Peacock's remark (Tyrrell and Peacock, 1926) on the eventual formation of chlorite + zeolite from palagonite is of particular interest. It will be remembered that the chlorite structure consists of regularly arranged talc-like and brucite-like sheets and, further, that the structure of talc is closely related to that of tri-octahedral montmorillonites like saponite. Caillere and

Henin (1949) succeeded in precipitating $Mg(OH)_2$ between the sheets of a montmorillonite to produce a pseudo-chlorite. Mixed-layer montmorillonite-chlorites have been reported in a number of altered basic glasses.

Various altered Cretaceous glassy tuffs at Mount Carmel, Israel, contain either mixed-layer clay-chlorites with montmorillonite or mixtures of different montmorillonites (smectites) such as saponite + a beidellite-nontronite (Singer, 1967). Indeed it seems highly probable that most palagonites contain more than one montmorillonite or mixed-layer phase. The compositions of the so-called palagonitic chlorites described by Gonshakova (1956) are suggestive of mixtures. An interesting case is offered by Ball (1966). Fragments retaining textural features of palagonite occur in Ordovician basic pumice tuffs of North Wales; these fragments now consist of the chlorite diabantite. Jurassic palagonites in Jamaica consist largely of chlorite with analcime cement (Raw, 1943). The analcime is now partly replaced by albite which also occupies plagioclase phenocryst positions in the rock.

Data from Hay and Iijima (1968) for their sideromelane-palagonite pairs are plotted in Figure 6 along with data for some other palagonites, montmorillonites from basic rocks and the few available spilitic chlorites. Corresponding plots for spilites and spilitic pillows appear in Figures 2 and 3. Two contrasted patterns of total FeO/MgO variety exists for the glass-palagonite pairs. Some pairs show little change in this ratio, other palagonites are notably richer in iron relative to magnesium than their parent glasses. Both patterns can be related to various smectites in which Ca^{2+} is an important exchangeable base or to smectites plus zeolites. No such relation to parent material can be established for the spilites though overlap with the field of basalt compositions is evident. Variation in total FeO/MgO is far more restricted for the spilites than for the smaller sample of palagonites. Only two of the pillows show enhanced marginal iron content and in both this is related to the presence of haematite not an iron-rich layer silicate. The main variety in total FeO/MgO in the spilites matches that found in the few analysed spilitic chlorites.

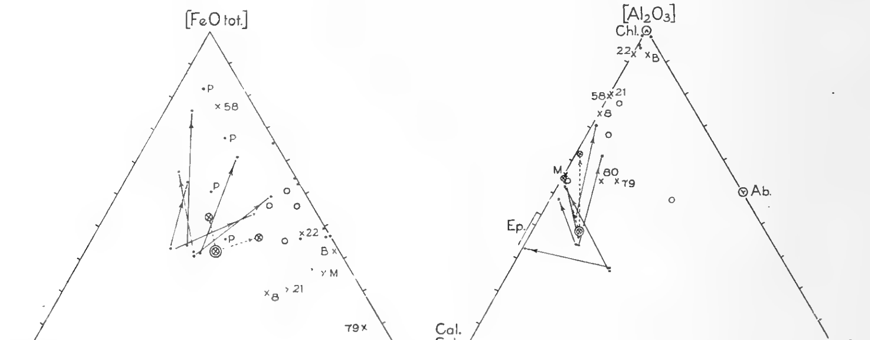

Fig. 6. Plots of FeO (tot.): MgO: CaO and Al_2O_3: Na_2O: CaO (both mol. props.) for selected basalt glasses, palagonites, clays and chlorites.

Key: dots joined by arrows—glass/palagonite pairs (Hay and Iijima, 1968), the arrows pointing to palagonite. Dots marked P—palagonites (Allen and Scheid, *Amer. Miner.*, 31 (1946): 302). Dots unmarked—chlorites from spilitic rocks (Kepezhinskas, 1965; Vallance, unpubl. data). Circles—palagonite chlorites (Gon'shakova, 1956). Circled crosses—basalt and clay alteration products (Singer, 1967). Crosses—B (Ball, 1966), M (Miyamoto, 1957), with numerals (Ross & Hendricks, 1945, Table 1)—clay chlorite and montmorillonites derived from mafic igneous rocks.

Palagonitization of glass particles, according to Hay and Iijima's (1968) data involves loss of all oxides except TiO_2. The situation with iron oxides is uncertain because iron is returned as total oxide. One may guess that the small loss registered for Fe_2O_3 combines a considerable diminution of FeO not quite compensated for by increased Fe_2O_3. Such appears to be the case with the Iceland palagonite (Tyrrell and Peacock, 1926, p. 66). Formation of montmorillonites from glass commonly involves fixation of less Al than was originally present. The extra Al appears to be precipitated mainly in zeolites and as these commonly occupy cavity positions it is evident Al is transferrable during palagonitization.

What might be a comparable relation between basalt glass and chloritic pillow selvedges (Table 4) implies loss of SiO_2, CaO and Na_2O and gains for the other oxides or perhaps neither appreciable gain nor loss for Al_2O_3. Only loss of CaO is truly common to both palagonites and the selvedges. The deep sea palagonite from the "Challenger" collection is rich in both Na_2O and K_2O (present in phillipsite?). In terms of a model whereby chloritic selvedges formed from glass via an intervening palagonite-like montmorillonite stage one can see a number of difficulties. Spilitic chlorites are much less characterized by ferric iron and carry greater amounts of aluminium (especially tetrahedral Al) than the common montmorillonites formed from basic glass. Furthermore, there is no evidence of the Al in the chlorites of spilitic rocks being supplied by reaction, say, of montmorillonites and zeolites.

Recent palagonites offer clear evidence of the response of basic glass to a hydrous medium the pH of which is increased by hydrolysis of the glass. In the higher pH range separation of iron from magnesium can be effected by redox control. The presence of CO_2 dissolved in the water could also lead to differences in response of Mg and Fe by pH adjustment (cf. Keller and Reesman, 1963). Significant amounts of Al are transferrable at least locally either in solution or as colloid. Far greater dispersal is possible for Ca and the alkalis. Under palagonitization much of the Al and some Si, Ca, Na, and K may be precipitated in zeolites. With chloritic spilites there is little sign of removal of Al from glass or of oxidation of divalent iron. Clearly a good deal of reconstitution would be required if these rocks passed through a palagonite stage. The Jamaican examples show that chlorite + albite can result from palagonitization. One may be tempted to speculate on deriving spilitic chlorite from some appropriate mixture of Fe-bearing saponite and beidellite but clear evidence is lacking. The reaction basic glass → chlorite could well be direct in spilitic alteration.

Spilites as Degraded Basalts

The relevance of water chemistry to palagonitization is obvious. Despite the differences just noted the analogy between chloritic spilites and palagonites seems sufficiently close to merit further enquiry. Indeed some of the differences are predictable. For one thing palagonite forms under what must be regarded as relatively exposed situations whereas commonly spilitic materials occur in geosynclinal piles. In the latter volcanic bodies would tend to be covered more or less promptly. Even glass might be buried before reaction with water had advanced far. Progressive consolidation consequent on burial serves to reduce porosity and permeability. Alteration proceeding in an environment of more restricted circulation of pore water would reflect this situation. Silica contents in water will tend to be greater there than in more freely circulating water associated with similar glass in, say, a near-surface terrestrial environment. Redox conditions may also be different in spilitic alteration. A common (though not exclusive) feature of spilite occurrences is an association, as at Nundle, with black siliceous sediments, presumably once muds rich in organic remains. The possibility of hydrous alteration of basalt being effected under alkaline reducing conditions cannot be ignored.

In attempting to reconstruct the story of spilite formation we return to the relatively simple model of a pillow with chloritic selvedge. It is to be expected that marginal parts of a pillow will be the first to react with available fluid. Further this response should be reasonably prompt in view of the glassy nature of selvedges. Formation of the marginal residuum from glass is accompanied by loss of other components. As the glass hydrolyses, the associated water gains, for instance, SiO_2, Ca^{2+} and Na^+. This will hold whether chlorite forms directly or through some intermediate montmorillonite stage. The low solubility of titanium leads to formation of "sphene" (the brown earthy materials commonly may be mixtures but X-ray characters for sphene are found in some examples) in the residuum here and this serves to fix some Ca. In acid media, an oxide phase such as anatase might be expected instead. No evidence has been found of the orthorhombic Na-Ti-silicate ramsayite which Sahama (1946, p. 108) thought might occur in spilitic rocks. It appears to be confined to a few primary Na-rich igneous rocks; it is unknown in hydrolysis. Enrichment of Ti to the extent found in the Rudha Cuillin pillow (Table 3) is exceptional. Such a case seems to require transfer of Ti for its accumulation to a level beyond that of normal residual enrichment. Though conditions for significant solution of Ti are extremely limited and likely to be unusual in nature the possibility of colloidal transfer must be recognized. The occurrence of crescentic patches of sphene in banded aggregates of chlorite at Mullion Island (Vallance, 1965, pp. 475-6) suggests an intermediate colloidal state.

As we have seen there is little evidence of extensive zeolite formation in spilitic bodies though the occurrence of phases like prehnite in cement and even authigenic albite not on original feldspar sites may in some cases be related to earlier zeolite. I am inclined to think zeolites played no major role in many spilites. There is certainly little to suggest their appearance as replacements of primary crystalline phases. It is envisaged that in a medium with restricted circulation concentration of SiO_2 may rise at least nearer saturation levels than in freely circulating waters; silica in colloidal suspension is not precluded. Silica yield to the fluid during hydrolysis of glass is taken to be of an order with the solubility of amorphous silica (Figure 5) and it will be remembered that increase in temperature from 25°C. to 100°C. involves an increase in that solubility by a factor rather greater than 2 (Krauskopf, 1967, p. 210). Higher silica activities in the fluid phase would favour stabilization of albite in place of zeolites at even relatively low temperatures. Such appears to be the case in parts of the Green River Formation of Wyoming (Hay, 1966).

Initial reaction of the glass must tend to increase pH and salinity of the water and as hydrolysis proceeds cracking induced by any volume change would enhance access of water to more crystallized parts of a pillow, perhaps already locally vulnerable by way of igneous cooling cracks. Access of the alkaline, saline water to the core continues and extends the alteration process.

As a simple case we assume an original core composed of Ca-plagioclase, clinopyroxene and interstitial glass. The glass will respond much as the selvedge material though slight differences (as yet unidentified) may exist reflecting the already-modified water chemistry. Hydrolysis of the glass again yields SiO_2, Ca^{2+} and Na^+ to the fluid. In this context the crystalline igneous phases are generally open to attack.

Replacement of Ca-plagioclase by albite is one evident result. Here the operation must be ionic exchange of Na for Ca, the valency requirements being met by appropriate substitution of Si for Al. There is no evidence here of any but direct replacement for albites on primary Ca-plagioclase sites occur as pseudomorphs, even to the extent of inheriting twinning characters. The obvious preference of albite for original sites must reflect a greater ease in adapting pre-existent feldspar lattices to equilibrium with the aqueous Na^+—higher $a SiO_2$ conditions by ionic exchange than in generating albite in new positions. Restriction to old sites is not, however, exclusive; albite may appear in cavities or veins or as scattered grains lacking any similarity in habit to basaltic felspars. Thus in the selvedge of a pillow from Lake Benna, Norway, albite is found as stumpy euhedra reminiscent in shape of some authigenic albites in sediments. Nonetheless a dominating relation of albite to primary sites is characteristic of spilites. It is intriguing to note that the mean value for Na_2O in spilites (Table 1) corresponds to about 36% modal feldspar. If all Na_2O in Nockolds' (1954) average tholeiite were present in An_{60} (and, of course, it is not) we should expect some 42% modal plagioclase. There is a broad similarity between modal feldspar contents of basalts and spilites. Modal feldspar is quite variable in basalt; variations in both the albite content and Na_2O of spilites should not be unexpected.

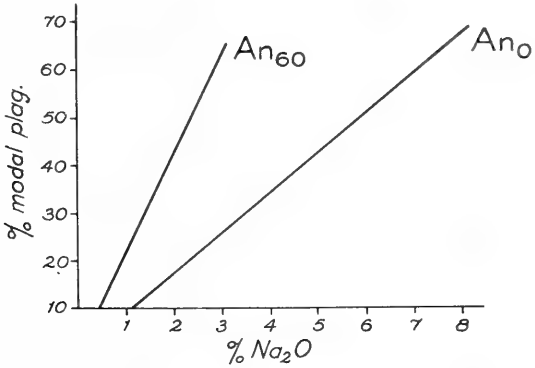

Fig. 7. Relations of wt% Na_2O against vol% modal feldspar (An_{60} and An_0) for comparison of soda contents of basalts and spilites.

The silica contents of spilitic pillow cores are similar to those of basalts and, indeed, little or no silica need be added to a core to satisfy stoichiometric requirements of the change Ca-plagioclase → albite. For instance, 10–15% of modal interstitial glass of basaltic composition would yield, on its conversion to a chlorite with 26% (wt.) SiO_2, sufficient silica for the needs of 40% modal An_{50} being converted to albite.

Whereas there is no evidence of ultimate gain or loss of silica in pillow cores the situation is less simple for other components. For one thing, the amount of glass that could supply silica to meet the needs of albite replacement of Ca-plagioclase would not yield sufficient sodium for the conversion. A source of Na outside the core is required. Here the situation is ambiguous. In some cases calculated bulk compositions suggest the sodium for albite could be derived from the body as a whole. Thus a pillow margin commonly carries little albite following alteration and the Na^+ displaced to solution during hydrolysis may suffice for albitization in the core. The Nundle pillow (Vallance, 1960, Table 3) appears to be such an example. However, my confidence in the adequacy of internal sodium economy (Vallance, 1965) was probably misplaced. Simple internal redistribution fits the bill in some cases; it seems to be far from general. The pillows listed in Tables 3 and 4 display enhanced soda contents relative to those of basalt. Smith's (1968) calculated bulk for the non-pillowy Cliefden spilite also shows rather higher Na_2O. There seems no escaping the view that for many spilites an additional, external supply of sodium is essential. Doubtless the agency for transfer is water and two possible external sources of sodium come to mind. Alteration of igneous material, such as glass shards, in sediments associated with the lavas could be a useful source but a more obvious supply exists where the pore water is of marine origin.

Replacement of Ca-plagioclase by albite releases Al and Ca. As with silica we see no clear sign of alumina contents of cores changing markedly from those of basalts. Yet the clarity and freedom from inclusions of many spilitic albites require removal of Al (and Ca) if these feldspars formed by replacement as the weight of evidence suggests. Transfer of aluminium must be effected either in solution or colloidal suspension or a combination of both. The removed Al, in any case, is precipitated close by. There appear to be a number of destinations, mostly silicates such as chlorite and, less commonly feldspar or hydromica (alkaline pH and higher $a SiO_2$ probably favour feldspar) or a Ca-bearing silicate like epidote. The feldspar in some cases is potassic; K-feldspar, in fact, becomes a major phase in some spilites. The distribution of potassium in spilitic pillows is highly irregular and not always predictable though the association of potassium with more oxidized ferric ion-rich materials appears to be common.

Fixing of Al in a Ca-bearing silicate phase may be related to low activity of CO_2. Inverse relations between calcite and hydrous Ca-Al silicates characterize many hydrothermal and burial metamorphic environments. Donnelly (1962) remarked on the distinctive distributions of wairakite and calcite in his West Indian spilites. Far commoner are the inverse relations of carbonate to epidote or pumpellyite. The presence of substantial carbonate or bicarbonate in solution will tend to act against formation of Ca-bearing silicates. In hydrous alteration of basic rocks activity of CO_2 perhaps only rarely becomes high relative to that of water but nevertheless may serve to control distribution of Ca. I suspect, too, it has an important influence on the metastable persistence of clinopyroxenes. An inverse relation between pyroxene and calcite certainly seems to exist. On the other hand, association of pyroxene with epidote or pumpellyite is by no means exceptional. In carbonated media, pyroxene may be expected to yield its Ca and some silica to the fluid leaving a chloritic residuum (or in an extreme case, be replaced by carbonate). In the formation of the chlorite the Al displaced from plagioclase during albitization could well play a part.

Whether the Ca^{2+} taken into solution is precipitated locally as carbonate or is carried away presumably depends on the CO_2 control. In general higher pCO_2 will favour solution. Where carbonate is deposited locally it usually occurs as cavity fillings though it may also form as a replacement material. Splendid examples of carbonate-chlorite pillow selvedges exist in the Fortescue River area of Western Australia and some of the pillows described by Narebski (1964) must be similar. One can expect also in nature cases where carbonate control is capable of limiting pH to a level where significant solution of Mg, for instance, may occur. The existence of Mg-bearing carbonates (and even Fe carbonates) in altered basic rocks is to be expected. At this stage it is difficult to define closely the influence of CO_2 control in spilitic alteration. Qualitatively the situation seems to be as outlined.

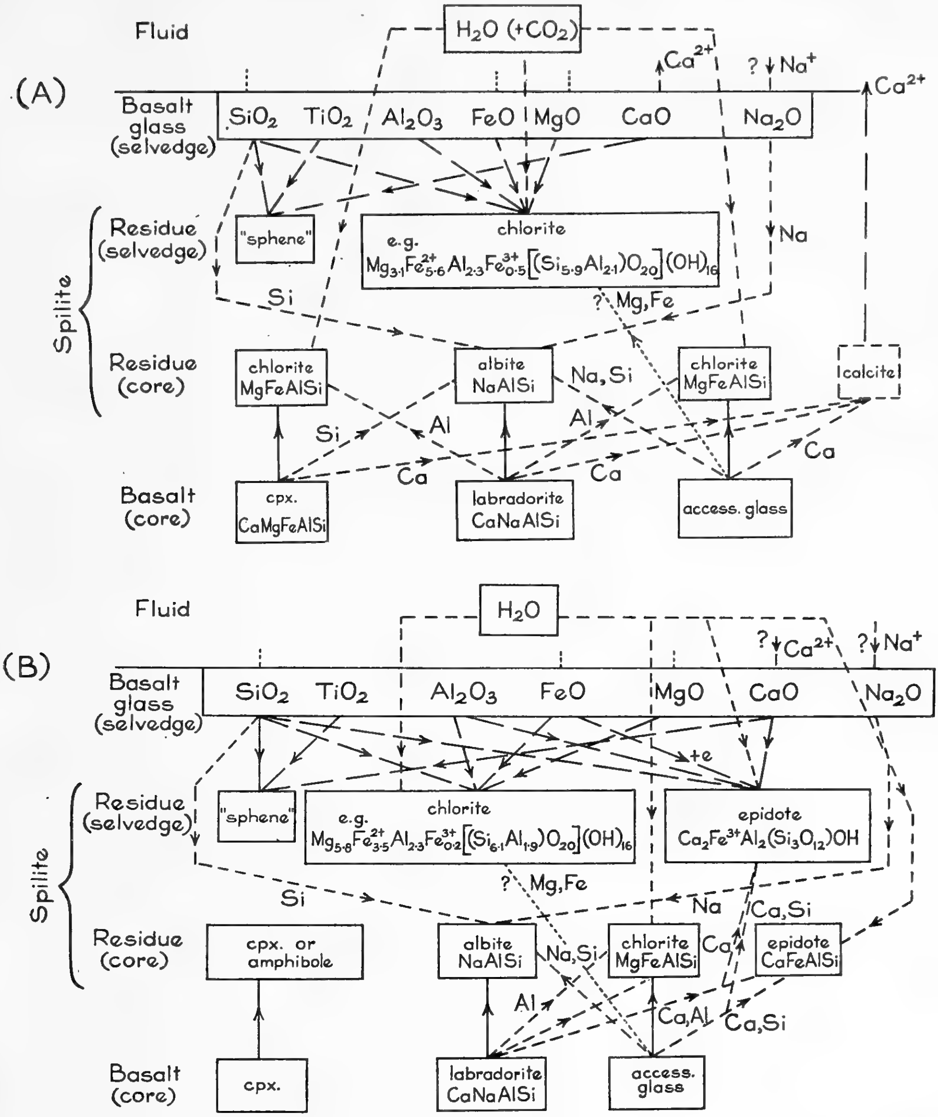

Fig. 8. Schemes of inferred adjustments during conversion to spilite of an idealized basaltic pillow (glass selvedge and mainly crystallized core). (A)—a case where aCO_2 is significant. (B)—a case where aCO_2 is negligible. pH is expected to be in the range about 7 to 9–10.

The postulated exchanges and redistribution patterns for two different types of spilitic pillows are summarized in Figure 8. These schemes should be taken as representations of overall adjustments; contemporaneity of all operations is not implied. The first outlines the common case of marginal chlorite-enrichment with general loss of Ca. Apart from the requirement of a somewhat alkaline medium and either initial low redox potential or subsequent adjustment as might be imposed by, say, sulphide-sulphate equilibria, a significant role is attributed to CO_2 in this system. The chlorite composition quoted as an example is based on that given by Battey (1956) for what may be an appropriate case.

The second example (Figure 8B) may be taken as the situation where calcium is accumulated in a silicate phase. Here it is envisaged that carbonate influence is relatively diminished. The course of mineral generation in this second type is somewhat ambiguous. It cannot, for instance, be assumed that epidote in the Ca-rich selvedge formed along with chlorite as hydrolytic residuum. Indeed, where non-carbonate Ca-rich selvedges occur it is not uncommon to find signs of epidote postdating chlorite. Thus in a carbonate-poor breccia at Nundle, small compact chloritized glass fragments have their margins infested with epidote.

Both types of contrasted selvedge patterns (chlorite-rich and chlorite-epidote-rich) may have been initiated in the same way, by formation of residual chloritic material. Early transfer of Ca from glass to solution is likely regardless of the influence of carbonate. The subsequent behaviour of Ca in solution is a different matter. Epidote in non-carbonate Ca-rich selvedges occurs commonly as clusters of granules associated with cracks within chloritic aggregates. Examples of epidote-replacement in massive spilites are even more obviously related to positions of easy fluid access. In both it seems reasonable to infer initial solution of Ca, subsequent precipitation as silicate being permitted by the low-carbonate environment. The common persistence of pyroxenes in such materials suggests maintenance of early low-carbonate conditions.

Externally-derived Ca^{2+} in solution is an obvious source for the replacing epidote found in sediments of the Salton Sea geothermal area (Keith *et al.*, 1968) but even in locally Ca-rich spilitic bodies there may be less need to seek outside supplies of calcium. In the bulk compositions of neither the Nundle nor the Porth yr Halen pillows is there evidence of overall Ca-content beyond that normally found in basalts. If epidote-rich selvedges represent possible subsequent adjustments of initially chloritic residua one may reasonably expect growth of epidote would involve reaction response in the chlorite. One predictable consequence of the generation of epidote would be adjustment to greater Mg relative to iron in the co-existing chlorite compared with chlorite of essentially monomineralic selvedges. Clearly more data are needed here; the few plotted in Figure 9 suggest some latitude in Mg/Fe of chlorites found with epidote though this latter very commonly approximates a composition with $\frac{1}{3}$ Al positions replaced by Fe^{3+} in these rocks (cf. Miyashiro and Seki, 1958).

The variety we have been discussing exists also in non-pillowy spilites. Our pillow models are representative not exclusive. Extension of the postulated schemes of hydrous degradation to more massive bodies is complicated by the less predictable distribution of contrasted primary igneous features. Again, those parts of such bodies initially exposed to reaction with water may be less glassy than pillow surfaces. The limiting case would be that of an entirely crystallized basalt though such is unlikely to be general in subaqueous flows. Probably most massive spilitic rocks originally carried at least accessory glass. Less glassy basalts will be expected to respond more slowly to hydrous environments and, indeed, such materials in a geosynclinal context could be buried to a significant degree before reaction is advanced. However, there is no reason to regard the operation of hydrous adjustments in massive rocks as different in essential character from the reactions postulated for alteration of pillows. Even where glass is of relatively minor abundance in a particular body alkaline fluid character may still prevail from an early stage, especially where pore water is of marine origin or associated fragmental materials are rich in glass. It will be recalled from the discussion of adjustments in pillow cores that replacement reactions require little material contribution from adjacent selvedges. If massive spilites began as basalts we should expect stoichiometric sufficiency of SiO_2 and Al_2O_3 (cf. Table 1 and Figure 1) for replacement of Ca-plagioclase by albite. But the need to seek an external supply of Na is likely to be even greater here than in the case of spilitic pillows. In offering associated fragmental material and/or marine water as competent sources one is merely emphasizing the relevance of total environment to spilitic alteration.

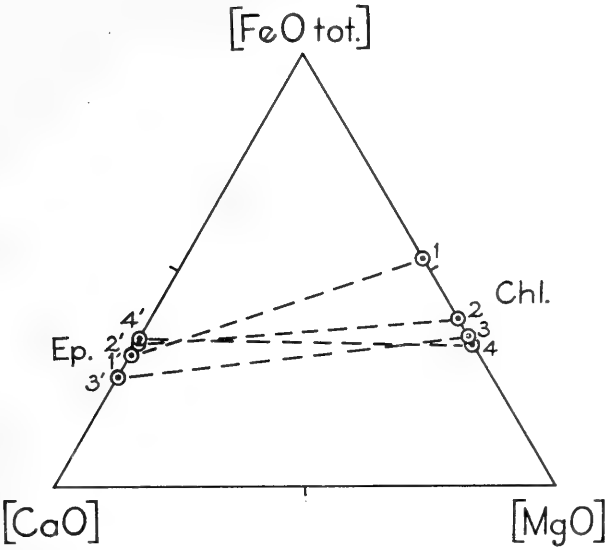

Fig. 9. Plots of FeO (tot.): MgO: CaO (mol. props.) for co-existing chlorites and epidotes in low grade metamorphic environments (cf. Figures 2 and 4).

1–1′ Pillow lava, An Aird, Tayvallich Peninsula, Argyllshire, Scotland. (Vallance, 1965; unpubl. data).

2–2′ Pillow lava, Lake Benna, Trondhjem district, Norway. (Vallance, unpubl. data).

3–3′ Metamorphosed mafic rock (greenstone), Atlantic Ocean. (Melson and Van Andel, 1966). Compositions approximate only.

4–4′ Epidotized metasediment, Salton Sea area, California. (Keith *et al.*, 1968) Chlorite composition approximate.

Figure 10 may serve to summarize part of the relation for massive spilites at Nundle. The join An_{60} -*aug* crossing the basalt field is based on analytical data for pyroxenes and some evidence from relic feldspars. It can be taken as a clue to original composition. The 17 rocks plotted mostly fall away from the join and from [CaO] towards *albite*. Local loss of Ca is at least as characteristic of this association as accumulation of Na. But whereas distribution of the latter is largely pre-determined by favourable sites for albite, Ca may pass in solution beyond a particular spilitic mass to be precipitated there or dispersed or it may be redeposited within the body, depending on local circumstances. The spilitic association at Nundle is characterized by development in sedimentary rocks with appropriate compositions of authigenic phases similar to those observed in the originally-igneous bodies. Furthermore regional study, chiefly by Crook (Packham and Crook, 1960), indicates the position of these materials in a zonable burial metamorphic situation. With increasing depth in the sedimentary succession above the spilites Ca-zeolites progressively take over from Na-zeolites. These spilites must surely have passed through the physical range of the zeolite field yet there is now no trace of former zeolite. Of course, it may have been entirely reconstituted (say to Ca-Al silicates like prehnite plus albite) or, as seems likely, its original formation was precluded by water chemistry.

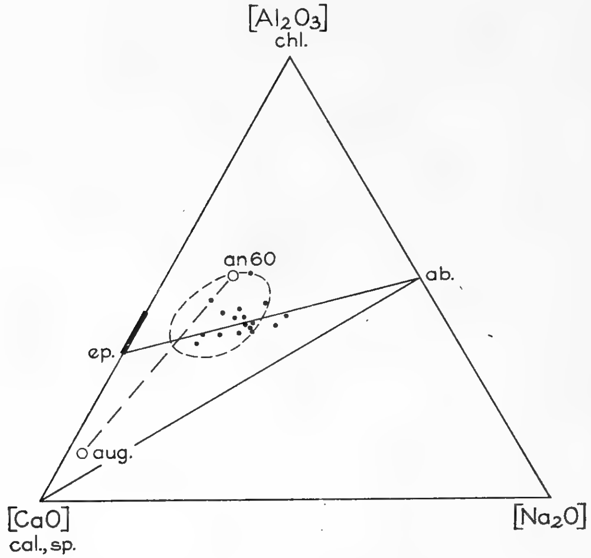

Fig. 10. Plots of Al_2O_3: Na_2O: CaO (mol. props.) for massive spilitic rocks from Nundle, N.S.W. For explanation see text and cf. Fig. 3.

Despite claims that some spilitic rocks are primary magmatic products I know of no case where a primary origin is exclusively demanded by the evidence available. Various details adduced to favour such an origin are equally capable of other interpretations. Some of the difficulties encountered by the primary model have been outlined earlier (pp. 19–21). Among these we saw how chemical compositions of spilites deviate from those of recognized magmatic rocks (cf. Shteinberg, 1964, pp. 81–87).

Trace-element compositions have also been claimed to support late-magmatic causes for spilites. Thus Amstutz (1953), remarking on the presence of Li and Sc in Swiss spilites, pointed to the fact that these elements may be enriched in late-magmatic fractions. The considerable Zr content in some of these rocks remained a puzzle. Reference to Table 3 will show that, in fact, trace compositions in spilitic pillows can be as diverse as major element compositions. Concentration of a given trace is related to major element chemistry of the particular phases present. As one example, there is notable content of Y and La in the Ti-rich (sphene-bearing) selvedge from Rudha Cuillin as well as considerable Zr. In a set of 12 diverse pillows for which Ga, V, Li, Co, Ni, Cr, Sc, Zr, Y, Sr, Ba, and Rb are known, only values for Cr, Ni, Sr and Rb fall entirely within the ranges noted by Prinz (1968) as found in basalts. Non-pillowy spilites analysed have only slightly less trace variety than the pillows. Enrichment of traces in spilites relative to basalts is not necessarily linked to late-magmatic operations. It is surely no accident that the traces apparently enhanced in spilites are also found in low-temperature environments such as those of diagenesis. Elements like Ga, Sc the rare earths, Zr, V, and Y are typical of sedimentary hydrolysates—a relation first emphasized by Goldschmidt (cf. Mason, 1966, p. 163). The accumulation of Li in the clay hectorite shows there is no necessary connection between Li and late-magmatic fractions.

Apart from those (rare) spilites found in intrusions sufficiently insulated to have cooled slowly and perhaps those within exceptionally thick flows, we can expect spilites to be not only secondary but post-magmatic secondary products, the particular causes of their formation being inherent in the environment. Whether the controls are local as in common hydrothermal metamorphism or more widespread as in burial metamorphism, all materials associated at a given position will be influenced (and, in turn, influence). The context of a once-effusive spilite is not confined to the body itself.

Too often spilites have been considered as narrowly distinctive and special. Their mineralogy and chemistry are too diverse to justify close, restrictive definition. Rocks rich in albite, in albite and chlorite, in chlorite, in chlorite and epidote, and so forth exist in close proximity and are essentially interrelated in terms of origin. It is ignoring nature to extract just one of the variants, give it a special name and dismiss the rest. As I see it, spilite should be used, if at all, to include all the variants found in association and derived from a common parent. We might then talk of *albite-rich spilites, albite-chlorite spilites, chlorite spilites, chlorite-epidote spilites,* etc. This runs counter to a common use of the term but in 150 years spilite has wandered away, by so-called refinement and redefinition, from Brongniart's original. Without wishing to urge a resurrection, one sees some historical sense in returning to a general, group-type status for spilite rather than continue with the notion of necessary albite-richness which is, after all, an accretion of the present century.

What all these various sorts of spilites share is a common history of adjustment to particular hydrous conditions. Present contrasts in mineralogy and chemistry reflect differences in original fabrics and variations in access of and response to hydrous fluids. We have a rock association that may be identified under the name spilite because reaction of solid basalt with water commonly leads to a certain range of pH and hydrolytic exchange. Alkalinity is a general consequence of silicate hydrolysis and where the aqueous medium is of marine origin a slightly alkaline character exists from the beginning of reaction. Stabilization of albite in preference to zeolites is taken to be a consequence of particular water chemistry at low temperatures; at higher temperatures the stability field of zeolites could be exceeded. In many cases there would also appear to be need of low redox conditions during spilitic alteration though it is not hard to find exceptions (such as albite-haematite spilites) to this. Perhaps the simplest way in which to judge the particular restriction of spilitization is to contrast spilitic products with the materials formed where solid basalt is exposed to waters of distinctly lower (acid) pH. Thus in many wall-rock alteration environments influenced by acid waters we find highly aluminous residua, low in magnesium, in iron, in calcium and so forth. Such are to be found among the miscellaneous collection of rocks called greenstones.

It is impossible at present to specify close limits for the temperature and pressure controls in spilitic alteration. The absence of any present formation of spilites at surface temperatures and pressures suggests a need of conditions in excess of 25°C. and 1 atmosphere. Yoder (1967) places spilite formation in the solidus range below 600°C. at 2–10 Kb water pressure (total pressure) but that gives plenty of latitude. Experimental studies and natural investigations suggest stabilization of epidote at rather variable temperatures and pressures. Conditions for laboratory synthesis of epidote do not offer useful detail as to its lower stability range. In hot spring systems White and Sigvaldason (1962) indicate epidote occurrences at from 140°C. at 750 metres to 240°C. at just over 400 metres depth. Temperatures above 300°C. and depths in excess of 900 metres are apparently required for formation of hydrothermal epidote in the Salton Sea area (Keith *et al.,* 1968). The stability of Fe-Mg-Al chlorites at lower temperatures and pressures is even less known. The mineral associations found in spilites are those typically attributed to the greenschist or prehnite-pumpellyite facies of metamorphism. But the relevance of enhanced $a\mathrm{SiO_2}$ (and, in some cases, $a\mathrm{CO_2}$) during basalt degradation could be in suppression of phases taken to be characteristic of zeolite facies (cf. Zen, 1961). Spilites might well represent adjustments under PT conditions ranging across those of diagenesis/zeolite facies to greenschist facies. We may expect local hydrothermal spilitization to be effective, as a rule, under lower pressures than could obtain in burial metamorphic situations. In both, the expected temperature range would be of the same order, at a guess about 100°C. to 350–400°C.

It could be argued that as low-grade metamorphic rocks spilites should receive a more orthodox metamorphic name, leaving perhaps spilite to what must be the very select few that may have formed by autometamorphism and thus have some tenuous claim for consideration with igneous rocks. There are, however, considerable difficulties in establishing a case for autolysis, especially in geologically old intrusions. In any case the majority of rocks called spilites do not belong to this type. These latter, though strictly metamorphic, retain close fabric analogies with their igneous parents and thus differ from rocks for which specificially metamorphic terminology is established. Perhaps it is only sentiment to urge retention of spilite on such grounds. Nevertheless there does seem to be merit in using the term as a general name for an association of low-grade products derived from basalt or basaltic andesite and retaining igneous fabric characters. These products contain chlorite (apparently in the main pychnochlorite/diabantite but ranging from brunsvigite to clinochlore/penninite in Hey's (1954) system) as the most widespread ferromagnesian phase. Albite, in preference to zeolites, is stabilized in these rocks and distribution of the albite is significantly determined by prior feldspar sites.

In this sense, spilite seems to have more to recommend it than the newer, somewhat related, term propylite. The latter term was first applied to the earliest and most altered lavas in generally andesitic Tertiary successions in the western United States (Richthofen, 1868). More recently it has come to be used for materials containing albite, chlorite, epidote, etc., found near the outer limits of wall-rock alteration zones, especially in mining areas. Economic geologists relate formation of such materials to processes of propylitization. Wall-rock adjustment is commonly connected with the action of waters acidified by oxidation of sulphides and insoluble residua from extreme attack are commonly aluminuous and clay-rich (argillic alteration; Lovering, 1950). From what was seen earlier we can expect reaction with wall-rock to effect neutralization of acid solutions through hydrolysis of silicates, just as happens in some modern hydrothermal fields (p. 25). Near the limits of fluid attack the initially-acid waters could be entirely neutralized providing conditions locally akin to those postulated for spilitic alteration. The occurrence of so-called propylitic assemblages in these circumstances reflects an accident of penetration and modification of water chemistry. Common spilitic alteration is more pervasive than that and far less of an accident.

LATER CONSEQUENCES OF BASALTIC DEGRADATION

Basaltic materials are as susceptible as any other rocks to the influences of higher-grade metamorphism. Many greenschists, amphibolites, pyroxene granulites and amphibole or pyroxene hornfelses are essentially equivalent in bulk chemistry to modern basalts. For these a basaltic parentage is reasonably inferred. However, debate continues over the origin of certain amphibolites—whether they were once igneous or sedimentary (cf. Shaw and Kudo, 1965). Part of this dialogue is based on observed departures of metamorphic compositions from igneous compositions and rather naive assumptions that departures from basalt chemistry in amphibolites imply non-igneous parentage. Where field evidence points to basaltic associations, metamorphic materials compositionally outside the restricted field of modern basalts are usually explained away as products of metasomatism. More interestingly in the present context, these metasomatic changes almost without exception are assumed to have been contemporary with higher-grade metamorphism. Of such is the stuff of traditional belief in metamorphic geology.

We saw earlier that basaltic rocks can acquire contrasted chemical characters through hydrogen ion metasomatism and ionic exchange in low-grade hydrous environments. Patches, practically monomineralic in some cases, exist in close proximity to materials nearer in composition to the parental basalt from which the body as a whole was derived. Depending on local circumstances one finds shifts away from basalt compositions towards those of modal chlorite, or epidote, chlorite-epidote, chlorite-calcite, chlorite-sphene, to mention a few examples. The distinctive trends of compositional variety found in spilitic pillows (Figures 2 and 3; Vallance, 1967*a*, Figure 1a) or in more massive spilites (Smith, 1968, Figure 7) represent certain interrelated tendencies. Thus in one common type of association a relatively aluminous Ca-poor composition (chlorite-rich) co-exists with a Ca-rich Al-poor composition (carbonate-rich). Perhaps the most direct means of assessing departures from normal basalt compositions is through use of normative characters; basalt norms are readily identified. Normative diopside is typical.

Norms of low-grade altered mafic materials include not only basaltic types but others lacking diopside (and containing corundum) and diopsidic types with, for example, larnite + nepheline + (leucite) or wollastonite + haematite + (quartz). Such variety is found in norms of spilitic pillows; among Smith's (1968) array with hypersthene-quartz normative bulk one encounters olivine-corundum and wollastonite-haematite-quartz normative materials. Modal chlorite-rich parts will be corundum normative, modal epidote is equivalent to normative anorthite + wollastonite + larnite + haematite. The norm of what is essentially a mixture of chlorite and epidote appears in Table 1 (selvedge of the Nundle pillow).

Materials with similarly diverse norms may be expected among mafic volcanic associations in those higher-grade situations where the subsequent metamorphism was essentially isochemical. Metamorphic decarbonation reactions will, of course, serve to diminish modal and normative carbonate contents. Low-grade carbonate-rich rocks tend to have relatively diminished contents of hydrolysate residua and their higher-grade metamorphic equivalents will also be poorer in components like Al_2O_3, TiO_2 and P_2O_5

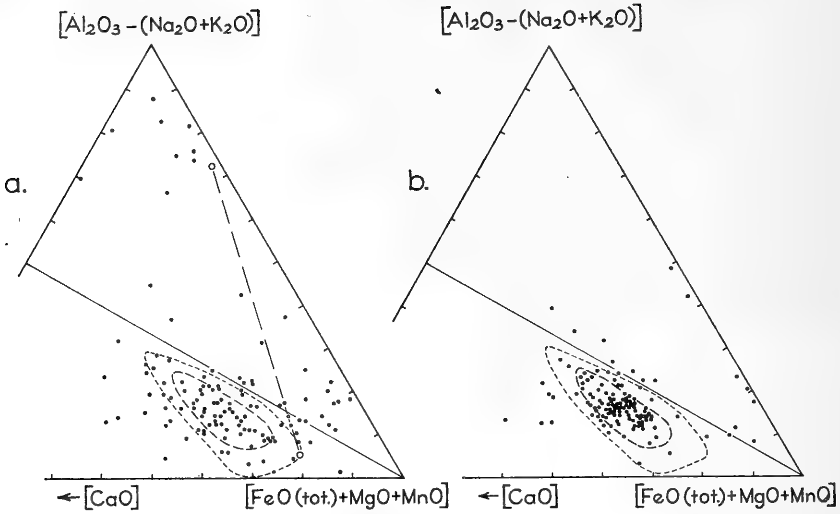

Fig. 11. ACF plots (with F including FeO (tot.)) of collected data for (*a*) rocks described as greenstones, greenschists, epidiorites, and (*b*) amphibolites. Sources: various, including Niggli *et al.*, (1930), Joplin (1963) and Kuznetsov 1939).

The two circles joined by a dashed line in (*a*) represent diabase and selwynite from Heathcote, Victoria. The fields enclosed by dashed lines are those of 350 Quaternary—Tertiary basalts, 90% of the sample falling within the inner line. Note the considerable range of alumina content in greenstones, etc. Some such compositions would not be recognized as amphibolites.

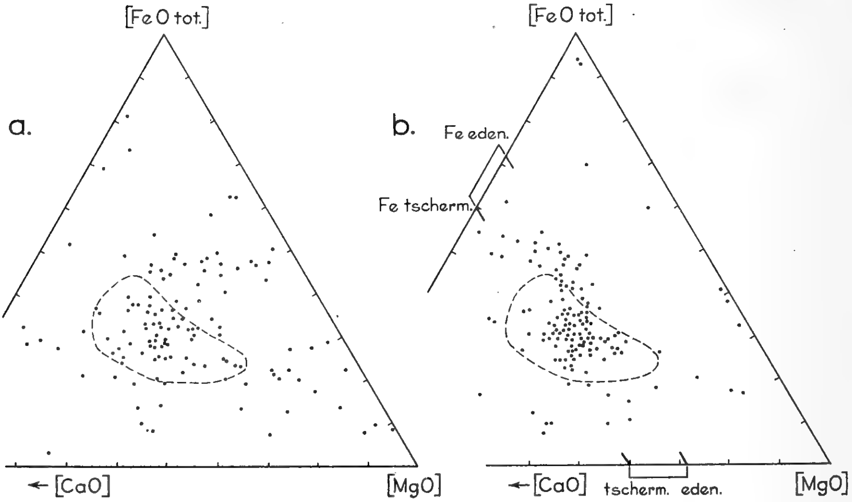

Fig. 12. Plots of FeO (tot.): MgO: CaO for greenstones, etc. (*a*) and amphibolites (*b*). Note the wide scatter for Fe/Mg and these to Ca in both these groups relative to basalt compositions. Variation of Fe/Mg is, in fact, greater than in the larger set of rocks described as spilites (cf. Fig. 2). Not unexpectedly most analysed rocks called amphibolites bear Ca- amphiboles falling here within the range edenite-Fe edenite-tschermakite-Fe-tschermakite.

than those with chloritized parents. Recognition of formerly epidote-rich materials in higher-grades of metamorphism may be complicated by adjustment of Fe^{3+} to Fe^{2+}. Likewise, low-grade haematite-rich compositions are possible progenitors of higher-grade magnetite-rich materials.

The most obvious departures from modern basalt compositions in alteration environments are those involving lime, silica and alkalis. We shall look briefly at two major groups, (1) Ca-poor (approximating chlorite-rich associations) and (2) Ca-rich (which may be relatively aluminous or non-aluminous depending on the characteristic Ca-phase, whether hydrous Ca-Al silicate or carbonate). From what is known of chlorites in degraded basalts there appears to be a preference for compositions with Si : Al (tetrahedral) $\approx$ 3 : 1. Although notable octahedral Al is also found these chlorites are generally far less aluminous than pelitic chlorites. Metamorphic dehydration of chlorites may be expected to yield silica-poor products. Thus in hornblende hornfels facies, anthophyllite (cummingtonite) + spinel or these with cordierite or olivine are expected derivatives from spilitic chlorite residua. The presence of silica in addition to the chlorite shifts bulk composition to favour generation of anthophyllite + cordierite + (quartz) under similar metamorphic conditions.

Metamorphism of chlorite + calcite is expected to yield an Al-poor amphibole plus a more aluminous chlorite if excess silica is available (e.g., 2 diabantite + 3 calcite + 7 silica = 2 actinolite + ripidolite + 4 water + 3 CO_2) or actinolite plus clinozoisite, depending on the composition of the mixture. More intense metamorphism leads to formation of hornblende and where albite was present an intermediate plagioclase. More chloritic compositions lead to, say, anthophyllite (cummingtonite) with hornblende; more carbonate favours hornblende with diopside or even diopside with Ca-garnet, vesuvianite, wollastonite. Ca-garnet and/or vesuvianite with plagioclase are predictable derivatives of epidote-rich materials at appropriate metamorphic grades.

Before mentioning some examples of these predicted metamorphic associations, it should be emphasized that the alteration products discussed earlier represent only portion of the possible range of alteration-derivatives from basalts. Passing mention has been made of highly aluminous compositions recorded in some greenstones. A considerable spread towards Al-richness in greenstones is evident in Figure 12. It probably reflects abundance of white mica and even aluminous phases like pyrophyllite. Although such residua are not expected in the usual patterns of spilitic alteration, an association of diabase and "selwynite" at Heathcote, Victoria, is of some interest as the diabase carries albite and has been termed a spilite. Selwynite is an evident alteration product of the diabase; its composition (Watson, 1925) suggests a considerable white mica content. Skeats (1908) reported modal corundum in both selwynite and diabase. The occurrence deserves careful re-examination but at the least it gives evidence of an unusually aluminous derivative from basalt. Aluminous compositions in basalt metamorphism, such as those of kyanite amphibolites have long been thought to pose petrogenetic difficulties (Tilley, 1937). Experience with altered mafic lavas shows that, in fact, some are so aluminous that assemblages including Al-silicates without amphiboles can result from their isochemical metamorphism. One wonders whether some occurrences of Mg-Al phases like sapphirine are not connected with similar prior adjustments. Biotite + cordierite is a common association in metamorphosed pelites; it occurs at Yalwal, N.S.W., in hornfelses that retain traces of relict basaltic texture (Vallance, 1967*a*, p. 93).

The Yalwal area offers splendid examples of the formation of Ca-poor hornfelses from originally basaltic parents altered to mixtures of residual Fe-rich chlorite plus silica. Contact metamorphic dehydration has produced Fe-rich cordierite—anthophyllite (gedrite) hornfelses, some of them almandine-bearing. Hornfelses with Ca-amphibole and Ca-richer types with diopside, etc., are associated in the thermal aureole with Ca-poor hornfelses, reflecting exactly the diversity observed outside the aureole. The Yalwal occurrence is of classic quality and doubtless will be acclaimed as such when Mr. V. J. Wall's definitive study of phase chemistry, etc., now almost complete, is published. Yalwal at once extends the Fe/Mg range of cordierite—anthophyllite rocks and provides an alternative to oft-postulated schemes of higher-grade material transfer as implied, for instance, by Mg or Mg-Fe metasomatism (Vallance, 1967*a*).

Mg metasomatism, though unproven, is a sturdy hypothesis. Soen (1968), for instance, though recognizing the possibility of deriving cordierite—anthophyllite hornfelses from chloritic mixtures, decides in favour of Mg metasomatism for a metamorphic association in Portugal. Soen believes Mg metasomatism involves fewer assumptions! In his discussion, Soen refers to a scheme of Tuominen and Mikkola (1950) suggested to account for such Ca-poor metamorphic rocks. Tuominen and Mikkola envisaged prior generation of chlorite by a sort of differentiation during tectonic metamorphism. It has no connection with the low-grade alteration model discussed here.

Where chlorite occurs without excess silica a phase like spinel is expected as a metamorphic product. Mr. Wall has corrected my failure to recognize spinel in some hornfelses at Yalwal. In other cases, less ferruginous than Yalwal, translucent spinel is readily apparent. Thus near Yetholme, N.S.W., anthophyllite—spinel hornfelses occur with cordierite—anthophyllite and hornblende-bearing hornfelses in thermally metamorphosed Sofala Volcanics (Watts, 1969). Three analysed examples are quoted in Table 6. The anthophyllite—spinel rock is evidently ultrabasic but its high Al content indicates a lack of rapport with ultrabasic primary igneous rocks (cf. Vallance, 1967*a*, Table 1, no. X). Present silica content is no useful guide to original igneous parentage; ultrabasic compositions are evidently derivable from basalts. Lower Al in the hornblende—olivine—spinel rock from Yetholme (Table 6, no. 5) may reflect association of carbonate with chlorite in the alteration products. These distinctive hornfelses are not directly traceable to comparable materials outside the aureole at Yetholme though the Sofala Volcanics are characterized by low-grade alteration features. It is of interest to record the association talc + chlorite + quartz in greenschists at Cow Flat, near Bathurst. One expects the colourless chlorite to be highly aluminous. Such an association may also represent adjustment of a chlorite + quartz mixture.

Two years ago, Mr. A. J. Irving discovered hornfelses containing cordierite and anthophyllite at Goobarragandra, near Tumut in southern N.S.W. Field relations there are somewhat ambiguous as both a serpentinite belt and associated, but older, chlorite-rich spilitic lavas are invaded by a granitic body. The analysed samples are too aluminous to be normal derivatives from the serpentinite suite (Table 6, nos. 8, 9). One carries two amphiboles (cummingtonite and pale hornblende) with olivine and spinel. The other contains anthophyllite and cordierite as well as spinel but is a far more complex material; olivine, enstatite, clinochlore, and phlogopite are also present. The association is obviously disequilibrium in character and, in addition, the major phases are quite irregularly distributed. Despite its present oddity such a material is more likely to have been derived from a basic than an ultrabasic parent.

Relatively Ca-poor mafic rocks occur in a contrasted metamorphic environment near Batlow, to the south-west of Tumut. This area forms an easterly (and probably higher-pressure) extension of the low-pressure Wantabadgery-Adelong-Tumbarumba regional metamorphic belt (Vallance, 1967*b*). Near Batlow almandine and staurolite as well as andalusite are found in pelitic/psammopelitic schists. Mafic volcanic materials occur here in greater abundance than in the main belt to the west and in them Mr. G. M. Bradley has discovered heterogeneous amphibolites containing cummingtonite + almandine + plagioclase (An_{50}) (Table 6, no. 11) as well as more usual hornblende + plagioclase types (the sample quoted, Table 6, no. 10, is from a locality some miles to the N.W., along strike). Apart from the intriguing association cummingtonite—plagioclase, the corundum normative character of the Batlow amphibolite suggests a link with the other examples discussed. The compositon of the rock can be matched by a mixture with roughly equal albite and epidote (20–25%), about 40% chlorite and some 10% quartz—hardly an exceptional alteration product. The occurrence of plagioclase with a Ca-poor amphibole (with 0·74% CaO) in the metamorphic product may be related to the Na (and formerly, albite) content of the rock.

Another, similar case with even higher Na is the cummingtonite—plagioclase amphibolite with minor hornblende from the Mount Isa region of Queensland (Table 6, no. 12). This is closely associated with rocks containing hornblende and plagioclase and others rich in grossular/andradite within a mafic volcanic formation apparently affected by a major batholithic body. Mr. C. J. L. Wilson has recognized cordierite—anthophyllite rocks in what must be comparable situations nearer Mount Isa. While on the subject of Ca-poor amphibolites, it is relevant to note Kanisawa's (1969) suggestion that humid weathering of basalt could account for the chemical features of certain Japanese cummingtonite- and garnet-bearing amphibolites. There seem to be too many differences from surface weathering products among altered basalts for Kanisawa's suggestion to be generally applicable.

Associations of epidote with chlorite and less abundant albite are commonly nepheline normative. Alkali basalts are, of course, also nepheline normative but one is inclined to the view that alteration products may acquire this characteristic regardless of the type of basalt parent. Does the greenstone hornfels from Kenidjack, Cornwall (Table 6, no. 1) really represent an alkali basalt or was it simply derived from a greenstone containing an appropriate assemblage?

Some splendid examples of Ca-rich hornfelses derived from spilitic materials in the Puddledock area of northern N.S.W. have been described by Spry (1954). Of hornfelses retaining igneous textural relics, Spry noted hornblende-, diopside-, and scapolite- or prehnite-rich types. Phases like Ca-garnet and wollastonite occur in amygdale positions. As Spry remarks, the Ca-richer hornfelses lacking textural relics are indistinguishable from calc-silicate rocks derived from calcareous sediments though these are unknown in the area.

Pillow lavas with Ca-rich selvedges have been converted locally to calc-silicate rocks in a contact zone at Mount Jagungal in the Snowy Mountains of N.S.W. The pillows now consist of cores with Ca-amphibole and plagioclase surrounded by rims and matrices containing such phases as clinozoisite, Ca-garnet and diopside (Table 6, nos. 3, 4). Later metamorphic generation of more aluminous epidote minerals seems to conform with the observations of Miyashiro and Seki (1958). Zoned calc-silicate bodies possibly formed by metamorphism of pillow lavas in Greenland are mentioned by Sørensen (1968).

TABLE 6

Metamorphosed Mafic Rocks

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	40·25	42·81	40·03	43·04	44·61	56·05	33·36	30·94	40·52	48·41	47·62	54·06
Al_2O_3	17·22	14·32	17·52	15·64	7·60	14·51	18·11	24·82	13·26	16·78	18·78	14·11
Fe_2O_3	1·88	0·90	6·08	9·54	2·51	0·08	4·49	2·69	1·45	2·90	3·21	2·66
FeO	11·16	7·26	6·37	1·87	9·98	16·53	6·45	10·46	9·69	9·03	13·30	10·76
MnO	0·24	0·17	0·17	0·16	0·15	0·17	0·22	0·21	0·12	0·32	0·11	0·07
MgO	7·78	4·34	9·64	4·72	20·73	10·00	26·28	20·69	21·77	5·35	5·20	7·45
CaO	14·82	22·11	13·85	22·85	9·06	0·60	1·99	0·55	6·51	13·33	6·22	4·35
Na_2O	1·20	1·83	0·95	0·17	0·60	tr.	0·40	0·36	0·88	1·89	2·62	4·14
K_2O	0·97	0·54	0·12	0·03	1·71	tr.	0·00	0·09	0·08	0·47	0·65	0·26
H_2O+	0·90	1·46	4·06	1·51	2·36	1·37	7·91	8·02	3·11	0·44	0·96	0·66
H_2O-	0·20	0·28	0·13	0·06	0·18	—	0·07	—	—	0·27	0·08	—
TiO_2	2·65	2·11	1·25	0·37	0·42	0·70	0·41	0·65	1·89	1·19	1·19	1·69
P_2O_5	0·65	0·13	0·10	0·03	0·13	0·38	0·32	0·28	0·20	—	0·14	0·06
CO_2	0·00	1·55	0·00	0·24	0·00	0·00	0·00	0·10	0·16	—	0·24	0·20
Cl	—	0·15	—	—	—	—	—	—	—	—	—	—
Total ..	99·92	99·96	100·27	100·23	100·04	100·39	100·01	99·86	99·64	100·38	100·32	100·47
Norms:												
Q	—	*	—	1·75	—	27·52	—	—	—	—	0·75	2·65
or	—	—	0·71	0·18	10·11	—	—	0·53	0·47	2·78	3·84	1·56
ab	—	—	5·91	1·44	4·71	—	3·38	3·05	7·45	15·99	22·17	35·02
an	38·74	29·27	43·19	41·83	12·99	0·50	7·78	0·27	29·98	35·92	28·43	19·14
lc	4·49	2·50	—	—	—	—	—	—	—	—	—	—
ne	5·50	8·39	1·15	—	0·20	—	—	—	—	—	—	—
C	—	—	—	—	—	14·33	14·60	24·03	0·74	—	3·35	—
di	23·56	41·03	19·74	25·35	24·88	—	—	—	—	24·97	—	0·69
wo	—	6·07	—	15·56	—	—	—	—	—	—	—	—
hy	—	—	—	—	—	54·35	21·60	32·82	9·84	12·90	32·96	33·10
ol	16·70	—	13·96	—	39·87	—	36·64	25·14	41·53	0·65	—	—
cs	0·57	1·68	—	—	—	—	—	—	—	—	—	—
hm	—	—	—	5·76	—	—	—	—	—	—	—	—
mt	2·73	1·30	8·82	5·48	3·64	0·12	6·51	3·90	2·10	4·20	4·65	3·87
il	5·03	4·01	2·37	0·70	0·80	1·33	0·78	1·23	3·59	2·26	2·26	3·22
ap	1·51	0·30	0·23	0·07	0·30	0·88	0·74	0·65	0·46	—	0·32	0·13
cc	—	3·53	—	0·55	—	—	—	0·23	0·36	—	0·55	0·45

* Halite omitted in calculation.

Some extraordinarily titaniferous (and Ca-rich) amphibolites are described by Szentpetery (1953) as occurring in the Bükk mountains of Hungary. Their status is, however, uncertain; they are described as though they were products of magmatic differentiation. One would like to know more about them.

As a final example, let us turn to the abundant greenstanes of the Western Australian goldfields region. Relict igneous features, at least gross features such as pillow arrangements, are still discernible but these rocks are very commonly found to consist of far more actinolite than chlorite in association with albite. Carbonate is ubiquitous. There seems to be a good case here for the former operation of a reaction of chlorite + carbonate to produce amphibole. The temperatures required for such a reaction must be within the range of greenschist facies and at most not much beyond the temperatures prevailing in spilitic alteration. Generation of amphibole may, in fact, have been the extreme stage of low-grade alteration rather than a feature of some later, superimposed metamorphism (cf. Table 2).

The list could be extended but enough has been said to demonstrate the point that contrasted metamorphic compositions can be matched among low-grade alteration products derived from mafic volcanic rocks. Formation of Ca-rich skarns and MgFeAl-rich, Ca-poor rocks does not necessarily imply operation of higher-grade metasomatic metamorphism. The possibilities of prior low-grade adjustments should be explored before postulating later metasomatism and those seeking means of distinguishing amphibolites of igneous origin from sedimentary amphibolites should bear in mind that even skarns can be formed from degraded basalts by isochemical metamorphism.

Notes to Table 6

1. Greenstone-hornfels. Carn Kenidjack, Cornwall. (Tilley, 1935.)
2. Basic hornfels. Puddledock, near Armidale, N.S.W. (Joplin, 1963, p. 273.)
3, 4. Selvedge (3) and matrix (4) of small metamorphosed pillow. Sample: 30931 (Univ. Sydney coll.). Summit of Mount Jagungal, Kosciusko State Park, N.S.W. Anal: W. H. Herdsman.
5. Hornblende-olivine-spinel hornfels. Sample: 33848. Mount Tennyson, Yetholme, N.S.W. Anal: W. H. Herdsman.
6. Cordierite-anthophyllite hornfels. Sample: 21929. Mount Tennyson, Yetholme, N.S.W. Anal: N. de Faria e Castro. (Sample dried at 105° C.)
7. Anthophyllite-spinel hornfels. Sample: 33828. Mount Tennyson, Yetholme, N.S.W. Anal: W. H. Herdsman.
8. Anthophyllite-spinel-cordierite hornfels. Sample: 36564. Goobarragandra, Tumut area, N.S.W. Anal: N. de Faria e Castro. (Sample dried at 105° C.)
9. Cummingtonite-hornblende-olivine-spinel hornfels. Sample: 36560. Goobarragandra, N.S.W. Anal: N. de Faria e Castro. (Sample dried at 105° C.)
10. Hornblende-plagioclase amphibolite. Sample: 40884. George's Hill, Adelong, N.S.W. (Vallance, 1953.)
11. Cummingtonite-plagioclase-almandine amphibolite. Sample: 41323. Gilmore Creek, near Batlow, N.S.W. Anal: N. de Faria e Castro.
12. Cummingtonite-plagioclase-hornblende amphibolite. Sample: 43009. Mackellar's Well, Mount Isa area, Queensland. Anal: N. de Faria e Castro. (Sample dried at 105° C.)

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APPENDIX

Sources of Data for Table 1 and Figure 1

(*a*) *Spilites* Barth, 1960; Benson, 1915*b*; Bloxam and Allen, 1960; Cann and Vine, 1966; Carvalhosa, 1961; Coleman and Lee, 1963; Crnkovic, 1963; De Roever, 1940; Dianova, 1958; Donnelly, 1966; Durand and Gagny, 1966; Eliseev, 1928; Fiala, 1966*a, b,* 1967; Goldschmidt, 1916; Hall, 1938; Khamrabaev, 1965; Lariviere, 1960; Lebedinsky and Makarov, 1962; Lidiak, 1965; Lupanov and Markin, 1964; Michel *et al.*, 1960; Miladinovic and Zivkovic, 1962; Pamic, 1961; Salimi, 1965; Savu, 1962; Sergeyev, 1963; Sidorenko *et al.*, 1964; Skripchenko, 1966; Smale, 1966; Spry and Banks, 1962; Vallance, 1960, unpubl. data; Väyryen, 1938; Velinskiy, 1965; Vuagnat, 1946; Wieser, 1957; Willems, 1940; Zavaritsky, 1960.

(*b*) *Spilitic Pillows* Coleman and Lee, 1963; Fiala, 1967, Narebski, 1964; Nicholls, 1959; Pichamuthu, 1957; Slavik, 1928; Vallance, 1960, 1965, unpubl. data; Vuagnat, 1946, 1949*a*, *b*.

References

AMSTUTZ, G. C., 1953.—Geochemistry of Swiss lavas. *Geochim. Cosmochim. Acta*, 3: 157-168.

———, 1958.—Spilitic rocks and mineral deposits. *Bull. Missouri Sch. Mines & Metall.*, Techn. ser., no. 96.

———, 1968.—Spilites and spilitic rocks. Basalts: The Poldervaart Treatise on Rocks of Basaltic Composition (ed. Hess and Poldervaart). New York. Interscience. Vol. 2: 737-753.

BALL, D. F., 1966.—Chlorite clay minerals in Ordovician pumice-tuff and derived soils in Snowdonia, North Wales. *Clay Minerals*, 6 (3): 195-209.

BARTH, V., 1960.—Devonsky vulkanismus Sternbersko-Hornobenesovskeho pasma v Nizkem Jeseniku. *Acta Univ. Palack. Olomucensis, Fac. Rer. Sci.*, 1, *Geogr.-Geol.*, 1: 1-131.

BATTEY, M. H., 1956.—The petrogenesis of a spilitic rock series from New Zealand. *Geol. Mag.*, 93: 89-110.

BENSON, W. N., 1915*a*.—The geology and petrology of the Great Serpentine Belt of New South Wales. Part iv. The dolerites, spilites, and keratophyres of the Nundle district. PROC. LINN. SOC. N.S.W., 40 (1): 121-173.

———, 1915*b*.—Idem. Part v. The geology of the Tamworth district. Ibid., 40 (3): 540-624.

BLOXAM, T. W., and ALLEN, J. B., 1960.—Glaucophane-schist, eclogite, and associated rocks from Knockormal in the Girvan-Ballantrae complex, south Ayrshire. *Trans. roy. Soc. Edin.*, 64 (1): 1-27.

BROWN, I. A., 1931.—The stratigraphy and structural geology of the Devonian rocks of the South Coast of New South Wales. PROC. LINN. SOC. N.S.W., 56: 461-496.

CAILLERE, S., and HENIN, S., 1949.—Experimental formation of chlorites from montmorillonite. *Miner. Mag.*, 28: 612-620.

Cann, J. R., and Vine, F. J., 1966.—An area on the crest of the Carlsberg Ridge: petrology and magnetic survey. *Phil. Trans. roy. Soc. Lond.*, A, 259: 198-217.

Carvalhosa, A., 1961.—Contribuiçao para o estudo dos ofiolitos do Baixo Alentijo.—Espilitos da regiao de Castro Verde—Messejana. *Commun. Serv. geol. Portugal*, 45: 371-390.

Coleman, R. G., and Lee D. E., 1963.—Glaucophane-bearing metamorphic rock types of the Cazadero area, California. *J. Petrol.*, 4 (2): 260-301.

Coombs, D. S., 1954.—The nature and alteration of some Triassic sediments from Southland, New Zealand. *Trans. roy. Soc. N.Z.*, 82 (1): 65-109.

Crnkovic, B., 1963.—Petrografija i petrogeneza magmatita sjeverne strane Medvednice. *Geol. Vjesnik* (Zagreb), 16 (1962): 63-159.

DeKimpe, C. R., 1967.—Hydrothermal aging of synthetic alumino-silicate gels. *Clay Minerals*, 7 (2): 203-214.

De Roever, W. P., 1940.—*Geological investigations in the southwestern Moetis region (Netherlands Timor).* Thesis, Univ. Amsterdam.

Dewey, H. and Flett, J. S., 1911.—British pillow-lavas and the rocks associated with them. *Geol Mag.*, dec. V, 8: 202-209, 241-248.

Dianova, T. V., 1958.—Vulkanogennye gornye porody vostochnoi chasti Pavdinskogo raiona. *Akad. Nauk SSSR, Uralsk Fil., Trudy Gorno-Geol. Inst.*, (Sverdlovsk), 33: 3-139.

Donnelly, T. W., 1962.—Wairakite in West Indian spilitic rocks. *Amer. Miner.*, 47: 794-802.

————, 1966.—Geology of St. Thomas and St. John, U.S. Virgin Isles. *Mem. geol. Soc. Amer.*, 98: 85-176.

Durand, B., and Gagny, Cl., 1966.—Observations sur le mode de gisement et les conditions de mise en place des coulées volcaniques spilitisées de Peyrebrune (région de Realmont) Tarn/France. *Geol. Rundschau*, 55: 329-341.

Eliseev, N., 1928.—O segozerskiich spilitach. *Zap. Ross. Miner. Obshch.*, 57 (1): 105-122.

Ellis, A. J., and Mahon, W. A. J., 1964.—Natural hydrothermal systems and experimental hot-water/rock interactions. *Geochim. Cosmochim. Acta*, 28: 1323-1357.

Eskola, P., 1934.—Prehnite amygdaloid from the bottom of the Baltic. *C.R. Soc. géol. Finlande*, no. 8: 2-13.

Fawcett, J. J., 1965.—Alteration products of olivine and pyroxene in basalt lavas from the Isle of Mull. *Miner. Mag.*, 35: 55-68.

————, and Yoder, H. S., Jr., 1966.—Phase relationships of chlorites in the system $MgO–Al_2O_3–SiO_2–H_2O$. *Amer. Miner.*, 51: 353-380.

Fiala, F., 1966*a*.—Silurské polštářové lávy Barrandienu. *Časopis pro Miner. a Geol.*, 11 (3): 267-276.

————, 1966*b*.—Potash-spilites in the Algonkian of the Barrandian Area. *Paleovolcanites of the Bohemian Massif*, (Prague): 87-99.

————, 1967.—Algonkian pillow lavas and variolites in the Barrandian Area. *Sbornik geol. Ved*, G, 12: 7-63.

Garrels, R. M., and Christ, C. L., 1965.—*Solutions, Minerals, and Equilibria.* New York. Harper & Row.

Goldschmidt, V. M., 1916.—Übersicht der Eruptivgesteine im kaledonischen Gebirge zwischen Stavanger und Trondhjem. *Norsk Vidensk. Skr.*, Mat.—Naturv. Kl., no. 2.

Gon'shakova, V. I., 1956.—Nekotorye termicheskie i rentgenostrukturnye dannye o palagonite v palagonitovikh mindalekamennikh diabazkh zapadnoi chasti Vilyuiskoi vpadini. *Izv. Akad. Nauk SSSR, Ser. geol.*, no. 4: 109-116.

Hall, A. L., 1938.—Analyses of rocks, minerals, ores, coal, soils and waters from southern Africa. *Union of Sth. Africa, Mem. geol. Surv.*, 32.

Hay, R. L., 1966.—Zeolites and zeolitic reactions in sedimentary rocks. *Geol. Soc. Amer., Sp. Pap.* 85.

————, and Iijima, A., 1968.—Petrology of palagonite tuffs of Koko Craters, Oahu, Hawaii. *Contr. Miner. Petr.*, 17 (2): 141-154.

Hemley, J. J., and Jones, W. R., 1964.—Chemical aspects of hydrothermal alteration with emphasis on hydrogen metasomatism. *Econ. Geol.*, 59: 538-569.

Hey, M. H., 1954.—A new review of the chlorites. *Miner. Mag.*, 30: 277-292.

Joplin, G. A., 1963.—Chemical analyses of Australian rocks. Part I: Igneous and metamorphic. *C'wealth of Austr., Bur. Miner. Resrcs. Geol. Geophys., Bull.*, 65.

Kanisawa, S., 1969.—Garnet-amphibolites at Yokokawa in the Abukuma Metamorphic Belt, Japan. *Contr. Miner. Petr.*, 20: 164-176.

Keith, T. E. C., Muffler, L. J. P., and Cremer, M., 1968.—Hydrothermal epidote formed in the Salton Sea geothermal system, California. *Amer. Miner.*, 53: 1635-1644.

Keller, W. D., and Reesman, A. L., 1963.—Dissolved products of artificially pulverized silicate minerals and rocks: Part II. *J. Sedim. Petr.*, 33: 426-437.

Kepezhinskas, K. B., 1965.—Statisticheskii analiz khloritov i ikh parageneticheskie tipy. Moscow. Publishing House "Nauka".

(Khamrabaev, I. Kh.—chief ed.), 1965.—Petrografiya Uzbekistana. 2. *Inst. Geol. i. Geofiz. im. Kh. M. Abdullaeva Akad. Nauk Uzbek. SSR., Minist. Geol. Uzbek. SSR.*, (Tashkent).

Kraüskopf, K. B., 1967.—*Introduction to geochemistry.* New York. McGraw-Hill.

Kuznetsov, E. A., 1939.—Geologiya zelenokamennoi polosy vostochnogo sklona srednego Urala. *Akad. Nauk SSSR, Geol. Inst.*, (Moscow & Leningrad).

Larivière, N. P. de, 1960.—Quelques précisions sur les formations spilitiques de la couverture triasique du massif cristallin du Grand Châtelard (Savoie). *Bull. Soc. géol. France*, 7 ser., 2: 108-112.

Lebedinsky, V. I., and Makarov, N. N., 1962.—Vulkanizm gornogo Kryma. *Akad. Nauk Ukrainsk. SSR, Inst. Miner. Resurs.*, (Kiev).

Lehmann, E., 1965.—Non-metasomatic chlorite in igneous rocks. *Geol. Mag.*, 102: 24-35.

Lidiak, E. G., 1965.—Petrology of andesitic, spilitic, and keratophyric flow rock, north-central Puerto Rico. *Bull. geol. Soc. Amer.*, 76: 57-88.

Lovering, T. S., 1950.—The geochemistry of argillic and related types of rock alteration. *Quart. Colorado Sch. Mines* 45 (1B): 231-260.

Lupanova, N. P., and Markin, V. V., 1964.—Zelenokamennye tolshchi Sobsko-Voikarskogo sinklinoriya (vostachnyy sklon Polyarnogo Urala). *Akad. Nauk SSSR, Geol. Muz. im. A.P. Karpinskogo, Trudy*, 12.

Manson, V., 1968.—Geochemistry of basaltic rocks: major elements. Basalts: The Poldervaart Treatise on Rocks of Basaltic Composition (ed. Hess and Poldervaart). New York. Interscience. Vol. 1: 215-269.

Marshall, R. R., 1961.—Devitrification of natural glass. *Bull. geol. Soc. Amer.*, 72: 1493-1520.

Mason, B., 1966.—*Principles of geochemistry.* Third edition. New York. Wiley.

Melson, W. G., and Van Andel, T. H., 1966.—Metamorphism in the Mid-Atlantic Ridge, 22°N latitude. *Marine Geol.*, 4: 165-186.

Meriläinen, K., 1961.—Albite diabases and albitites in Enontekiö and Kittilä, Finland. *Bull. Comm. géol. Finlande*, no. 195.

Michel, R., Moret, L., and Tane, J. L., 1960.—Sur la présence de spilites potassiques dans la couverture triasique du Pelvoux (Alpes dauphinoises). *C. R. Acad. Sci.* (Paris), 251: 184-187.

Miladinovič, M., and Zivkovič, M., 1962.—Magmatske stene Crnogorskog primorja. Magmatic rocks of the Montenegrin littoral. *Geol. Vjesnik*, 15 (1): 75-91.

Miyamoto, N., 1957.—Iron-rich saponite from Maze, Niigata Prefecture, Japan. *Miner. J.*, (Japan), 2: 193-195.

Miyashiro, A., and Seki, Y., 1958.—Enlargement of the composition field of epidote and piemontite with rising temperature. *Amer. J. Sci.*, 256: 423-430.

Naboko, S. I., 1963*a*.—Gidrotermal'nyy metamorfizm porod v vulkanicheskikh oblastyakh. *Akad. Nauk SSSR, Sibirsk. Otdel., Inst. Vulkan.* (Moscow).

———, 1963*b*.—Conditions of the present-day hydrothermal metamorphism of volcanic rocks. *Internat. Geol. Rev.*, 5 (7): 850-858.

Narebski, W., 1964.—Petrochemia law puklistyche Gór Kaczawskich i niektóre ogólne problemy petrogenezy spilitów. *Pr. Muz. Ziemi*, 7: 69-206.

Nicholls, G. D., 1959.—Autometasomatism in the Lower Spilites of the Builth Volcanic Series. *Quart. J. geol. Soc. Lond.*, 94: 137-162.

———, 1965.—Basalts from the deep ocean floor. *Miner. Mag.*, 34 (Tilley Vol.): 373-388.

Niggli, P., Quervain, F. de, and Winterhalter, R. U., 1930.—Chemismus schweizerischer Gesteine. *Beitr. Geol. Schweiz, Geotechn. Ser.*, 14.

Nockolds, S. R., 1954.—Average chemical compositions of some igneous rocks. *Bull. geol. Soc. Amer.*, 65: 1007-1032.

Packham, G. H., and Crook, K. A. W., 1960.—The principle of diagenetic facies and some of its implications. *J. Geol.*, 68: 392-407.

Pamic, J., 1961.—Karakteristike magmatskih stijena iz dijabaz-rožnjačke serije u okolici Jablanice i Prozora (Bosna i Hercegovina). *Rapp. III-ème Congr. Geol. Yougoslavie . . . 1959* (Titograd), 1: 363-382.

Pichamuthu, C. S., 1957.—Pillow lavas from Mysore State, India. *Bull. Mysore Geol. Assoc.*, no. 15.

Prinz, M., 1968.—Geochemistry of basaltic rocks: Trace elements. Basalts: The Poldervaart Treatise on Rocks of Basaltic Composition (ed. Hess and Poldervaart). New York. Interscience. Vol. 1: 271-323.

Raw, F., 1943.—Some altered palagonite tuffs from Jamaica and the origin and history of their chlorites. *J. Geol.*, 51 (4): 215-243.

Richthofen, F. von, 1868.—Principles of the natural system of volcanic rocks. *Mem. Calif. Acad. Sci.*, 1 (2): 20-24.

Rittmann, A., 1958.—Geosynclinal volcanism, ophiolites and Barramiya rocks. *Egyptian J. Geol.*, 2 (1): 61-65.

Ross, C. S., and Hendricks, S. B., 1945.—Minerals of the montmorillonite group. Their origin and relation to soils and clays. *U.S. geol. Surv., Prof. Pap.* 205-B: 23-79.

Sahama, T. G., 1946.—On the chemistry of the mineral titanite. *Bull. Comm. géol. Finlande*, no. 138: 88-120.

Salimi, F., 1965.—Étude petrographique des roches ophiolitiques des Préalpes romandes. *Schweiz. Miner. Petr. Mitt.*, 45 (1): 189-268.

Savu, H., 1962.—Cercetări geologice si petrografice în reguinea Troas—Pîrnesti din masivul Drocea. *Dări de Seamă ale Sedintelor* (Rumania), 44 (1956-7): 137-158.

Shaw, D. M., and Kudo, A. M., 1965.—A test of the discriminant function in the amphibolite problem. *Miner. Mag.*, 34 (Tilley Vol.): 423-435.

Shteinberg, D. S., 1964.—O khimicheskoi klassifikatsii effuzivn'ikh gorn'ikh porod. *Akad. Nauk SSSR, Uralsk. Fil., Trudy Inst. Geol.*, (Sverdlosk), 72.

Sidorenko, V. V., Baikova, V. S., and Stepanov, I. V., 1964.—Vulkanogenno-kremnistaya gruppa formatsii Sakmarskoi Zony na zapadnom sklone yusnogo Urala. *Akad. Nauk SSSR, Otdel. Nauk o Zemle, Otdel Monograf. Kollektsii*, (Moscow-Leningrad).

Singer, A., 1967.—The argillation of sub-marine tuffs from the Mount Carmel, Israel. *Clay Minerals*, 7 (1): 101-110.

Skeats, E. W., 1908.—On the evidence of the origin, age, and alteration of the rocks near Heathcote, Victoria. *Proc. roy. Soc. Vict.*, 21 (n.s.): 302-348.

Skripchenko, N. S., 1966.—Vulkanogenno-osadochnoe rudoobrazovanie (na primere kolchedannikh mestorosdenyy Severnogo Kavkaza). Moscow. Publishing House "Nedra".

Slavik, F., 1928.—Les "pillow-lavas" algonkiennes de la Bohême. *Int. geol. Congr., C.R. 14th Sess.*, (Spain, 1926), 4: 1389-1395.

Smale, D., 1966.—The petrology and age relations of rocks in the Moonabie Range, South Australia. *Trans. roy. Soc. Sth. Austr.*, 90: 153-165.

Smith, R. E., 1967.—Segregation vesicles in basaltic lava. *Amer. J. Sci.*, 265: 696-713.

———, 1968.—Redistribution of major elements in the alteration of some basic lavas during burial metamorphism. *J. Petrol.*, 9 (2): 191-219.

Soen, O. I., 1968.—Magnesium-metasomatism in basic hornfelses near Farminhao, Viseu district (Northern Portugal). *Chem. Geol.*, 3: 249-279.

Sørensen, P. B., 1968.—Comments on the zoned calc-silicate lenses in the Frederikshåb area. *Grønlands geol. Unders., Rapp.* 15: 49-50.

Spry, A., 1954.—The thermal metamorphism of portions of the Woolomin Group in the Armidale district, N.S.W. Part I. The Puddledock area. *J. Proc. roy. Soc. N.S.W.*, 87 (4): 129-136.

———, and Banks, M. R. (eds.), 1962.—The geology of Tasmania. *J. geol. Soc. Austr.*, 9 (2).

Sukheswala, R. N., and Poldervaart, A., 1958.—Deccan basalts of the Bombay area, India. *Bull. geol. Soc. Amer.*, 69: 1475-1494.

Szentpetery, Z., 1953.—A déli Bükkhegység diabáz- és gabbrótömege. *Ann. Inst. geol. publ. Hungarici*, 41 (1).

Tilley, C. E., 1935.—Metasomatism associated with the greenstone-hornfelses of Kenidjack and Botallack, Cornwall. *Miner. Mag.*, 24: 181-202.

———, 1937.—The paragenesis of the kyanite-amphibolites. Ibid., 42: 555-567.

Tyrrell, G. W., and Peacock, M. A., 1926.—The petrology of Iceland. *Trans. roy. Soc. Edin.*, 55 (1): 51-76.

Vallance, T. G., 1953.—Studies in the metamorphic and plutonic geology of the Wantabadgery-Adelong-Tumbarumba district, N.S.W. Part II. Intermediate-basic rocks. Proc. Linn. Soc. N.S.W., 78: 181-196.

———, 1960.—Concerning spilites. Ibid., 85: 8-52.

———, 1965.—On the chemistry of pillow lavas and the origin of spilites. *Miner. Mag.*, 34 (Tilley Vol.): 471-481.

———, 1967*a*.—Mafic rock alteration and isochemical development of some cordierite-anthophyllite rocks. *J. Petrol.*, 8: 84-96.

———, 1967*b*.—Palaeozoic low-pressure regional metamorphism in South-eastern Australia. *Meddel. Dansk geol. Foren.*, 17 (4): 494-503.

———, 1969.—Recognition of specific magmatic character in some Palaeozoic mafic lavas in New South Wales. *Geol. Soc. Austr., Proc. Specialists' Symposia* (Canberra, 1968), in press.

VÄYRYNEN, H., 1938.—Petrologie des Nickelerzfeldes Kaulatunturi—Kammikivitunturi in Petsamo. *Bull. Comm. geol. Finlande*, no. 116.

VELINSKIY, V. V., 1965.—Petrogenesis of the West Sayan spilite-keratophyre. *Doklady Akad. Nauk SSSR*, 163: 146-149 (English transl., pp. 963-966 in original issue).

VUAGNAT, M., 1946.—Sur quelques diabases suisses.—Contribution à l'étude du problème des spilites et des pillow lavas. *Schweiz. Miner. Petr. Mitt.*, 26: 116-228.

———, 1949*a*.—Variolites et spilites. Comparaison entre quelques pillow lavas britanniques et alpines. *Arch. des Sci.*, 2 (2): 223-236.

———, 1949*b*.—Sur les pillow lavas dalradiennes de la péninsule de Tayvallich (Argyllshire). *Schweiz. Miner. Petr. Mitt.*, 29: 524-536.

———, 1959.—Les basaltes en coussins d'Aci Castello et du Val di Noto. *Rend. Soc. miner. Italiana*, 15: 311-321.

WATSON, J. C., 1925.—The chemical composition of selwynite. *Rec. geol. Surv. Vict.*, 4 (3): 472-474.

WATTS, B. J., 1969.—Geology of the Mt. Tennyson area, south of Yetholme, N.S.W. PROC. LINN. SOC. N.S.W., 94 (1): 81.

WHITE, D. E., 1957a.—Thermal waters of volcanic origin. *Bull. geol. Soc. Amer.*, 68: 1637-1658.

———, 1957*b*.—Magmatic, connate, and metamorphic waters. Ibid., 68: 1659-1682.

———, and SIGVALDASON, G. E., 1963.—Epidote in hot-spring systems, and depth of formation of propylitic epidote in epithermal ore deposits. *U.S. geol. Surv., Prof. Pap.* 450-E: 80-84.

WIESER, T., 1957.—Charaktererystyka petrograficzna albitofirów, porfirów i diabazów z Mrzyglodu w okolicy Zawiercia. *Kwartal. Geol.* (Warsaw), 1 (1): 113-122.

WILLEMS, H. M. V., 1940.—On the magmatic provinces in the Netherlands East Indies. *Geol. Mijnb. Gen. Nederl. en Kol., Verh.*, geol. ser., 12 (3): 289-477.

WILSHIRE, H. G., 1967.—The Prospect alkaline diabase—picrite intrusion, New South Wales, Australia. *J. Petrol.*, 8 (1): 97-163.

YODER, H. S., Jr., 1967.—Spilites and serpentinites. *Carnegie Inst., Ann. Rept. Director Geophys. Lab.*, 1965-1966: 269-279.

———, and TILLEY, C. E., 1962.—Origin of basalt magmas: an experimental study of natural and synthetic rock systems. *J. Petrol.*, 3 (2): 342-532.

ZAVARITSKY, V. A., 1960.—The spilite-keratophyre formation in the region of the Blyava deposit in the Ural Mountains. *Intern. Geol. Rev.*, 2: 551-576, 645-687.

ZELENOV, K K., TKACHENKO, R. I., and KANAKINA, M. A., 1965.—Pereraspredelenie rudoobrazuyushchikh elementov v protsesse gidrotermal'noi deyatel'nosti vulkana Ebeko (ostrov Paramushir). *Akad. Nauk SSSR, Geol. Inst., Trudy*, 141: 140-167.

ZEN, E-an, 1961.—The zeolite facies: an interpretation. *Amer. J. Sci.*, 259: 401-409.

EXPLANATION OF PLATES

PLATE I

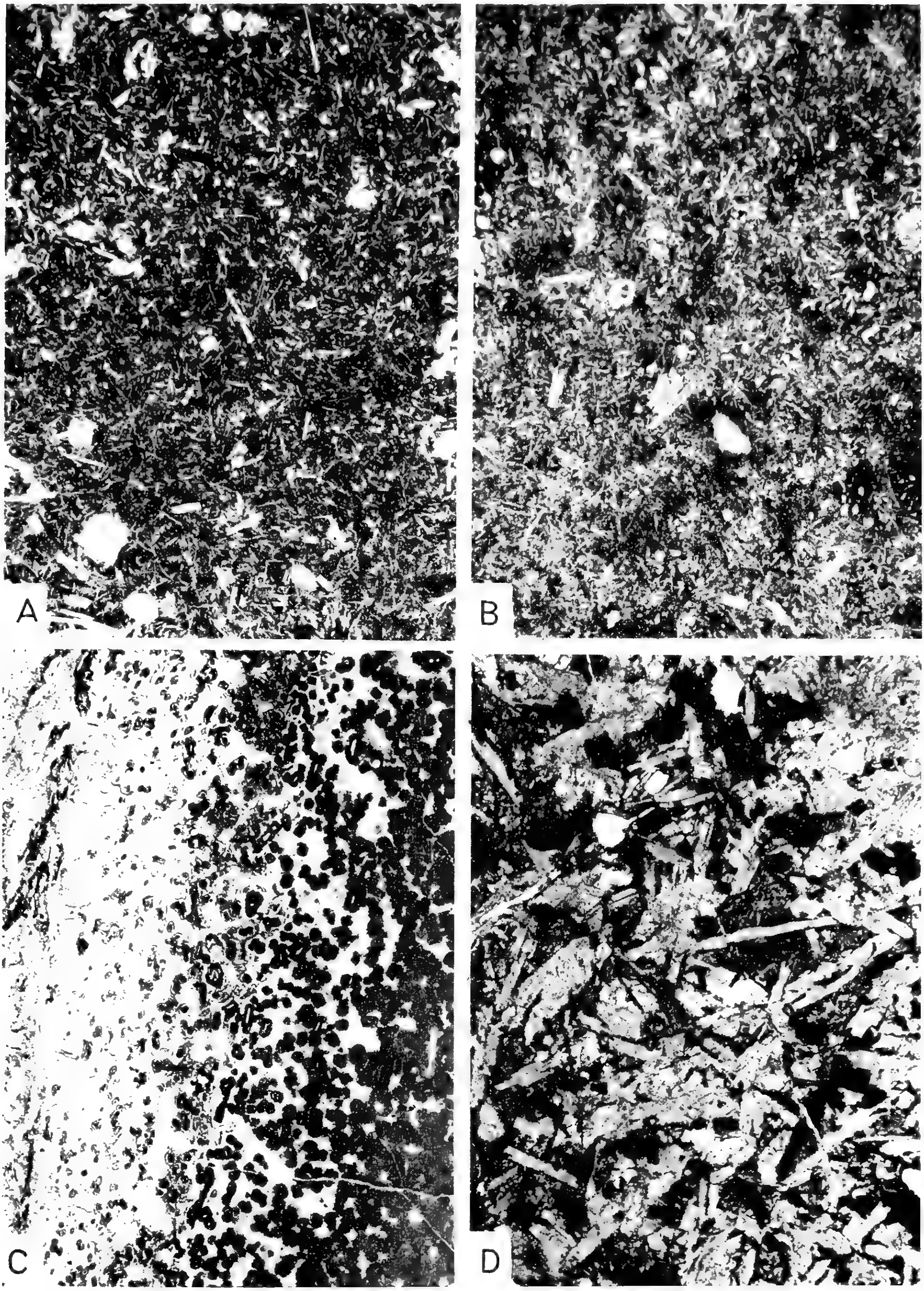
A. Spilite (13237). Summit of Tom Tiger, Nundle, N.S.W. Ordinary light, magnification × 7.

B. Spilite (13236). Half-mile west of Devil's Elbow, Nundle—Hanging Rock road, N.S.W. Ordinary light, magnification × 7.

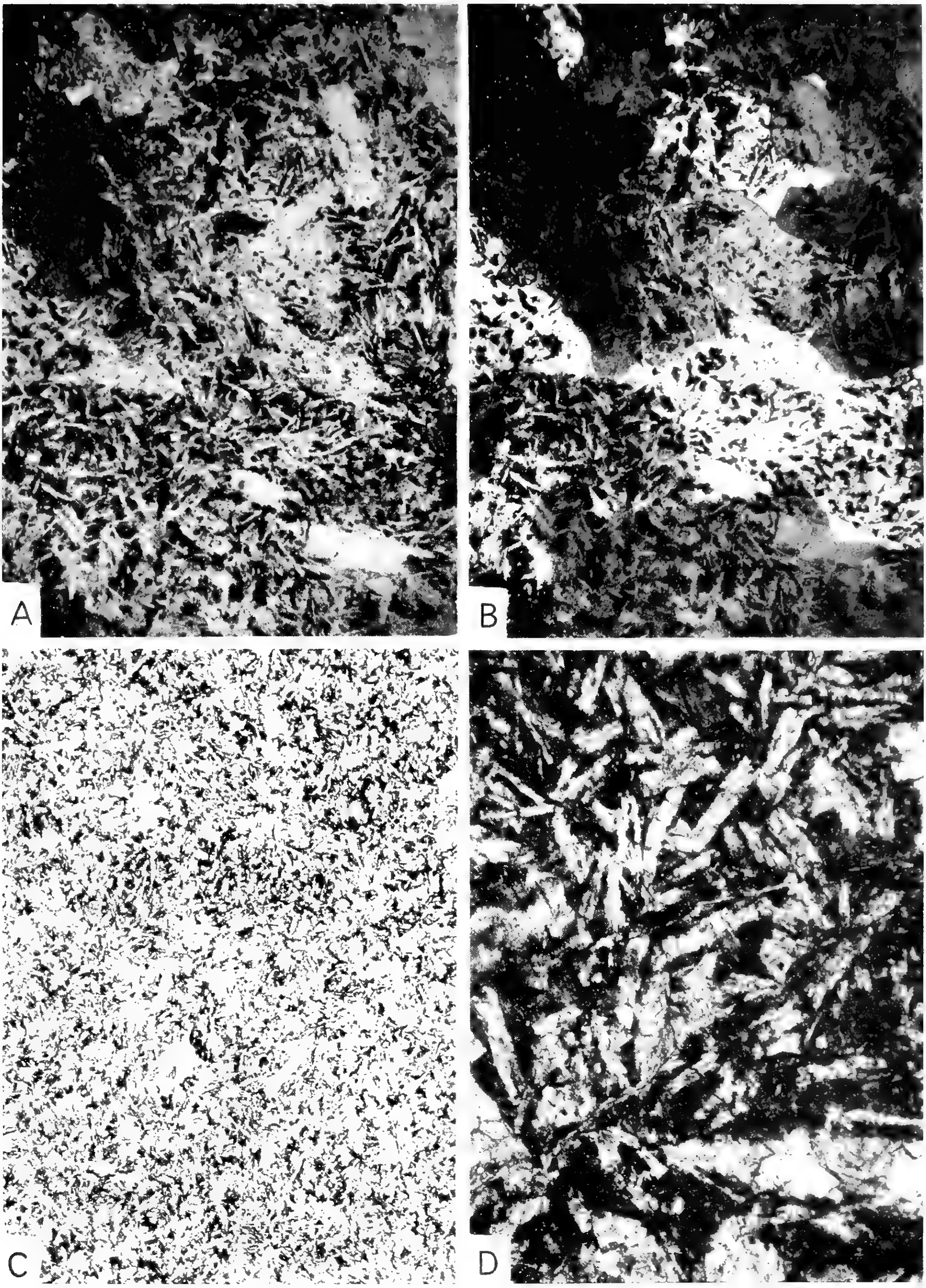
(Note greater abundance of chloritic groundmass in 13237. The lower Na_2O content of this sample (3·06%) relative to that of 13236 (4·98%) is clearly a function of the lower concentration of feldspar phenocryst/microlite sites.)

C. Chloritic selvedge of spilitic pillow (39089). Headland north of Nobby's Beach Port Macquarie, N.S.W. Ordinary light, magnification × 7.

(Outer margin of the pillow is to the left; passing inwards there is an increase in original feldspar sites and these are rendered obvious by mantles of sphene.)



Spilites again: some consequences of the degradation of basalts.



Spilites again: some consequences of the degradation of basalts.

D. Pumpellyite spilite (35962). South Range quarry, Houghton, Mich., U.S.A. Ordinary light, magnification × 15. Specimen by courtesy of Dr. S. O. Agrell.

(Pumpellyite here replaces feldspar, etc., in Keweenawan basalt. The portion illustrated adjoins a vein of pumpellyite.)

Photographs by Mr. G. Z. Foldvary.

PLATE II

A. "Quartzite" patch in altered basalt (36429). Back Creek road, south of Lochiel, Pambula district, N.S.W. Ordinary light, magnification × 35.

B. The same field as A, seen between crossed polars.

C. Chloritized basalt (chlorite spilite) (32081). Boolijah Creek, Yalwal, N.S.W. Ordinary light, magnification × 18.
(Analyzed sample—Vallance, 1967*a*, Table I, anal. VII).

D. Epidotized basalt (epidote spilite) (28075). Por. 9, Parish of Yowaka, Pambula district, N.S.W. Ordinary light, magnification × 35.

CONTRIBUTIONS ON PALAEOZOIC FLORAS. 3

CORDAICLADUS ADAMSII (FEISTMANTEL) RIGBY *COMB. NOV.*

J. F. Rigby*

Departamento de Geologia e Paleontologia da Faculdade de Filosofia, Ciências e Letras da Universidade de Sao Paulo

(Text-fig. 1)

[Read 26th March, 1969]

Synopsis

Specimens from New South Wales described by Feistmantel under the name *Caulopteris Adamsi* are considered to be cordaitalean stems by analogy with stems from elsewhere.

Cordaicladus adamsii (Feistmantel) Rigby comb. nov.

1878. *Caulopteris* (*?*) *Adamsi* Feistmantel, *Palaeontographica,* Suppl. iii, p. 94, pl. xii, figs. 1, 2.

1883. *Caulopteris* (*?*) *Adamsi* Feistmantel, in Tenison Woods, Proc. Linn. Soc. N.S.W., v. 7, p. 132-133.

1890. *Caulopteris Adamsi* Feistmantel, *Mem. geol. Surv. N.S.W.,* Palaeont. 3, p. 135-136, pl. xxi, figs. 1, 2.

1904. Caudex of *Glossopteris,* in Etheridge, *Rec. Aust. Mus.,* v. 5, pt. 1, p. 46–49, fig. 3.

1905. *Caulopteris? adamsi* Feistmantel, in Arber, *Cat. Brit. Mus., Glossopteris Flora,* p. 152-153.

Feistmantel (1878, 1890) placed three specimens in *Caulopteris* under a new specific name, *Adamsi,* largely because he had insufficient evidence to place them anywhere else. He was aware that the choice of the generic name *Caulopteris* may not have been without question. He figured two specimens, now housed in the Mining Museum, Sydney, that bore the following numbers (the figures refer to Plate XXI of Feistmantel, 1890): 2822—fig. 1, 2823—fig. 2. He did not figure a third specimen, 2824, which shows only an isolated leaf scar.

His figures accurately portray the specimens. Specimen 2822 is of two stems having prominent, widely spaced leaf scars, each with a large number of cicatrices. The scar at the lower right of Feistmantel's figure, on the thicker stem, is 25·5 mm. long, 9 mm. wide and has 9 cicatrices. Specimen 2823 is an isolated leaf scar. The same slab of rock also bears a thin *Phyllotheca.* Specimen 2824 is also an isolated leaf scar, it is 17 mm. long, 5 mm. wide and has 8 cicatrices.

Etheridge (1904) figured and described a stem which he regarded as a caudex of *Glossopteris.* It was associated with leaves of *Glossopteris ampla* which he estimated "to have been, when perfect, at least two feet in length by one foot wide". Dana (1849) described the midrib of this species as "very stout and broad, $\frac{3}{4}$ to 1 inch at base". The assumption of the association of

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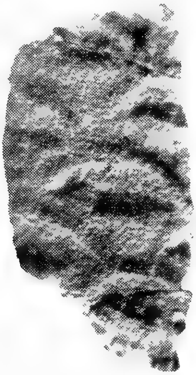
[*] Visiting Professor, under a Fellowship awarded by the Fundaçao de Amparo à Pesquisa do Estado de Sao Paulo.

the leaves and the stem appears to have been quite reasonable from the material available to Etheridge. He differentiated between his specimen and the specimens described by Feistmantel as *Caulopteris Adamsi* only in the spacing of the leaf scars. To me the scars themselves appear identical. I have not seen Etheridge's specimen.

Arber (1905) discussed the specimens figured by Feistmantel (1878, 1890). He said "I am unable to see any resemblance in Feistmantel's figures to the European fern-stems included under *Caulopteris,* and I have no hesitation in saying that the attribution of these specimens to that genus is unjustified".

There the matter rested until Meyen (1962) pointed out that Angara *Cordaites* were borne on *Cordaicladus.* He considered most leaves previously placed in *Noeggerathiopsis* by Russian and Gondwana palaeobotanists to be *Cordaites.* Meyen (personal communication) is of the opinion that Feistmantel's specimens would be more accurately designated *Cordaicladus,* but had insufficient information to include this in print.

Although Grand'Eury (1877) had given a very detailed account dealing with *Cordaites* leaves growing attached to stems of *Cordaicladus,* the latter frequently similar to the stems of *Caulopteris Adamsi,* no one related the leaves of *Noeggerathiopsis* with this genus until Meyen (1962) presented his ideas. The thicker stem of specimen 2822 is proposed as the holotype.



Text-fig. 1. *Cordaicladus adamsii* (Feistmantel) Rigby *comb. nov.* from Burdekins Gap, N.S.W. Natural size.

Until comparatively recently it was thought that logs of *Dadoxylon* and other similar genera of gymnospermous wood, common in the Lower Gondwanas, were trunks of the tree that bore leaves of *Noeggerathiopsis.* This idea was dispelled by the publication of evidence that *Glossopteris* could not possibly be a fern (Plumstead, 1952). Plumstead (1958) pointed out that these numerous logs must have represented the trunk of the tree that bore *Glossopteris,* they could not possibly all represent the trunk of the plant that bore *Noeggerathiopsis* which was altogether not a common member of the flora.

Now there appear to be only five known specimens of Gondwana stems that were likely to have borne leaves of *Noeggerathiopsis,* and all come from the Newcastle District, New South Wales, the four listed above, and a fifth specimen from Burdekins Gap, shown on Text-fig. 1.

This specimen is a sandstone cast of a compressed stem. No plant tissue remains. The cast has poorly preserved impressions of the leaf scars clearly visible on the obverse side (figured), and partly visible on the reverse side. In common with the other specimens, the leaf scars are very large. The extant species *Schizolobium parahylia* (Vell.) Toledo (Caesalpinioideae, ranging through much of the Tropical Americas) also has abnormally large leaf scars. These scars expand considerably after leaf fall until they are 10 cm. or more in width. I postulate that the same happened on stems of *Cordaicladus adamsii,* that the leaf scars on the fossil specimens are expanded scars, and do not represent the size of the scar at abscission.

The specimen is 48 mm. long and 22–24 mm. wide. There are six series of scars visible on the obverse face. Some scars extend for the full width of the stem. The largest and most distinct scar is 22 mm. wide and 15 mm. along the length of the stem. On an uncompressed stem, the original width would have been in the order of 36 mm. along the circular surface.

There are 7 or 8 cicatrices; the precise number is difficult to determine because of the preservation. Each cicatrix is oblong and may have a single depression towards its upper end—other than this, there is no indication of vasculation.

The scars are slightly asymmetrical, suggesting a spiral phyllotaxy of probably $^5/_2$. The thick stem in Feistmantel's specimen, 2822, also has a spiral phyllotaxy with a possible arrangement of $^5/_2$. It is impossible to postulate a phyllotaxy for Etheridge's specimen.

The scar outline is similar to that of *C. gibbosus,* but the cicatrix arrangement appears closer to that of *C. subschnorrianus.* No close relationship is indicated at lower than generic level.

Locality: The specimen formed part of a collection from the northern end of the type section of the Markwell Coal Measures, Burdekins Gap, near Karuah, New South Wales. The containing beds had been deposited in a fossil gully in the coal-measures. The collection is housed by the Department of Geology, University of Newcastle, N.S.W.

Acknowledgement

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References

Arber, E. A. N., 1905.—Catalogue of fossil plants of the Glossopteris Flora in the Department of Geology, British Museum, &c., lxxiv-225 pp., pl. 1-8. (London.)

Dana, J. D., 1849.—In Wilkes' U.S. Exploring Expedition. Vol. X. Geology. Text & Atlas. (Philadelphia.)

Etheridge, R., Jr., 1904.—Further observations on the caudex of *Glossopteris. Rec. Aust. Mus.,* 5 (1): 46-49.

Feistmantel, O., 1878.—Palaeozoische und mesozoische Flora des östlichen Australiens. *Palaeontographica,* Suppl. 3 (3): 53-130.

————, 1890.—Geological and Palaeontological Relations of the Plant-bearing Beds of Palaeozoic and Mesozoic Age in Eastern Australia and Tasmania, &c. *Mem. geol. Surv. N.S.W.,* Palaeont. 3.

Grand'Eury, C., 1877.—Flore carbonifère du Department de la Loire et du centre de la France. *Mem. Acad. Sci. Inst. Nat.,* 24: 1-624.

Meyen, S. V., 1962.—Materialy k poznaniyu morfologii vegetativnogo pobega Angarskikh kordaitov. *Paleont. Zh.,* 1962 (2): 133-143.

Plumstead, Edna P., 1952.—Description of two new genera and six new species of fructification borne on *Glossopteris* leaves. *Trans. geol. Soc. S. Afr.,* 55: 281-328.

————, 1958.—The habit of growth of Glossopteridae. *Trans. geol. Soc. S. Afr.,* 61: 81-94.

THE SUBMICROSCOPIC STRUCTURE OF THE ORAL MUCOSA OF THE PHALANGER (*TRICHOSURUS VULPECULA*)*

RICHARD TUCKER
Department of Veterinary Anatomy, University of Queensland, Brisbane

(Plates III-VIII)

[Read 26th March, 1969]

Synopsis

The structural pattern of the oral mucosa of the phalanger, *Trichosurus vulpecula*, is investigated, and compared with that of the oral mucosa of the ox, *Bos taurus*, and of the finch, *Steganopleura annulata.*

It is found that in the oral mucosa of the phalanger the intracellular fibrillous net develops stronger than in ox. Within the cell the net is distributed peripherally, a condition also known in some birds. The characteristics of phalanger's oral mucosa is an extensive incorporation of cytoplasm into the fibrillous bundles as well as appearance of spacious enlargements of the intercellular spaces.

The similarities between the proteinaceous bodies in plants and protozoans to the tubular structure of nets in phalanger are discussed.

INTRODUCTION

The fine structure of the oral mucosa has been investigated in a limited number of species only and no report on its morphology in marsupials is known to me. Consequently our previous studies on the oral mucosa (Tucker 1966, 1968) were extended to the phalanger (*Trichosurus vulpecula*) in an attempt to obtain additional comparative data. As the mechanism of the food intake is a main source of forces acting on oral mucosa it is of interest to note that in eating the phalanger nibbles constantly and as a marsupial it feeds itself orally at a much earlier stage than do the placental mammals. In addition, marsupials in the pouch initially attach themselves to a teat, so this could act on and modify the oral mucosa of a marsupial to a greater extent than is the case with placental mammals.

MATERIAL AND METHODS

Portions of the oral mucosa of the phalanger (*Trichosurus vulpecula*) from the vicinity of the frenulum were collected under ether anaesthesia, immediately fixed in 4% gluteraldehyde at 4°C. for 2 hours, washed overnight in 2% sucrose, buffered with sodium cacodylate (pH 7·3), and then post-fixed in 1% osmium tetroxide, dehydrated in alcohol, and embedded in epon. The sections were stained on the grid with 5% uranyl acetate and then with lead citrate. The sections were viewed on a Siemens Elmiskop I.

RESULTS

The composition of the oral mucosa

The cells of the oral mucosa of the phalanger are uniform and have large, generally chromatin-poor nuclei (Plate III, figs 1 and 2) with marginally-distributed chromatin and a prominent nucleolus (Plate III,

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* Written on the occasion of Professor H. Grau's anniversary.

fig. 2). Also shallow invaginations of the nuclear membrane were often observed (Plate III, figs 1 and 2). The distribution of the cell organelles is a characteristic one—the nucleus lies centrally, the fibrillous net peripherally, and between them spreads out a relatively clear cytoplasm with single or cluster-like granules in it. (Plate III, figs 1 and 2). In the peripheral portion of the cell (Plate III, fig. 1), are present strong bundles of fibres, broad and ribbon-like, which join each other, spreading out through the marginal cytoplasm as a common cellular net (Plate III, fig. 3, Plate IV, figs 4 and 5). The marginal condensations of fibres produce numerous and powerful desmosomes (Plate IV, fig. 6, Plate V, fig. 7) each of which is firmly attached to a fibrillar bundle, and through it to the intracellular fibrillous net (Plate V, figs 8, 9, 10 and 11).

The transverse sections through desmosomes and through the fibrillous ribbons have shown that the light areas which give them at times a doughnut-like appearance are in fact portions of the cytoplasm incorporated into the bundle. Smaller cytoplasmic accumulations, trapped between and along the fibrils, give the impression of a whole bundle being tube-like in structure (Plate VI, figs 12, 13 and 14).

In the proximity of fibrillous bundles and desmosomes are present irregular aggregations of single fibrils which in transverse sections simulate the granules (Plate VI, fig. 15).

The intercellular spaces produce (according to the section) a considerable number of uniformly spherical, large, and evenly-spaced intracellular sinuses (Plate VII, figs 16 and 17) and much more seldom large and irregular enlargements (Plate VII, fig. 18).

In the intercellular spaces of the mechanically active mucosal cells, microvilli were observed only in a few isolated instances. They are however well developed around the secretory cells (see below). The intercellular fluid contains some dark granules and at the level of the desmosomes it condenses to form 3 distinct bands, parallel to the cell surfaces (Plate VII, fig. 19). The intercellular sinuses of the phalanger's mucosa are flanked with thick fibrillous bundles and bulky desmosomes (Plate VII, figs 20 and 21, Plate VIII, fig. 22). The remnants of a substance of varying electronic density were traced in many sinuses. Also in a few cases very regular cytoplasmic spheres have been seen (Plate VIII, fig. 23). This suggests the existence of cellular interdigitations.

In the oral mucosa of the phalanger a number of goblet cells were observed. These cells, although usually single, tend here to accumulate in a circumscribed area (Plate VIII, fig. 24). In the early secretory stages they possess some endoplasmic reticulum and the intercellular spaces between them are crowded with microvilli (Plate VIII, fig. 25).

The nuclei of the goblet cells possess more chromatin than the epithelial cells of the oral mucosa. In the cytoplasm of goblet cells are placed small elongated mitochondria as well as large areas of granules. The secretory droplets are round in sections and their growth leads to the compression of the cytoplasm and consequently to the increase of its electronic density. Capillaries and the large accumulations of collagen fibres are present in the proximity of the goblet cells.

Discussion

Our previous researches on the epithelial cells of the oral cavity (Tucker, 1966, 1968) have shown extensive development of fibrillous proteins which perform mechanical tasks. In this respect the oral mucosa of phalanger shows, 1. A greater development of mechanical organelles: fibrils, desmosomes and nets, 2. a tubular arrangement of protein not seen in other mammals and 3. a pronounced incorporation of cytoplasm into the tubular or fibrillous nets, a property which is only slightly indicated in other mammals.

In this respect it is of interest to note that proteinaceous bodies of fibrils, and tubular structures resembling those in the oral mucosa of the phalanger have been described in some plants—*Nicotiania tabacum, Pisum sativum, Phaseolus vulgaris* and *Cucurbita maxima* (Cronshaw and Esau, 1968). According to the shape of the proteins they are described as P. 1, 2, 3, or 4 bodies. The incorporation of cytoplasm into proteinaceous nets in the phalanger bears some similarity to the incorporation of cytoplasm by P. 3 proteinaceous bodies of *Cucurbita,* and in some places by P. 4 type bodies.

In plants and mammals the accumulations of proteins are formed without any limiting membrane around them and they push away all other organelles of the cell (Tucker 1966, 1968; Cronshaw and Esau, 1968). Cronshaw and Esau outlined the development of proteinaceous bodies in *Cucurbita.* No detailed study of the ontogeny of fibrillous nets in mammals has yet been undertaken but our previous comparative studies (Tucker 1966, 1968) indicate that they originate from single fibrils on the peripheral portion of the cytoplasm.

The formation of mechanical organelles observed in mammalian epithelial cells is probably a very general property of cells as fibrillar organization of a similar type has been reported for the giant Amoeba *Chaos chaos* (Nachmias, V. T. 1968).

A particularly striking feature of the oral mucosa of the phalanger is the extreme development of the intracellular fibrillous net. The fibrillous net is more regular than that in the oral mucosa of the ox and the fibrillous bundles in the net, including desmosomes, achieve much greater strength than those in the ox.

The volume of fibrillous bundles and the frequently perpendicular position of them to each other made it possible to see the laterally irregular spreading out of fibrils and the engulfing of cytoplasm into the bundle (Plate VI, figs 12, 13 and 14). This may explain the presence of the doughnut-like desmosomes described earlier in the ox (Tucker, 1966) as well as the internal structure of the fibrillous bundles, which in transverse sections may appear as a set of small tubules. As the cytoplasm incorporated into the bundle has a relatively small electronic density, the whole arrangement can be considered to be a repetition of the relationship between the intercellular sinuses and the strong fibrillous elements in so far as the areas of small density are surrounded by the dense fibrillous elements. Also the intracellular sinuses and the enlargements of the intercellular spaces are larger than in the ox and their structure is simpler. Microvilli are seldom seen. The enormous development of the fibrillous bundles and the size of enlargements of the intercellular spaces suggests that in phalanger the exchange of energy between those systems is efficient. Further, such a transition of energy is probably connected with a considerable magnitude, or with a considerable frequency of stresses or both. It may be due to an early intake of the solid food.

In addition, the lips of a young in the pouch can be used as an attachment organ to the teat.

With reference to the differences between the intercellular spaces around the goblet cells and those around the mechanically-working cells it can be noted that such enlargements of the intercellular space which contain villi have also probably a greater stress dispersing ability than the simple enlargements of slits (Tucker, 1966). The above supposition is corroborated by the lesser rigidity of the goblet cells than that of the fibrillous cells of the oral mucosa. Further, in the case of the sudden collapse of a goblet cell during normal secretory activity, the presence of microvilli may make it easier to preserve the intercellular spaces because of the resistance of the microvilli to pressures from the surrounding cells (Text figs 1 and 2).

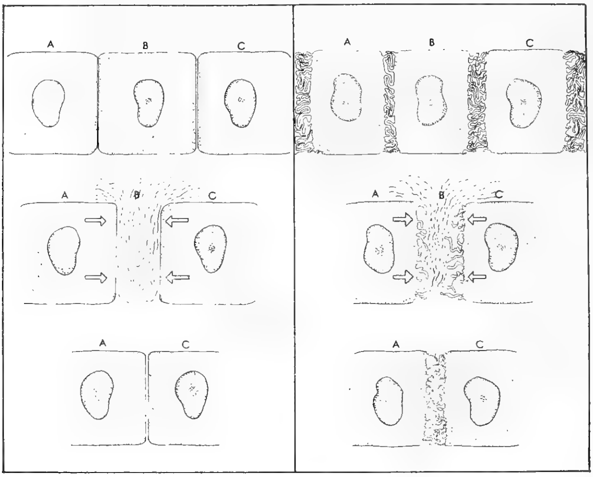


Fig. 1.

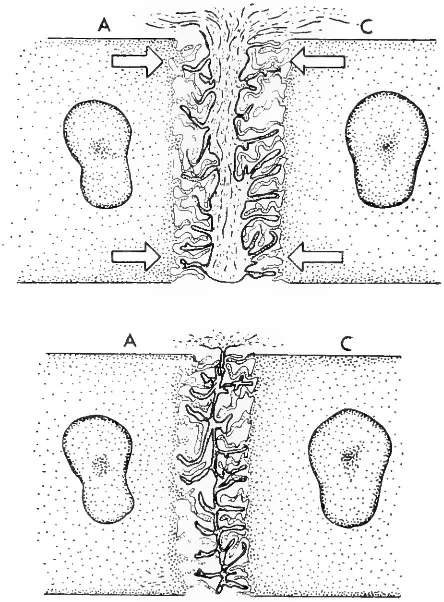


Fig. 2.

In the oral mucosa of ox (Tucker, 1966, 1968) the enlargements of the intercellular spaces have usually a complex morphology with microvilli while in phalanger the corresponding enlargements are simple, (without microvilli). This is accompanied by the augmentation of the fibrillous net in the cells of the oral mucosa of phalanger (as compared with that in the ox). The predominant distribution of fibrils on the periphery of the epithelial cells resembles conditions in some birds (Tucker 1968). Also in finch (*Steganopleura annulata*) the intercellular processes of the epithelial cells interdigitate causing a tortuous outline of the intercellular spaces while in phalanger the processes of 2 cells seem to be often at the same level resulting in a series of the bulbous enlargements of the intercellular space (Text fig. 3). In the phalanger the cytoplasm may be incorporated into the fibrillous bundles along the whole length of the bundle, while in ox this was observed only at the base of fibrillous condensations (Tucker, 1966).

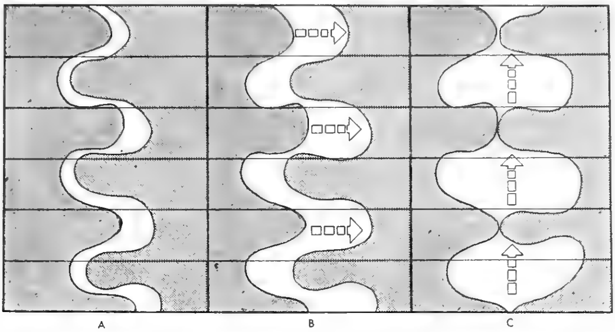


Fig. 3.

Acknowledgements

It is the author's pleasure to acknowledge the financial support received from the Rural Credits Development Fund of Australia and the help of Mrs. L. Endean in preparation of the manuscript. Mr. D. Gowanlock and Miss A. Robinson of the Electron Microscope Unit contributed to the preparation and manipulation of the material. My thanks are also due to Mr. Hardy of the above unit for his interest in this investigation.

References

Cronshaw, J. and K. Esau, 1968.—P. Protein in the phloem of *Cucurbita*. 1. The development of P. protein bodies. *Journal of Cell Biology*, 38, No. 1:25.

Nachmias, V. T., 1968.—Further electron microscope studies on fibrillar organizations of the ground cytoplasm of *Chaos chaos*. *Journal of Cell Biology*, 38, No. 1 : 40.

Tucker, R., 1966.—Electron microscopy studies of the mechanical adaptations in bovine epithelial cells. *Res. in Vet. Sci.*, 7, No. 4.

————, 1968.—Surface specializations of mechanically laden epithelia. *Res. in Vet. Sci.*, 9, No. 5: 381.

EXPLANATION OF PLATES

Plate III. 1. × 4,000, shows the general composition of the oral mucosa.
2. × 20,000, shows the nucleus of a mucosal cell with a nucleolus and peripheral nuclear invaginations.
3. × 46,000, shows the composition of the fibrillous net.
Plate IV. 4. × 72,000, shows the orientation of fibre bundles, running perpendicularly to one another, in the fibrillous net.
5. × 64,000, shows ribbon formation in the net.
6. × 60,000, shows a large desmosome.
Plate V. 7. × 56,000, shows marginal doughnut-like condensations and desmosomes.
8. × 40,000, shows a desmosome and its attachment to the fibrillous net.
9. × 36,000, shows a desmosome and its attachment to the fibrillous net.
10. × 16,000, shows a desmosome and its attachment to the fibrillous net.
Plate VI 11. × 20,000, shows a desmosome and its attachment to the fibrillous net.
12. × 60,000, shows a transverse section through the fibrillous complex.
13. × 56,000, shows cytoplasmic inclusions in the fibrillous condensations.
14. × 50,000, shows the engulfing of the cytoplasm by the fibres.
15. × 60,000, shows the granules in the cytoplasm.

PLATE VII 16. × 20,000, shows the distribution of intercellular spaces.
17. × 20,000, shows the distribution of intracellular sinuses.
18. × 32,000, shows a large, irregular enlargement of an intercellular space.
19. × 80,000, shows parallel lines in the intercellular space on the level of desmosomes.
20. × 20,000
21. × 36,000
PLATE VIII. 22. × 20,000 } show the close relationship between intercellular spaces and fibrillous bundles.
23. × 16,000, shows intracellular sinuses containing interdigitating processes or remnants of cytoplasmic material.
24. × 4,000, shows the accumulation of secretory cells and the reduction of cytoplasm.
25. × 20,000, shows an intercellular space with microvilli between secretory cells in the oral mucosa of the phalanger.

EXPLANATION OF TEXT FIGURES

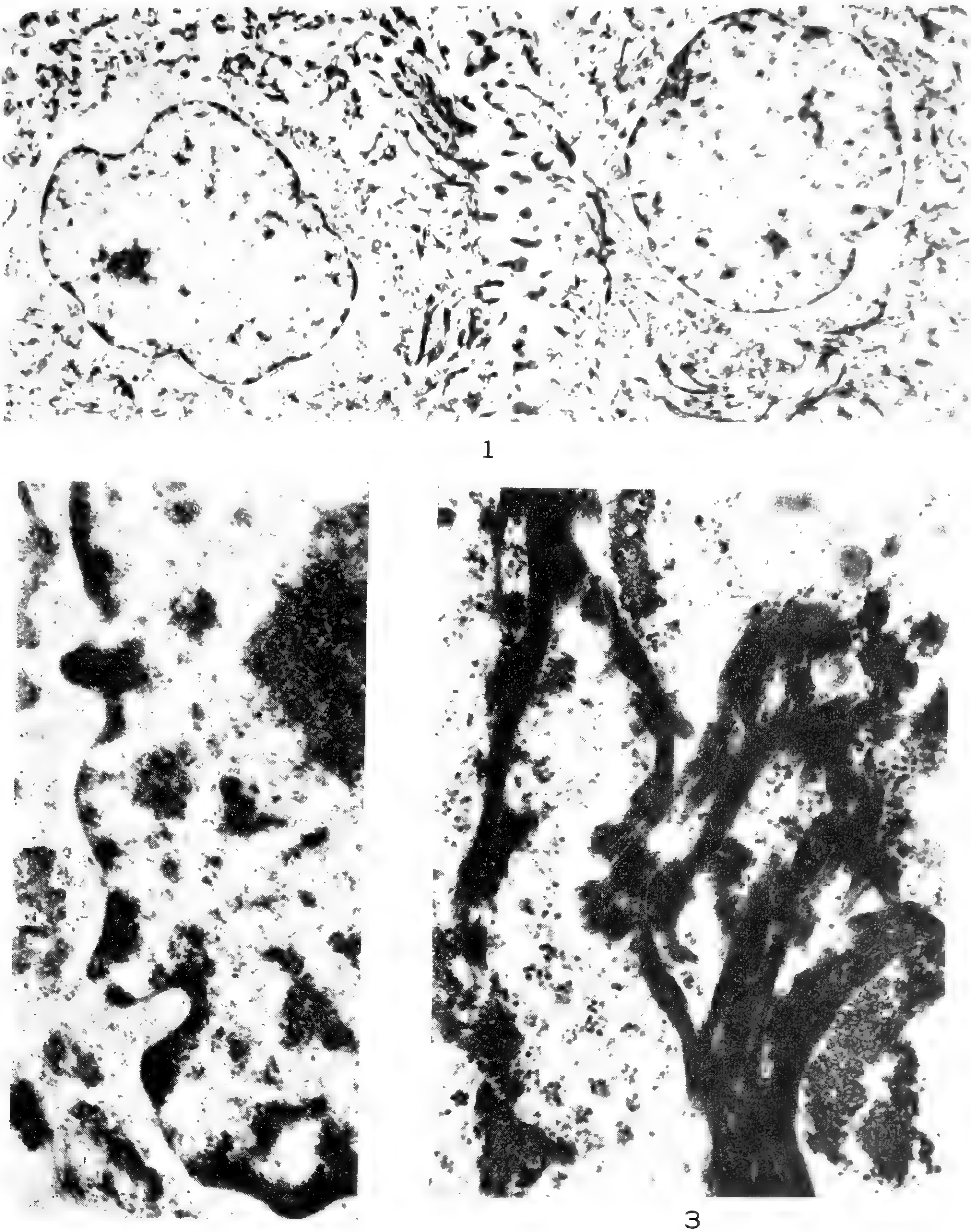
Fig. 1. Diagram illustrating the possible influence of microvilli on the maintenance of the intercellular space. In the left-hand column the cell B is shown undergoing holocrine disintegration. The stresses from the surrounding tissue push the cells A and C together, closing completely the space between them. Note that none of the cells A, B, or C has microvilli, and that consequently the maintenance of the intercellular space is very difficult.

In the right-hand column the general situation is repeated, except that cells A, B and C have microvilli. In consequence, even if the cell B is completely destroyed, the microvilli of cells A and C still facilitate the maintenance of the intercellular space.

Fig. 2. Shows the reduction of the middle cell in such a way that the cytoplasm pours out, but the cellular membrane remains in situ. In such a case, the remnants of this cell may facilitate the initial stages of formation of a new intercellular space.

Fig. 3. A diagram illustrating the difference in sequences of the cellular processes in the oral mucosa.

A represents the condition in birds, *B* shows an intermediate position often seen in the oral mucosa of the ox, and *C* illustrates the processes in a new relative position, and formation of the larger intercellular spaces as seen in the phalanger.



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The submicroscopic structure of the oral mucosa of the phalanger (*Trichosurus vulpecula*).

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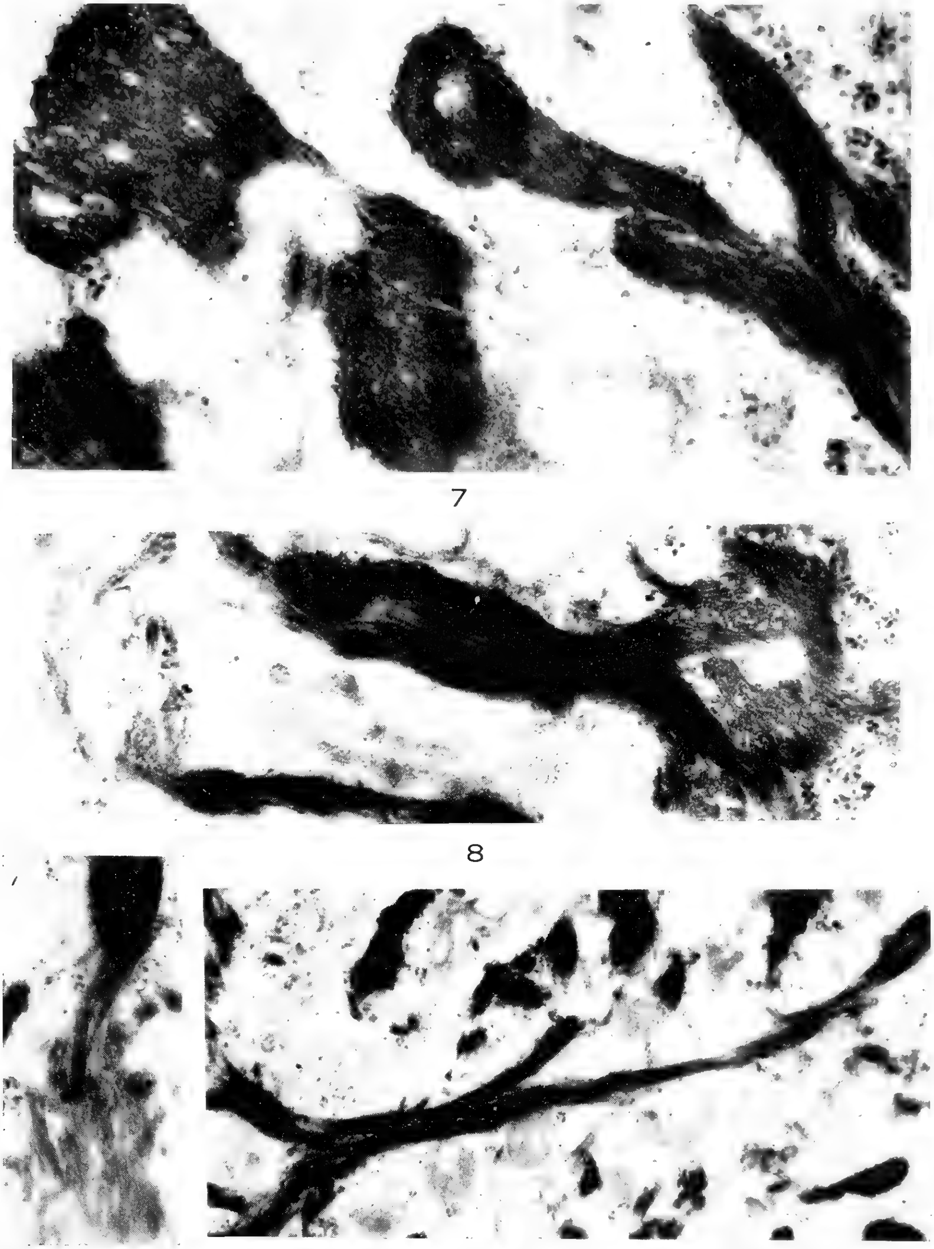
The submicroscopic structure of the oral mucosa of the phalanger (*Trichosurus vulpecula*).



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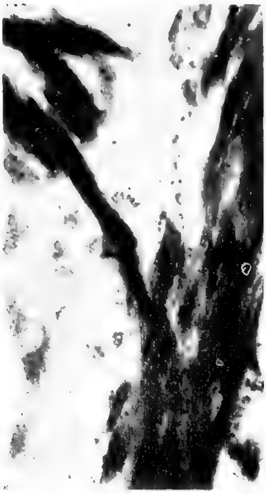

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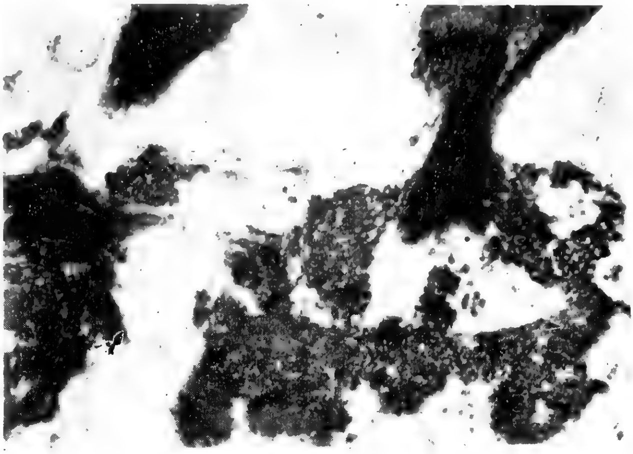

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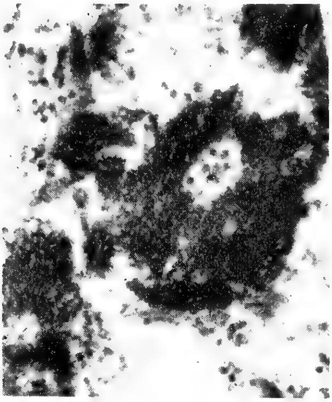

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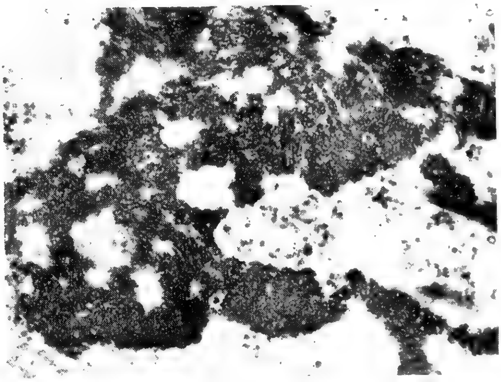

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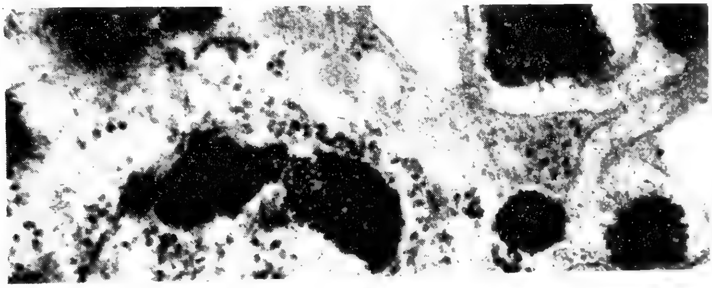

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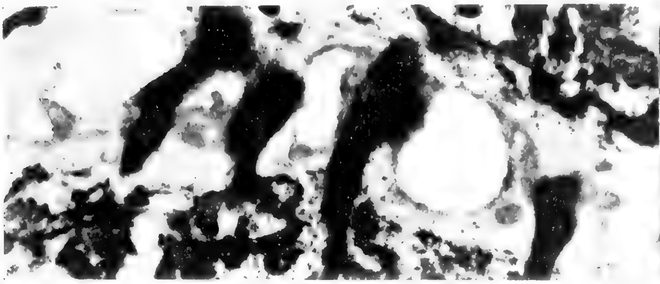
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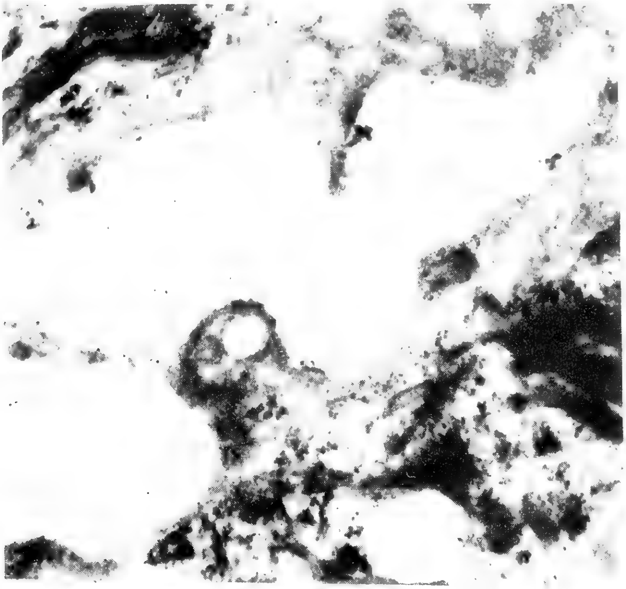
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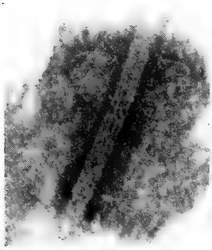
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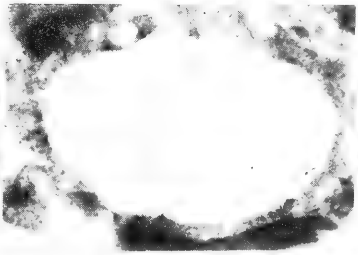
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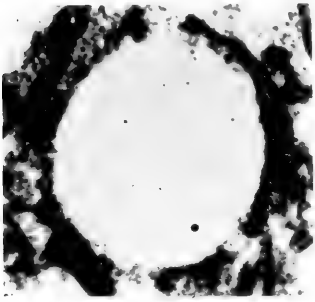
The submicroscopic structure of the oral mucosa of the phalanger (*Trichosurus vulpecula*).



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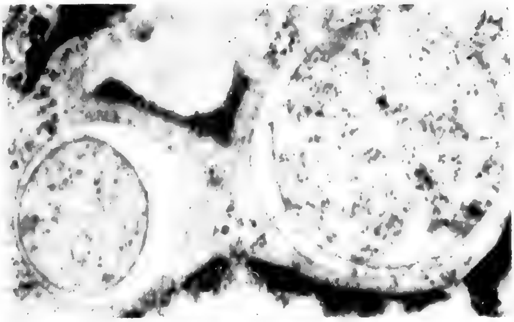

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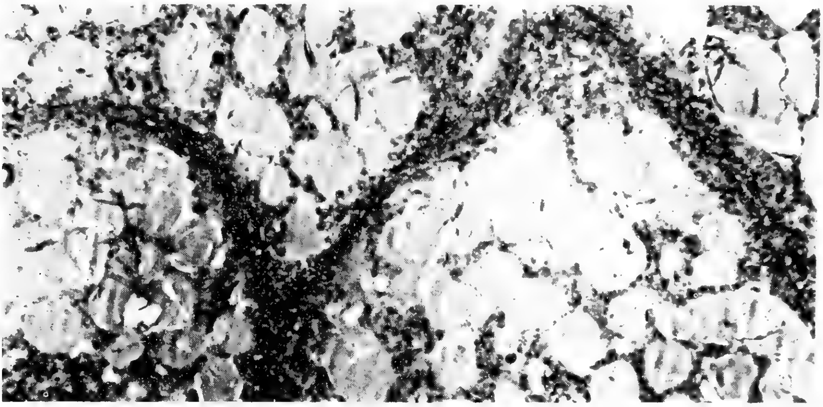

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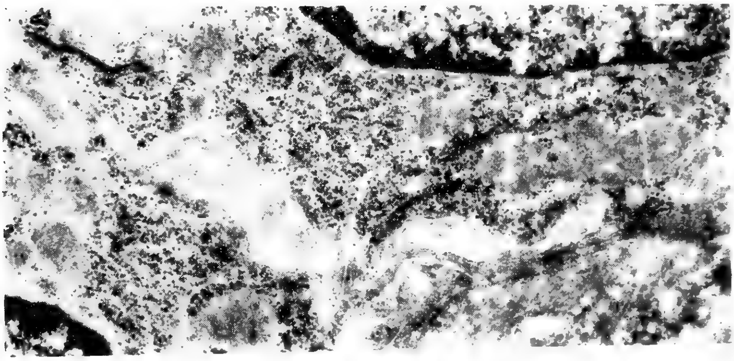

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The submicroscopic structure of the oral mucosa of the phalanger (*Trichosurus vulpecula*).

THE FAMILY OZOBRANCHIDAE REDEFINED, AND A NOVEL OZOBRANCHIFORM LEECH FROM MURRAY RIVER TURTLES (CLASS HIRUDINOIDEA; ORDER RHYNCHOBDELLIFORMES)

LAURENCE R. RICHARDSON*

[Read 26th March, 1969]

Synopsis

A new genus is provided for a leech from *Emydura macquari* at Lake Boga, Victoria, novel in possessing digitiform gills, etc. This is the first freshwater clitellate rhynchobdellid known in Australia. The external features of *Ozobranchus branchiatus* and *O. margoi* are described from specimens taken from marine turtles at Heron Island, which gives the first record of *O. margoi* in the southern hemisphere, and is the fifth time the species has been taken. The redefined Family Ozobranchidae excludes the genus *Branchellion*.

Specimens of a small ozobranchiform leech sent me by Mr. John Goode and Mr. Peter Meyer of Victoria, possess 8 pairs of gills which are tapering cylindrical, digitiform, terminating bluntly without division into the tufts of finely filamentous gills typical of the ozobranch, and so resemble the gills on the late embryo and newly hatched ozobranch; but these are adult specimens. These leeches were taken from *Emydura macquari* at Lake Boga, 10 miles from Swan Hill, Victoria, on the Murray River system. Egg-capsules of *Bdellasimilis barwicki* Richardson 1968 were taken with the leeches, but no leech cocoons were seen. According to Sanjeeva Raj (1954), the only other freshwater species of ozobranch is *Ozobranchus papillatus* Kaburaki 1921, in North India.

Previously (Richardson, 1968) only the marine *Ozobranchus branchiatus* was known from Australia, being figured by MacDonald (1877) but not identified by him or described in detail, and referred to without detail by Goddard. Through Dr. John Pearson I received two specimens of *Ozobranchus* taken from *Chelonia mydas* at Heron Island by Dr. H. R. Bustard early in 1968. One specimen is *O. branchiatus,* the other the rare *O. margoi* which has been taken only four times previously, originally in the Mediterranean, twice in Japanese waters, and once in the Bay of Bengal. This is the first record of *O. margoi* on *Chelonia mydas,* and the first time in which two species of ozobranch have been taken from this turtle. The external details of these two specimens are described; but the condition of both was unsuitable for close internal study by dissection, which is most unfortunate for there are conflicts in the accounts of the internal anatomy of *O. branchiatus* and the one account of the internal anatomy of *O. margoi* is questionable on some points.

The Lake Boga leech is the first clitellate rhynchobdellid found in Australian freshwaters. It is clearly a new genus. The external and internal morphology conforms to that of the ozobranch leeches so far as known and as seen in the dissection of the two marine species, and provides a morphological basis for the establishment of a separate family, so removing the ozobranchids from the Family Piscicolidae, a small but initial intrusion into the systematic complexities of the clitellate rhynchobdellids.

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* 4 Bacon St., Grafton, N.S.W.

The rhynchobdellid leeches possess a small circular pore-like "mouth" on the anterior sucker and an eversible cylindrical proboscis with a restricted, very narrow lumen so that all are liquid feeders. They have long been and are currently accepted as divided into two families: the Family Glossiphonidae Vaillant 1890, non-clitellate leeches, the body without division into a distinct anterior sucker, a neck, and abdomen, freshwater, predatory, and sanguivorous or otherwise parasitic; and the Family Piscicolidae Johnston 1865, clitellate, the body with a narrow-based anterior sucker, a neck distinct from the sucker, and in most the neck also sharply defined from the abdomen, temporary to permanent ectoparasites of aquatic animals (fish, mollusca, arthropods, etc.), marine and freshwater, sanguivorous (and possibly some mucus feeders).

With over 45 genera (Soos, 1965), the piscicolids are the most richly diversified group in the Hirudinea as currently understood. Only two of these genera possess external gills: the genus *Branchellion* Savigny 1822, marine, ectoparasitic on fish (chiefly elasmobranchs), with 3 pairs of gills on each branchiate somite, etc.; and the genus *Ozobranchus* Quatrefages 1852, marine and freshwater, ectoparasitic—typically on Chelonia, with only one pair of gills per branchiate somite, etc. Because of the presence of gills in both, the two genera have been nearly always, and are currently associated systematically. Since *Branchellion* is typically piscicolid, the association of the two has resulted in *Ozobranchus* being retained in the Piscicolidae.

Vaillant (1890) summarizes earlier writers in recognizing a Family Ichthyobdellidae (now Piscicolidae) divided into a sub-family Branchellionae (*Ozobranchus, Branchellion, Calliobdella, Hemibdella*) and a sub-family Pontobdellinae. Leigh-Sharpe (1916) provided a more extended Branchiobdellinae; Pinto (1921), a Family Ozobranchidae, and later a sub-order Ozobranchida; Caballero (1960), a sub-family Branchelliinae; etc.—all such containing both genera of gilled "piscicolids". Poirier and Rochebrune (1884) provided a Family Lophobdellidae for a new ozobranchid leech; but neither this nor the Family Chelyobdellidae of Apathy (1890) for another ozobranch, nor any of the other proposals have been sustained in the recent reviews of the Piscicolidae by Knight-Jones (1962) and by Soos (1965), nor earlier (Autrum, 1936), etc., excepting that Silva (1960) retains a Tribe Branchiobdellinae containing the gilled "piscicolids" and some other genera, those having external pulsatile vesicles. In this group, the ozobranchs alone lack such vesicles, and the implied relationship cannot be sustained.

From my earlier experience of *Branchellion* and other piscicolids, the detailed study of the new ozobranchid emphasized the strong contrasts between the branchellionid and ozobranchid leeches, and the homogeneity of the latter both externally and internally so far as is known. In the genus *Branchellion* (see Meyer, 1941; Richardson, 1949; Moore, 1952; etc.) the the proboscis ends in segment viii or ix and glands enter at this point; a thin-walled tubular oesophagus continues to xiv, followed by a crop with 4 pairs of lateral caeca and a perforated median postcaecum; the intestine has several pairs (4) of lateral compartments. All this and other features are piscicolid and differ from the ozobranch.

Disregarding the presence of gills, then in the absence of lateral keeling, tubercles or conspicuous papillae, with less than four pairs of eyes, an annulation of a low order, and fully separate postcaeca, the ozobranch leeches would fall in Soos's analysis (1965) of the piscicolids into association with *Arctobdella* and *Sanguinothus*, two marine genera having only 18 (19—Knight-Jones, pers. comm.) independent ganglia on the nerve cord, but three are fused into an "anal ganglion of Apathy" and appear as a single element. Both have the typical short piscicolid proboscis, lateral pouches on the intestine, etc. and a relationship of the three cannot be sustained. In my own analysis (1959), the ozobranchs were associated with *Oceanobdella* (=*Abranchus*), *Ganymebdella,* and *Ottionobdella,* all having separate postcaeca (to these would be added *Arctobdella* and *Sanguinothus* described in 1961) but this group of five genera is unacceptable on the above basis. In the analysis by Knight-Jones (1962), the ozobranchs would fall into a group containing *Arctobdella, Ottoniobdella, Cryobdella,* etc. In contrast, *Branchellion* would become grouped with (Richardson) *Cystobranchus, Calliobdella;* with (Soos; Knight-Jones) *Trachelobdella* and *Calliobdella;* and shows conformity with the abranchiate *Calliobdella* in many respects.

There is nothing here to suggest that *Branchellion* is other than a piscicolid; that the branchellionids and ozobranchs have resemblance other than in the possession of gills; or that the ozobranchs have fundamental relationship with any group of genera in the Piscicolidae. Accordingly I provide below a separate family for the ozobranchid leeches. Under the Rules, there is no option other than to revive but redefine the Family Ozobranchidae Pinto 1921.

FAMILY OZOBRANCHIDAE PINTO 1921 (REDEFINED)

Clitellate rhynchobdellid leeches; no external pulsatile vesicles; mouthpore excentric; short proboscis followed by a longer pharynx terminating at xii/xiii; anterior intestine partially or completely a crop but lacking morphological compartments and with an anterior pair and posterior pair of caeca; posterior intestine with an anterior region carrying four pairs of dorsally directed tubular diverticula, the posterior region acaecate; testes compact, paired; male paired ducts terminate in a median muscular organ; anterior ganglionic mass includes 8 somital ganglia.

Marine and freshwater. Ectoparasitic on aquatic Chelonia and Crocodilia, known also from dolphins and the pouch of pelicans.

Type genus: *Ozobranchus* Quatrefages 1852.

The above definition being based on *Ozobranchus* might include the presence of gills, and the division of the abdomen into a branchial region carrying only one pair of gills to each somite, and a postbranchial region. With the example of *Branchellion* in the otherwise abranchiate Piscicolidae, it is reasonable to anticipate that the Ozobranchidae might attract abranchiate genera when a more complete knowledge of the clitellate rhynchobdellids has been gained. Such genera should conform to the nature of the ozobranch alimentary canal and reproductive systems. In the typical piscicolid male system, the paired male ducts terminate as well-developed separate dilated atrial cornua which enter independently into a median atrium (usually referred to as a "bursa"), a morphological organization associated with the production of a cylindrical sharp-ended spermatophore showing an essential double nature. There is no knowledge yet of the ozobranch spermatophore, but the terminal organs of the male system do not conform to the production of the typical piscicolid spermatophore. There is some morphological similarity to the terminal male organs in *Calliobdella* and *Trachelobdella* (e.g. *T. leptocephali* Ingram 1957) in the seminal vesicles each connecting by a short duct into a median muscular organ opening into the bursa. *C. lophii* (=*T. punctata*) has a short sac-shaped single-chambered spermatophore; but otherwise both genera are typically piscicolid, as is shown in the alimentary system. Conductive tissue is lacking in *Trachelobdella* and *Ozobranchus* (Selensky, 1915). All this appears to express parallelism but not relationship, a circumstance such as in the hirudinids (Richardson, 1969).

GENUS OZOBRANCHUS Quatrefages 1852

Ozobranchidae; ozobranchiform; anterior abdominal somites carrying each one pair of gills divided distally into many filaments; separate male and female genital pores; crop extends the length of the anterior intestine; anus at xxvi/xxvii.

Marine and freshwater. Ectoparasitic on *Chelonia,* recorded also from dolphins and the pouch of pelicans.

Type species: *Hirudo branchiata* Menzies 1791. Tropical Pacific.

Of the six species currently accepted in *Ozobranchus* (Soos, 1965), *O. branchiatus, O. jantseanus* (as also *"Lophobdella" quatrefagesi*) have separate genital pores. *O. shipleyi, O. margoi,* and *O. polybranchus* have a common genital pore, as in the new leech from Lake Boga. I have shown (Richardson, 1969) that generic relationships in the hirudinid leeches can be determined only from the internal morphology. This has been the approach with the rhynchobdellids for the past 80 years. The presence of one, as against two genital pores indicates probable differences in the terminal organs of the reproductive system such as may require a division of the above leeches into two groups, probably generic in status. The genus *Lophobdella* Poirier and Rochebrune 1884 was listed by Harding (1927) as a possible synonym of *Ozobranchus,* accepted as such by Autrum (1936) who figures *O. quatrefagesi* (1932) as also Harant and Grasse (1959). The species is not referred to by Sanjeeva Raj (1954) or Soos (1965) although both list crocodiles as hosts for *Ozobranchus,* this being known only for *quatrefagesi.* Both *branchiatus* and *quatrefagesi* have seven pairs of gills and two genital apertures; but the latter are described by Poirier and Rochebrune as on annuli 7 and 8 from which it is clear that *quatrefagesi* is a species uniannulate on the venter of the neck and so distinct from *branchiatus.*

OZOBRANCHUS BRANCHIATUS (Menzies 1791)

(Fig. 1 A, B, & D; Fig. 3 J)

Although a classical text-book animal for over a hundred years, records of this species are few. Sanjeeva Raj and Penner have only recently (1962) given the first detailed description of the externals. Taken originally in the Pacific, it is now known from Japanese waters, off the east and west coasts of India, off Sarawak, off Florida, and in Australian waters. The only known host is the green turtle, *Chelonia mydas,* with infestations ranging up to many hundreds on a single turtle. There is no previous record of it associated with a second species. The following description is based on a single specimen taken early in 1968 from near the vent of *C. mydas* at Heron Island by Dr. H. R. Bustard.

It is compactly club-shaped with strongly marked intersomital and interannular furrows; transversely and longitudinally convex above; flattened below; the anterior sucker wider than and set off from the neck which is briefly covered posteriorly by a prepuce. The abdomen is divided into the anterior branchial region carrying seven pairs of tufted filamentous lateral gills, and a shorter postbranchial region terminating to provide a wide basis for the heavily muscular sucker. The lateral margins diverge from the base of the anterior sucker to a maximum width at about the fourth pair of gills, are then subparallel, converging only slightly to curve obtusely from xxiii posteriorly. Nephropores are not detectable. Somital sense organs are low in profile, central in a_1 a_2 and obvious on the dorsum of the abdominal somites, but not on the venter.

The total length is 10·5 mm. The ovoidal anterior sucker is 1·5 mm. wide by 1·7 mm. high; the neck, 1·2 mm. wide by 1·0 mm. deep anteriorly, increasing to nearly 2·0 mm. in both diameters posteriorly where it is subcircular in section. The greatest width of the abdomen is 3·6 mm. at the fourth pair of gills where the depth is 3·0 mm., increasing to a maximum depth at about xxii behind which the depth diminishes and the dorsal profile is rounded to the base of the sucker. The base is about 2·8 mm. wide, more than half the width of the sucker which is 3·0 mm. wide and 2·75 mm. in length.

The colour (preserved) is white without pigment or pattern.

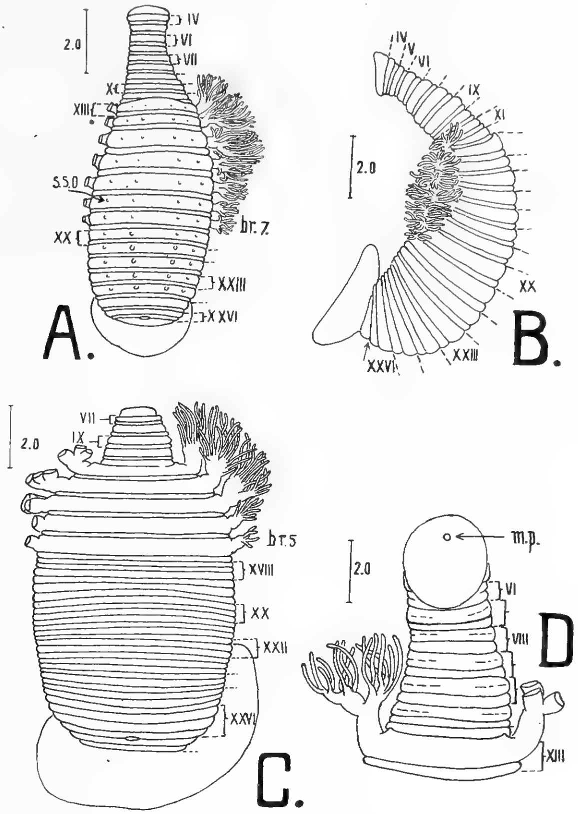

Fig. 1. A. *Ozobranchus branchiatus*, dorsal view, and B. lateral view. C. *Ozobranchus margoi*, dorsal view. D. *O. branchiatus*, ventral view of anterior sucker and neck. See key to lettering on figures, p. 80.

The face of the anterior sucker is oblique; the mouth-pore excentric, about half-way between the centre and the dorsal margin which is formed by the velum and continuous with the lateral and ventral margins, the margins being all anterior to the well-defined anterior limit of iv, so that iv does not contribute to the margin. Somite iv is 2–annulate, with $a_1 a_2 > a_3$ and complete on all aspects. There are no indications of eyes on iv. Somite v is narrower than iv, is 2–annulate on all aspects with $a_1 a_2 > a_3$ above but more nearly subequal below; vi with $a_1 a_2 > a_3$ above and below, and with traces of a furrow a_1/a_2 at the margins; vii to xi, 2–annulate above and below with $a_1 a_2 > a_3$ on all aspects, and with weak indications of a_1/a_2 on the ventral intermediate and submarginal areas; xii, 2–annulate above and below, with $a_1 a_2 = a_3$; the male genital pore is situated in the furrow $a_1 a_2/a_3$, and the female pore in the middle of xii a_3.

The abdominal somites xiii to xxvi, are regularly 2–annulate, with $a_1 a_2 > a_3$ above and below, a_1a_2 longer above than below and markedly more so in the postbranchial somites. The anus is at xxvi/xxvii. Somite xxvii is uniannulate in this specimen, not 2–annulate as in Sanjeeva Raj and Penner (1962), and xxvii does not continue onto the venter.

The first gill is of the general dimension of the second, but with fewer filaments; the second and third are nearly equal in size with about 15 filaments in the tuft; the fourth, smaller; the fifth, smaller again and with some 8 filaments; the sixth smaller; and the seventh the smallest in the series, markedly smaller than the first, and with some 8 filaments.

The specimen is not well-preserved internally. The internal anatomy so far as seen in hand dissection is ozobranchid. The anterior ganglionic mass is just posterior to vi/vii, with two independent ganglia between it and the terminal mass of the male reproductive system, the nerve cord then arching high over the mass so that the third ganglion is anterodorsal, and the fourth dorsal; closely similar to *Bogabdella*. The proboscis terminates at vi/vii, followed by a strongly muscular pharynx extending to xii/xiii, with two pairs of elongate glands entering at a point about two-thirds along the length, each gland a cord of large cells. The pharynx arches above the terminal mass of the male system to join to a tubular crop, filled with blood, swollen, and as seen from above apparently divided into five sub-equal compartments weakly marked off from each other by shallow open lateral grooves; but as these grooves do not continue onto the dorsal and ventral aspects of the crop, and as the postcaeca originate from the middle area of the side-wall of the last "compartment", there is nothing here of true morphological compartmentation. There is a pair of small thin-walled latero-ventral anterior caeca at the anterior end of the crop but these contain no blood, and large blood-filled completely separate postcaeca; but no other caecation.

The crop curves ventrally posteriorly, so that the posterior end is low in the body-cavity and the intestine is ventral on the floor of the paramedian chamber, horizontal, then arches dorsally with an ascending limb and a descending limb which connects to the rectum. The anterior diverticulate portion includes the ventral horizontal portion and the ascending limb. The four pairs of large dorsally directed tubular diverticula are nearly equal in diameter to the posterior nondiverticulate portion of the intestine, follow a tortuous path, intertwine, extend to the dorsal aspect of the body-cavity, are long and fully occupy the paramedian chamber.

Four pairs of testes are present in the usual position, but nothing further could be determined of the male system excepting a narrow elongate muscular organ crossing obliquely over the dorsal surface of the terminal mass of the male system. The ovaries are elongate, cylindrical, of the form and size in *Bogabdella* but extending further anteriorly before tapering into the tubular oviducts which are bridged beneath, but not above the crop, by a commissure of the diameter of the oviduct. Short paired oviducts descend from this bridge to join into a short small vagina beneath the nerve cord. There was no expansion on the lower portion of the oviducts.

The regional anatomy of the alimentary canal conforms generally to the account by MacCallum and MacCallum (1918), but I saw nothing to correspond to the second, posterior pair of branched tubular glands entering the crop. In the section shown in their Pl. xxxv, it would seem that these "glands" are actually a pair of thin-walled anterior caeca. The ovaries and oviducts seen in the present specimen agree with the description by Oka (1904) and not that by the MacCallums who describe very short oviducts joining to a longer common oviduct.

The present specimen is most valuable in showing the expansion of the whole length of the anterior intestine into a storage organ, a crop extending for its full length from the proboscis to the posterior intestine, and the absence of morphological compartmentation. The proboscis could not be drawn back through the encirclement of the anterior ganglionic mass by tension on the pharynx.

OZOBRANCHUS MARGOI (Apathy 1890)

(Fig. 1 C)

One specimen taken from *Chelonia mydas* at Heron Island early in 1968 by Dr. H. R. Bustard. Deposited in the Australian Museum, Sydney, N.S.W., Coll. No. W. 4185.

This is the first record of this rare species in the southern hemisphere, as also of its occurrence on *Chelonia mydas.* Otherwise it has been known (Sanjeeva Raj, 1959) in the original collection of thousands of specimens from the head of a single turtle, *Thalassochelys corticata,* in the Mediterranean; two specimens obtained by Oka from *Delphinus longirostris* in the Sea of Sagami, Japan and two further specimens from *Caretta olivacea* on the coast of Fukoka; and finally by Sanjeeva Raj in 1959 who took over a thousand specimens from the right fore-limb of *Eretmochelys imbricata* in the Bay of Bengal near Madras.

Apathy's account is unavailable. Oka's descriptions are meagre. Selensky (1915) gives an internal anatomy of specimens taken by Apathy but essentially no external detail. Sanjeeva Raj (1959) briefly records the taking of the leech. The external features are inadequately known and the species poorly defined other than in the presence of five pairs of filamentous gills.

Unfortunately, my specimen is unsuitable for a detailed study of the internal anatomy. Sufficient was seen to establish that the figures given by Selensky (Pl.i, Fig. 2, general morphology; Pl.vi, Fig. 16, reproductive system) are highly diagrammatic to the point of being misleading and cannot be interpreted correctly from the detail in the text. For example, in Pl.i, Selensky shows a somewhat compartmented crop, wide throughout its length and nowhere narrowed as necessary for this organ to pass through the bridged and limited passage between the oviducts as shown in Pl.vi where the passage is no larger than the second one which is only of such size as to pass the nerve cord.

The single specimen is contracted; the total length, 12·5 mm.; the neck region, 2·0 mm. long, about 0·5 mm. wide anteriorly where it is transversely elliptical, increasing in width posteriorly to become subcircular and about 2·0 mm. in each dimension at the end. The abdomen is broadly ovate in outline; the dorsum longitudinally convex; the venter nearly flat; and uniformly deep over most of the postbranchial region. The abdomen widens rapidly along the branchial somites to a width of nearly 6·0 mm. which is maintained back to xxii/xxiii where it narrows gradually posteriorly to end obtusely and provide a base 2·0 mm. wide to the very large heavy muscular thick posterior sucker which is essentially circular and nearly 8·0 mm. in diameter. Since it is contracted, the sucker must be of very large size in life.

The animal is white, without colour or pattern excepting that the gill-filaments are light brown.

The contracted anterior sucker is deeply cupped. The mouth-pore could not be seen but the point of the needle indicated that it is subterminal. There are no indications of eyes. The neck is strongly contracted and somite xii almost completely concealed beneath the prepuce. When the prepuce is split along the midventral line, a single genital pore is seen and the point of the needle did not indicate a second pore. The branchiate region is about a third of the length of the abdomen. The first four gills arise each from an anteroposteriorly compressed base which is about as long as the secondary divisions to which the filaments are attached. The first gills are large, about equal to or slightly larger than the second; the third smaller than the second; the fourth much smaller than the third; and the fifth pair much reduced in size and with only some 6 or 7 filaments. The anus is concealed and followed by two annuli complete on all aspects. The posterior sucker is slightly cupped, the rim, thin, and the inner surface, plain. Somital sense organs and nephropores could not be detected.

The contracted cupped form of the anterior sucker prevents recognition of somites i to vi; vii, the first obvious somite, is 2–annulate with $a_1 a_2 > a_3$ above as also viii to x, and as x and xi are recognizably 2–annulate below, the general nature of vii to x is almost certainly 2–annulate above and below; xi, 2–annulate with $a_1 a_2 = a_3$; xii, apparently undivided, with a single genital pore median in the somite; xiii to xvii, 2–annulate above with a_1 $a_2 > a_3$, and the gills extend from a_1 a_2 in each, the furrow a_1 a_2/a_3 is indicated in the marginal region below but not present in the median region of the venter. From my experience with the new leech, it would seem that the branchiate somites are 2–annulate above and below.

In the strongly contracted condition, with no obvious land-marks for the determination of the somital annulation in the postbranchial region, there were indications on one side or other, occasionally across the dorsum of furrows which were deeper than the ordinary interannulars and apparently intersomital. The interannulars were less definite to almost obscure, even erratic on the median third of the dorsum, and all furrowing on the venter was vague and unreliable. Using the "intersomitals" gave the following annulation: xviii (3); xix (2); xx, xxi (3); xxii, xxiii, xiv (4), a pattern so improbable as to be rejected.

The alternative is a 3–annulate condition for xviii to xxvi, which agrees with the uniformity of annulation in *O. branchiatus,* in *O. shipleyi,* and in the new leech. This places the anus at xxvi/xxvii, with xxvii postanal, 2–annulate, and complete on all aspects, dorsal, lateral and ventral. I can see no indication that this is not the correct annulation in the postbranchial region.

So far as seen, the internal anatomy is ozobranchid: the anterior ganglionic mass commences at vi/vii; the ventral nerve cord arches high over the terminal mass of the male system, but the ganglionation of the nerve cord could not be determined. The proboscis is short, anterior to the encirclement of nerve tissue; the long muscular pharynx extends back in xii/xiii with a pair of right and of left glands entering well before the posterior end, each gland a cord of large cells. The anterior intestine was disintegrated excepting for the large postcaeca extending separately back to the paramedian chamber of the body-cavity. The posterior intestine has an anterior ventrally situated short diverticulate portion carrying four pairs of very long tubular dorsally directed diverticula, and a longer acaecate portion with a loop having an ascending and a descending limb, all excepting the descending limb within the median chamber of the body-cavity. The paramedian longitudinal palisades of the dorsoventral musculature are well formed on either side of the posterior intestine and meet posteriorly as a tranverse sheet and the posterior portion of the intestine passes through a foramen high in this sheet, descending behind it to the rectum.

The female reproductive system was grossly swollen, soft, and disintegrated on manipulation. Nothing could be determined from it. Four pairs of testes were present, the last at xvii/xviii. Anterior to the first testis, there was a compactly coiling ensheathed mass of epididymis dorsal to an ensheathed compact, closely coiling narrow muscular duct, which would seem to be the long ejaculatory duct described by Selensky. This is dorsal to an elongate transparent, thin-walled colourless sac containing clear bodies which are of similar size and appear to be mature sperm-balls. The ventral element seems to be the spermatic vesicle of Oka and Selensky, but is much larger in size than in their figures. The above three structures are paired and posterior to the terminal mass of the male system. A thin-walled median, non-muscular elongate ovoid organ attached to the posterodorsal aspect of the terminal mass of the male system, contains white, immature sperm-balls and would seem to correspond to the duct of the seminal receptacles of Oka and Selensky, but the latter could not be recognized.

BOGABDELLA, gen. nov.

Ozobranchidae; ozobranchiform; anterior abdominal somites carrying each one pair of elongate bluntly terminating digitiform gills; common genital aperture in the middle of xii; large seminal vesicles; ejaculatory ducts, short; seminal receptacles as expansions of the oviducts; no median copulatory duct; anus in the posterior margin of xxvii.

Freshwater. Ectoparasitic on Chelonia. Australian Region.

Type species: *Bogabdella diversa* n. sp. (As below). Type deposited in the Australian Museum, Sydney, N.S.W. Coll. No. W. 4184, taken by Mr. Peter Meyer from *Emydura macquari* at Lake Boga, near Swan Hill, Victoria, Nov. 26, 1967.

(Boga, geogr. name; bdellos, a leech. f.)

BOGABDELLA DIVERSA, n. sp.

(Fig. 2 E, F, G, H, I; Fig. 3 K, L)

A small leech with the body divided into a distinct anterior sucker wider than the neck; a single pair of eyes; mouth subterminal; short sturdy neck covered briefly by a prepuce; the enlarged abdomen carrying 8 pairs of digitiform gills on the anterior region, and the postbranchial region terminating in a large thick strongly muscular sucker wider than the abdomen. The epidermis is without papillae and generally transparent in life. Colour, dependent on internal structures of which the large paired dark simple independent postcaeca are obvious. Lacking cutaneous pigment excepting for 10 elongate radiating white patches on the dorsum of the posterior sucker.

Preserved, 4·0 to 5·0 mm. long contracted and 7·5 mm. in full extension. The smallest specimen, 2·0 mm. extended. In an extended preserved animal of a total length of 7·25 mm., the anterior sucker and neck total 3·0 mm. in length; the sucker is 1·0 mm. in width. The neck gradually widens to a maximum of 1·5 mm. at the posterior end where the depth is the same. The abdominal region is 4·0 mm. long; the branchiate portion, 2·6 mm. long; the greatest width, 2·3 mm. in the vicinity of the last gill which is also the region of greatest depth, 2·0 mm. The posterior sucker is circular, 3·0 mm. in diameter and nearly 1·0 mm. in thickness. The proportions of the body vary greatly with contraction. In a strongly contracted specimen, the total length is 4·0 mm.; the anterior sucker and neck total 1·0 mm.; the branchiate region, 1·25 mm.; the maximum width, 2·3 mm.; and the posterior sucker is 4·0 mm. in diameter.

The anterior sucker is excentrically attached, the face oblique and broadly oval, the dorsal length about twice that of the ventral. It is shallow, thick-rimmed, and the preocular region forms a distinct short rounded velum. White sensory patches are present on the margin of the velum and of the sucker. The small pore-like mouth is median, located just below the edge of the velum, and subterminal. The single pair of brown eyes are spaced well apart, deeply situated and do not show a distinct outline. The narrow neck forms the base of the sucker. The neck is transversely oval in section anteriorly, deepening and widening to subcircular posteriorly, and in contraction the prepuce fully covers xi and xii. The abdomen is longitudinally and transversely convex above, flattened below, and increasingly convex above posteriorly, deepening so that the posterior third of the abdomen in the fully extended animal is almost circular in section. The whole abdominal region is more depressed in the fully extended animal and also in the strongly contracted animal in which it terminates obtusely.

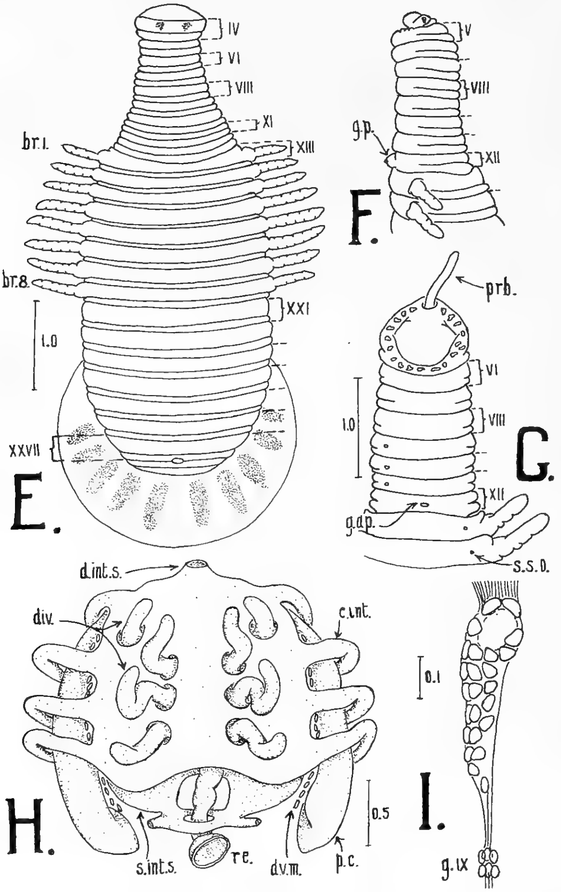

Fig. 2. *Bogabdella diversa*: E. dorsal view; F. lateral, and G. ventral views of the anterior region; H. posterior coelomic system; I. anterior ganglionic mass, left lateral aspect. See key to lettering on figures, p. 80.

The anterior portion of the abdomen carries 8 pairs of simple, undivided, bluntly terminating, slightly tapering digitiform gills which are transversely ridged or unevenly corrugated in life, translucent, slightly swollen at the base, and appear to be divided internally by a longitudinal vertical septum. They increase in length from the first to the fourth or fifth, then progressively shorten, but the last gill is always obviously, even if only slightly, longer than the first. In life, the longest gill when extended is more than half the width of the abdomen. The swollen base is not pulsatile. The anus is situated at the base of a distinct pit. The mouth of the pit is always widely open and remote from the base of the sucker. The base of the sucker is about one-third of its width. The sucker is centrally attached but oblique to the long axis of the body due to the fore-shortening of the venter of the body in the postbranchial region.

The body-wall varies in thickness. In dorsal view, the narrow proboscis can be seen between the mouth and the anterior ganglionic mass; many clitellar gland cells; and the large postcaeca. The ventral aspect of the neck is quite transparent, to such degree that the proboscis, anterior ganglionic mass, several independent ganglia of the ventral nerve cord, the muscular pharynx, the mass of the terminal organs of the reproductive system, the seminal vesicles posterolateral to this mass, the diverging rows of the testes, and the postcaeca can all be readily distinguished. These internal structures are visible according to the regional development of the muscular layers of the body-wall, the distribution of the pigmented botyroidal tissue, and the clitellar glands. These large gland cells are situated between the level of the anterior end of the anterior ganglionic mass and the anterior end of the postcaeca as a thick sheet internal to the botyroidal tissue, dorsal and lateral to the internal organs, and in greatest numbers in the genital and pregenital regions. The cells are arranged on longitudinal cords, there being numerous ducts but there are no aggregations of ducts into columns as known in some piscicolids (e.g. *Branchellion*, Meyer, 1941; *Bdellamaris*, Richardson, 1953). The botyroidal tissue is present as a sheet lining the dorsal and lateral aspects of the muscular envelope, thinnest dorsally in the pregenital and genital regions, and increasingly thicker posteriorly to the base of the sucker, but very thin on the ventral aspect of the postbranchial region.

Annulation.—(Fig. 2 E, F, G.) Somital sense organs are minute, rarely visible, never showing as a complete series, and to be seen only on partially extended live specimens where a few supramarginals and submarginals may show as very small white points which are central in the length of a_1a_2 on the neck and abdomen. The nephropores could not be detected. In contraction, fine superficial longitudinal furrowing may subdivide the annuli into narrowly rectangular areas; but such vanish as the animal extends. The intersomital and interannular furrows are definite in the live animal at all times, but are obliterated in the fully extended preserved specimen. They do not show on the venter of the postbranchial portion of the abdomen other than at the margins in the partially contracted preserved specimen.

The dorsum of the anterior sucker is crossed by a furrow which is incomplete laterally, just anterior to the eyes, and an incomplete furrow behind the eyes marking off the ocular annulus which is followed by a shorter annulus, defining iv which is clearly 2–annulate, with $a_1\ a_2 > a_3$, the eyes in a_1a_2, and iv is incomplete, there being no indication of a_1a_2/a_3 on the margin of the velum or on the face of the sucker. The region anterior to iv is a well-defined velum which can be turned ventrally over the upper portion of the face of the sucker. Somite v is narrower than iv, forms the base of the sucker, and iv/v extends onto the lateral aspect so that v then forms the lateral and ventral portions of the margin of the sucker. Somite v is 2–annulate with $a_1\ a_2 > a_3$, and uniannulate below. The intersomital furrows on the neck are more pronounced than the interannular and the annulation of vi to x is clearly 2–annulate above with $a_1 a_2 > a_3$, and uniannulate below. Somite x widens and with xi and xii forms the genital region, apparently the clitellum, and although xi and xii are 2–annulate above, the annuli are short, and in these two somites $a_1 a_2 = a_3$ above. The single external genital pore is commonly mounted on a low, rounded, ventrally directed papilla on xii which shows no annular furrows below, but the papilla may be retracted, the external genital pore in the middle of xii, and covered by the prepuce.

Somite xiii is widened and longer than the anterior somites, divided into $a_1 a_2 > a_3$ above, uniannulate below; the furrow $a_1 a_2/a_3$ terminates behind the base of the gill so that $a_1 a_2$ carries the gill, forms the prepuce above, and strongly sets off the abdomen from the neck. Somites xiv to xx are all 2–annulate above with $a_1 a_2 > a_3$, uniannulate below, and each carrying a pair of gills on $a_1 a_2$. Somites xxi to xxvii are postbranchial, 2–annulate above with $a_1 a_2 > a_3$, uniannulate below, and the somite shorter on the ventral aspect than on the dorsal. The shortening of the somites on the venter is associated with the strong longitudinal convexity of the dorsum of the postbranchiate region.

An anal pit is situated at the posterior border of xxvii. There are two annuli of equal length behind the anus and these are complete on all aspects, dorsal, lateral and ventral, as also xxvii, and these are obviously a provision for an increased flexibility of the body on the sucker made necessary by the great size and thickness of the large and heavy muscular sucker. There is no indication of annulation on the dorsum of the posterior sucker, and the ventral face is plain.

Internal anatomy.—Dorsoventral musculature. (Figs. 2 H; 3 L.)

Dissection showed this system obvious only as strongly developed almost continuous sheet-like paramedian palisades standing between the intestine and the postcaeca, from about xx to xxv or xxvi, so that the postbranchial region contains a very well-formed tall median longitudinal chamber containing the diverticulate and posterior portions of the intestine, and the diverticula; and lateral chambers containing the postcaeca. In the branchial region of the abdomen, the testes and seminal vesicles were rather freely movable in the absence of a paramedian palisade as such, and only some few dorsoventral strands of muscle were present, there being nothing in the nature of a palisade. I could find no indication of formed longitudinal intermediate palisades.

In view of the mass of the posterior sucker, it seems quite possible that the well-developed paramedian palisade may have some function in relation to the sucker. There is certainly no paramedian palisade of this order in the hirudinids where the posterior sucker is moderate to small in size (Richardson, 1969).

Central nervous system.—(Figs. 2 I; 3 L.) There are only 19 independent ganglia on the ventral nerve cord, differing from the usual pattern in leeches of : 21 such ganglia; an anterior ganglionic mass containing 6 somital ganglia; and a posterior mass of 7 somital ganglia. The external somital organization conforms to the usual circumstance of 27 preanal somites.

The first two independent ganglia are pregenital and ventral. The cord then arches high over the terminal mass of the male system, the third ganglion being anterodorsal to the mass; the fourth median dorsal; the fifth posterodorsal; and the sixth posterior and nearly ventral. The sixth and seventh ganglia are slightly crowded, the interspace being no more than the length of a ganglion. The seventh to nineteenth ganglia are ventral, at first well-

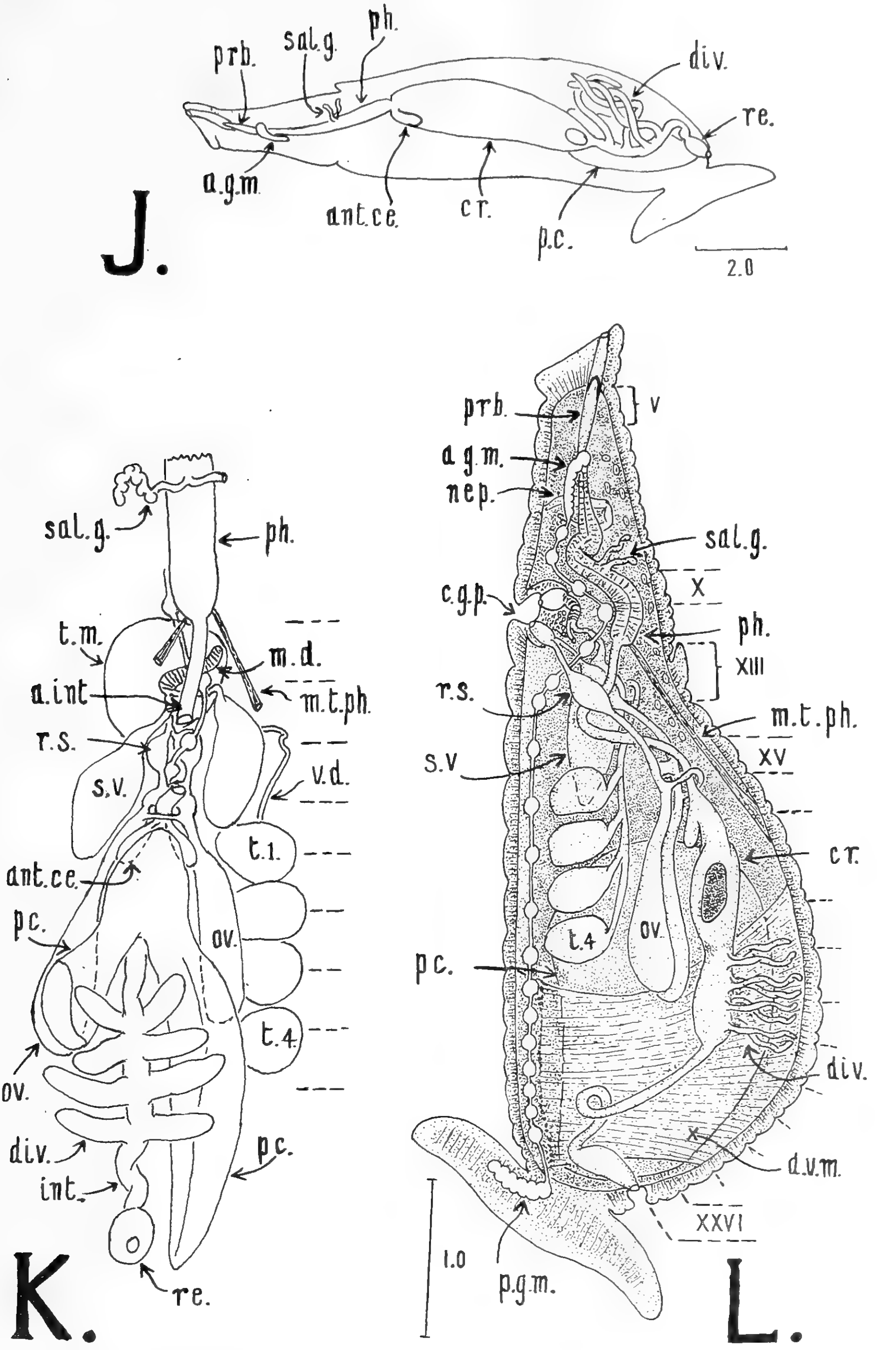

Fig. 3. J. *Ozobranchus branchiatus*, alimentary tract, semi-diagrammatic, only the left intestinal diverticula are included. K. *Bogabdella diversa*, dorsal view of alimentary and reproductive systems dissected and removed, the ovaries and posterior testes displaced laterally. L. *B. diversa*, semidiagrammatic, general internal anatomy from the left aspect. (Note: For clarity, the dimension and form of various organs have been slightly altered and this figure should be read with reference to K, but the postcaeca are shown here as when fully expanded.) See key to lettering on figures, p. 80.

spaced, then closer approximated, the interspace diminishing to about one half of the length of a ganglion, illustrating internally the fore-shortening of the ventral aspect of the postbranchial region; but since the reduction of the interspaces is progressive, there is no indication of an anal ganglion.

Assuming the last independent ganglion to be that of xxvii as usual, the fifth ganglion posterodorsal to the mass of the male system will be the somital ganglion of xiii; the fourth, dorsal to it and above the genital pore, will be xii; and the first independent ganglion will be that of ix.

A whole mount cleared preparation of the posterior sucker stained with acetic alum-carmine shows seven pairs of radiating ganglia in the posterior ganglionic mass, as typical in leeches. Three preparations in a similar manner of the anterior ganglionic mass dissected out from the animal, show 24 (one, 25) ganglionic capsules on the one side, indicating that the mass consists of 8 somital ganglia (the additional capsule in the one case does not disturb this conclusion, and is an error in reading the preparation). This agrees with Selensky's finding (1915) that the anterior ganglionic mass in *O. margoi* consists of the ganglionic components of 8 somites, with the first independent ganglion being the somital ganglion of ix. It will be seen in the figure presented here that the mass is markedly longer in form than in the case where the ganglionic mass contains only the usual 6 somital ganglia.

Alimentary tract.—(Fig. 3 K, L.) This consists of a short proboscis anterior to the anterior ganglionic mass; a longer muscular pharynx; an anterior intestine initially narrowly tubular giving off posteriorly two small ventrolateral caeca, then expanding into a short crop with paired separate postcaeca; a posterior intestine divided into an anterior diverticulate portion and a simple tubular posterior portion; a short rectum.

The protruded proboscis is narrowly cylindrical, weakly muscular, and about 0·5 mm. long. It is housed in a thin-walled sheath extending back to the anterior end of the anterior ganglionic mass in which there is a restricted passage through which the proboscis connects to the much wider strongly muscular pharynx. This latter has also been referred to by authors as "proboscis"; but in dissection it is clear that the passage through the ganglionic mass is of such small diameter that little if any of this muscular organ can pass through it so that it is preferable to distinguish it as a separate organ. No protractor muscles could be found on the pharynx. The pharynx extends from vii to xii/xiii and is ensheathed throughout its length. It is provided with two short tortuous tubular glands, each a cord carrying a few large white gland cells. These enter the dorsal aspect of the pharynx at about the middle of its length. The lumen in both the proboscis and pharynx is minute.

Two long narrow diverging bands of muscle extend from the posterior end of the pharynx back to originate on the dorsal aspect of the body-wall envelope on either side of the mid-line at about xvi/xvii. These would seem to correspond to the retractor muscles described in some piscicolids (e.g. the pontobdellids, Llewellyn, 1966; etc.); but in view of the improbability of protrusion of this pharynx in the ozobranch, the muscles would appear to serve another function. The pharynx is not shortened in the strongly contracted animal, but thrown into a transverse fold in ix and x. The pregenital region is the most extensible portion of the body. In full extension, the posterior end of the pharynx remains in xii. It seems then that the function of these muscles is not the retraction of an anteriorly extended organ, but the retention of the posterior end of the pharynx in position during extension of the pregenital region, this to prevent the transmission of traction onto the anterior intestine such as would interfere with the function of the crop and postcaeca. The open loop on the first part of the anterior intestine probably has the same functional value. On this interpretation, it is more correct to term these the mm. teniens pharyngis.

The anterior intestine commences at the end of the pharynx as a thin-walled narrowly tubular organ extending posteriorly, dipping ventrally behind the terminal mass of the reproductive system, then ascending between the oviducts to pass between the two transverse bridges joining the oviducts and to give off two short simple thin-walled ventrolateral caeca before expanding into a thick-walled chamber in xvii or xviii and xix which gives off the large thick-walled postcaeca. There is nothing in the tubular region which is suggestive of a crop of the usual nature, no indication of compartments or of other potential for storage. The thin wall of this region is almost transparent and without rugae, as also the ventrolateral caeca in full contrast to the thick wall of the major chamber which is of the same nature as the wall of the postcaeca. The latter extend lateral to the paramedian palisades back into xxv when empty and into xxvii when full. The postcaeca are deep, the dorsal margin curving ventrally, the lower margin almost straight, both conforming to the shape of the abdomen. The lateral face is convex; the medial face partially concave providing space for the intestinal diverticula, ovaries and the posterior testes which lie medial to the postcaeca in the median longitudinal chamber. When partially empty, the postcaeca are light brown above, of the colour of the botyroidal tissue; but brightly bluish green below, a colour of high intensity such as I have not seen in these organs in other leeches.

The posterior intestine is thick-walled, stoutly tubular initially as an anterior diverticulate portion dorsal in xx to xxiii, and shorter than the more narrowly tubular very thin-walled posterior portion. There are four pairs of dorsally directed diverticula originating from the dorsolateral aspect of the anterior region on this intestine. They are thick-walled, narrowly tubular, elongate, corrugated and much folded, intertwining above the intestine; but short, stoutly tubular and brownish in colour when contracted. The posterior portion of the intestine descends ventrally behind the diverticulate region, is thrown into an open loop before connecting to the ventral end of the thin-walled rectum which is short, almost vertical and in xxvii. The anal pit is of the depth of the body-wall.

Reproductive system.—(Fig. 3 K, L.) There is a row of four subspherical testes on each side; the rows diverging posteriorly; the last two pairs of testes being medial to the anterior portion of the postcaeca. As determined by external annulation, the posterior testes are at xix/xx; the anterior, at xvi/xvii. The seminal vesicles are more elongate than the testes and extend from xvi/xvii anteriorly to xiii where they are lateral to the oviducts and the terminal mass of the male system. The vasa efferentia and vasa deferentia could not be seen in simple dissection, but from the manner in which the testes could be moved, it seems that the efferentia open from the dorsal aspect of the testes. In a dissection stained with acetic alum-carmine, a portion of the vas deferens could be seen anterior to the first testis, extending forward into xiv and reflecting posteriorly from there as though to enter the medial face of the seminal vesicle just before the posterior end. The seminal vesicles taper anteriorly each into a short ejaculatory duct, in part applied to the face of the terminal mass of the male system, and then the two enter separately into the end of an elongate muscular organ which is entirely bound to the face of the terminal mass, passes obliquely dorsolaterally over the anterior portion of the mass to enter it on the right side. This thick-walled muscular duct ends distally in a swollen papilla in the male bursa which opens at the male genital pore in the common genital chamber. This organ has been referred to as a "penis" (Selensky, 1915) but it is bound so firmly to the face of the terminal mass that it seems most unlikely it is protrusible. I was entirely unable to demonstrate a bulbous or spherical male atrium receiving the paired ducts as described in *O. margoi* by Selensky.

The ovaries vary greatly in size. Non-gravid, the two short ovaries lie side by side lengthwise in the median longitudinal chamber of the body-cavity, beneath the alimentary canal, the posterior end in xix or beneath the diverticulate portion of the posterior intestine. They are posteriorly bluntly rounded, elongate pyriform with a thin transparent wall. All dissected in this condition showed a single large ovum at the posterior end of the ovary, and the ovarian cord simply reflexed anterior to the ovum. The gravid ovaries are enlarged in diameter and lengthened, extending to the posterior end of the diverticulate region on the intestine and uniformly tubular to the level of the first testis so that they extend from xxiv to xvi and occupy the greater length of the abdomen, being morphologically longer than as known to me in the piscicolids. They then each contain in the order of 10 or 12 large dense ova, and the cord is not obvious. The ovaries narrow anteriorly into oviducts which are tubular, widen slightly where they are connected by a bridge transversely above the anterior intestine immediately anterior to the expansion into a crop, and wider again below this to provide the ventral bridge which is more of the appearance of a small compartment connecting the oviducts. Below this, they narrow again as independent ducts expanding each into a distinct vertical chamber just dorsal to the nerve cord, continuing independently below the chambers as narrow oviducts which join separately into the median vagina which is closely applied to the posterior face of the terminal mass. The mouth of the vagina opens into the common genital chamber.

I was unable to demonstrate anything in the nature of a median copulatory duct or paired seminal receptacles and their associated ducts separate from the oviducts as described in *O. branchiatus* (Oka, 1904) and *O. margoi* (Selensky, 1915) and it would seem that the expanded chambers on the lower portion of the oviducts are seminal receptacles.

Coelomic system.—(Fig. 2 H.) On initially opening the abdomen, in several specimens the contents of the coelomic system were seen to be gelled and to present a delicate but definite cast of the coelomic chambers and circumintestinal connections.

A narrow tubular sinus dorsal to the crop expands into a wide flat chamber above the posterior end of the crop and posterior intestine. There are two longitudinal rows, each of four perforations through which the intestinal diverticula pass to become loosely tortuous in the space above the chamber. The chamber is extended laterally on each side by four tubular loops which pass through the paramedian palisade into the paramedian chamber, the first anterior to the root of the postcaecum and so encircling the posterior end of the crop, the other three descending lateral to the postcaecum. These join to the subintestinal sinus which is also flattened, but not as wide as the dorsal and bifurcates posteriorly, the two ends being connected by a dorsal and a ventral transverse commissural sinus so forming a loop around the posterior portion of the intestine. From this loop, short right and left small tubular sinuses extend laterally and then ventrally, possibly to the ventral median longitudinal sinus but this could not be demonstrated.

General observations.—The four original specimens sent me by Mr. John Goode were dead and partially decomposed when received. Mr. Goode then arranged with Mr. Peter Meyer for further material, and Mr. Meyer sent me 8 specimens. He noted that 6 were clustered on the neck of *Emydura macquari* and were very difficult to remove. When they came into my hands some 48 hours later, they were in excellent condition, clear, translucent, quietly active, and the postcaeca expanded with blood. They survived well in water in a petrie dish. I killed the last specimen, still active, 10 days later.

This leech is essentially sedentary. It performs the usual undulatory movement which is commonly referred to as respiratory, but in a rather leisurely manner; the amplitude of the wave is low, and the length is long. The gills move in a metachronial manner as the wave passes along the body; but not at other times, and the gills are generally inactive although capable of an occasional movement. One gill might contract slightly; another, extend; but there is nothing in the nature of a rhythmical movement of the gills in the quiet animal. The gills are insensitive, show no response to stroking with the needle or to other simple stimuli, as is also the case with *Branchellion parkeri.*

Movement of a colourless fluid in the gills can be detected in the motion of small non-pigmented cells. During movement of the body, this fluid was seen to surge in the gill as though on the two sides of a longitudinal vertical septum extending the full length of the gill; but at rest no regular movement of the fluid could be determined. There seemed to be nothing of the nature of the capillary network found in *O. margoi* by Selensky (1915). There was never any indication of pulsation in the swollen basal portion of the gill, nor could pulsatile vesicles be detected adjacent to the base of the gill. Although the transparency of the body was favourable, no contractions of lateral longitudinal vessels were seen.

Sedentary, with the body raised slightly and obliquely on the posterior sucker, the animal has the swollen semiglobular abdomen, short neck, and large posterior sucker which collectively is typically "ozobranchid". The body lowered to the surface can be elongated, the elongation being mainly of the branchial and anterior portions of the body, these regions becoming narrowed and depressed; the anterior sucker bluntly and narrowly triangular; but the postbranchial region remains convex and swollen. MacDonald's figure (1877) is an excellent representation of the extended ozobranch.

The animal moves when gently encouraged to do so, and then there is little of the usual graceful and precise looping which is general among leeches. This is an animal in which the bulk and diameter of the large posterior sucker interferes significantly with movement. With the body extended parallel to the surface, the anterior sucker gains attachment. The body then contracts, slowly dragging the posterior sucker forward across the surface, and if a loop is formed it is at this last moment when the nearly contracted body is raised as a small loop just sufficient to enable the sucker to be placed flat for attachment. Because of the relatively large diameter of this sucker, only a short step is taken. One specimen was 4·0 mm. long contracted; extended to 7·5 mm.; and the step was not more than 4·0 mm. It is a slow, clumsy, poorly managed movement, differing from the piscicolid *B. parkeri* which can move gracefully, rapidly, and most erratically.

Otherwise also, the animal is embarrassed by the mass of the large sucker. It cannot swim. Dropped into water, it sinks without control. Fallen onto its back, the righting reaction is entirely unusual. It is quite typical of other leeches to secure an attachment with the anterior sucker, and to employ this as a fixed point on which to rotate the body lengthwise from the anterior to the posterior end to gain normal orientation to the surface. *B. diversa* fallen onto its back in water, does not so far as I saw ever gain attachment with the anterior sucker. It appears to attempt to do so, partially and slowly turning the sucker and neck on the long axis, an action spreading onto the first few somites of the abdominal region and no further. Then, as though the release of a lengthwise torsion-tensioned rod, the anterior end rotates rapidly in the opposite direction and the whole animal jerks over into normal orientation without either sucker having first been in contact with the surface. This final action is extremely rapid and positive. It can be recognized that the necessity for some such action as this comes not only from the great mass and diameter of the sucker, but also from the attachment of such a sucker obliquely to the globular relatively inflexible postbranchial region where the capacity for contraction and extension is minimal.

Bogabdella diversa is sensitive to strong light from above, with which it may move or contract, and responds most unusually to strong light from below. With this, it erects the body on the posterior sucker, then coils the neck ventrally in a flat spiral with the anterior sucker on the inside of the spiral, and this is turned down under the branchial region. It remains with the anterior end coiled in this manner until the light is turned off.

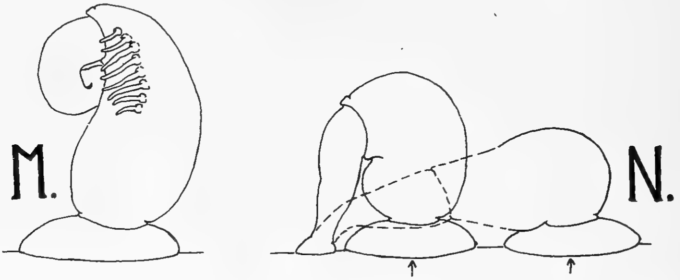

Fig. 4. *Bogabdella diversa*: M. Attitude adopted when subjected to strong light from below. N. Diagram to show the limitation on the length of step due to the large diameter of the posterior sucker and the reduced extensibility of the postbranchial region. See key to lettering on figures, p. 80.

Various authors describe ozobranchs as in a "solid mass", in "clumps", "aggregated" on the host. Five specimens of *B. diversa* were separated widely from one another in a petrie dish at 8.00 p.m. In the morning they were closely aggregated. This was repeated several times. It would appear that aggregation is a natural requirement and clumping on the host something more than the occupation of a limited suitable site. Two placed apart in a petrie dish did not act in the above manner.

The general appreciation of the zoology of the ozobranch is derived from the relatively limited knowledge of *O. branchiatus*. MacCallum and MacCallum (1918) describe and figure the somewhat circular depressed cocoon attached to the turtle; the young leech, unable to swim because of the large sucker; and large colonies indicative of prolonged infestation. The life-history of *Chelonia mydas* would suggest that copulation is the only occasion on which this sedentary leech could transfer from one host to another; but although hermaphrodite, a new infestation would require the transfer of an already inseminated leech, or two others as the minimum. Transfer at copulation would fit to the fact that to date *branchiatus* is known from only *C. mydas*, which is then the entire world of this leech, a rigidly defined host-parasite relationship in which speciation of the leech by isolation would be fully anticipated.

The wider host-list for *O. margoi* undermines this proposition, especially now with *C. mydas* known as a host also for *O. margoi*. *B. diversa* offers a convenient opportunity for the intimate study of the zoology of an ozobranch which combined with the incidence on turtles at Lake Boga could make a most valuable contribution to our understanding of these leeches.

The utilization of the blood-meal is unusually rapid. Only the postcaeca contained blood when the leeches were received here, and the postcaeca are essentially empty of blood after five or six days away from the host at summer temperatures.

The body-wall becomes increasingly transparent in the starving animal. A loss of condition is first shown in the appearance of erosion at the tips of the gills, followed by constrictions across the gills which divide the gill into sections, and then sections break away progressively from the distal end of the gill, to leave finally only the base of the gill to mark its former presence. There is no obvious loss of body-fluid in this amputation by constriction. As the section breaks away there is no rush of fluid in the stump which seems to be tightly sealed off. In one specimen in good condition when received, the last gill on the left side was indicated by only a short rounded lobe. Such might be a consequence from an earlier period of physiological stress.

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References

(* indicates not seen)

* Apathy, St., 1890.—*Pseudobranchellion margoi* (Nova familia Hirudinearum). *Orvosterm. Ertesito.*, 15 : 110–113, 122–127.

Autrum, H., 1936.—Hirudineen. Bronns Klassen u. Ordnungen des Tierreichs. Bd.4, Abt.iii, B. 4 : 1–96.

Caballero, Ed. y C., 1960.—Hirudineos de Mexico, xxii. Taxa y nomenclatura de la Clase Hirudinea hasta generos. *Ann. Inst. Biol.*, xxx (1 & 2): 227–242.

Harant, H., and Grasse, P., 1959.—Annelides, etc. Traite de Zoologie. T.v, P.1. Classe des annelides achetes ou hirudinees ou sangsue : 471–593.

Harding, W. A., and Moore, J. P., 1927.—Hirudinea. (Harding, Rhynchobdellae : 35–96). Fauna of British India. Taylor & Francis. London.

Ingram, D. M., 1957.—Some Tasmanian Hirudinea. *Pap. Proc. roy. Soc. Tasmania*, 91: 191–232.

Knight-Jones, E. W., 1962.—The systematics of marine leeches. App. B.: 169–186. In Mann, Leeches (Hirudinea). Intl. Ser. Pure & Appl. Biol. Permagon Press. Oxford.

Leigh-Sharpe, W. H., 1916.—*Platybdella anarrhichae*, with a note, erratum, and an appendix. *Parasit.*, 8 : 274–293.

LLEWELLYN, L. C., 1966.—Pontobdellinae (Piscicolidae: Hirudinea) in the British Museum (Natural History) with a review of the subfamily. *Bull. Brit. Mus. (Nat. Hist.) Zool.*, 14 (7) : 389–439.

MACCALLUM, W. G.. and MACCALLUM, G. A., 1918.—On the anatomy of *Ozobranchus branchiatus* (Menzies). *Bull. Am. Mus. nat. Hist.*, xxxviii (xii): 395–408.

MACDONALD, J. D., 1877.—A new genus of Trematoda and some new or little known parasitic Hirudinei. *Trans. Linn. Soc. Zool.*, (Ser. 2) i: 209–212.

MEYER, MARVIN C., 1941.—The rediscovery together with the morphology of the leech *Branchellion ravenelii* (Girard 1850). *J. Parasit.*, 27 (4) : 289–298.

MOORE, J. P., 1952.—New Piscicolidae (leeches) from the Pacific and their anatomy. *Occ. Pap. Bishop Mus.*, xxi (2) : 17–43.

OKA, A., 1904.—Uber den Bau von *Ozobranchus. Annot. Zool. Japan*, 5 (3): 133-145.

PINTO, C., 1921.—Classificacao dos Hirudineos. *Brazil Med. Ann.*, xxxv (12): 1–7.

POIRIER, and ROCHEBRUNE, A. T., 1884.—Sur un type nouveau de la classe des Hirudinees. *C. R. Acad. Sci.*, 98: 1597–1600.

RICHARDSON, L. R., 1949.—Studies on New Zealand Hirudinea. pt. ii. *Branchellion parkeri*, a new ichthyobdellid leech. *Zoo. Pub. Vict. Univ. Coll.*, No. 1 : 3–11.

————, LAURENCE R., 1959.—N.Z. Hirudinea. iv. *Makarabdella manteri* n.g., n.sp., a new marine piscicolid leech. *Trans. roy. Soc. N.Z.*, 87 (3 & 4) : 283–290.

————, ————, 1968.—An annotated list of Australian leeches. PROC. LINN. SOC. N.S.W., 92 (3) : 227–245.

————, ————, 1969.—A contribution to the systematics of the hirudinid leeches, with descriptions of new families, genera and species. *Acta Zool. Acad. Sci. Hungar.* In Press.

SANJEEVA RAJ, P. J., 1954.—A synopsis of the species of the genus *Ozobranchus* (de Quatrefages 1852). Hirudinea-Annelida. *Journ. Bombay nat. Hist. Soc.*, 52 (2 & 3): 473–480.

————, 1959.—Occurrence of *Ozobranchus margoi* Apathy (Hirudinea : Annelida) in the Indian Seas. *Current Sci.*, 28: 496.

————, and PENNER, LAWRENCE R., 1962.—Concerning *Ozobranchus branchiatus* (Menzies 1791) (Piscicolidae: Hirudinea) from Florida and Sarawak. *Trans. Am. micr. Soc.*, lxxxi (4): 364–371.

SCRIBAN, I. A., and AUTRUM, H., 1932/1934.—Ordnung der Clitellata: Hirudinea Egel. Kukenthal. Handb. der Zool. Bd. 2, L. 15, T.8: 119–352.

SELENSKY, W., 1915.—Etudes morphologiques et systematiques sur les hirudinees. L'organisation des ichthyobdellides : 1–256. Petrograd.

SILVA, P. H. D. H. de, 1960.—A key to the genera of the family Piscicolidae (Hirudinea). *Ceylon J. Sci.* (Bio. Sc.), 3 (2) : 221–233.

————, and BURDON-JONES, C., 1961.—A new genus and species of leech parasitic on the fish *Cottus bubalis. Proc. zool. Soc. Lond.*, 136 (3) : 343–357.

————, and KABATA, Z., 1961.—A new genus and species of leech parasitic on *Drepanopsetta platessoides* (Malm) the long rough dab. *Proc. zool. Soc. Lond.*, 136 (3): 331–341.

SOOS, A., 1965.—Identification key to the leech (Hirudinoidea) genera of the world with a catalogue of species. 1. Family Piscicolidae. *Acta zool. Acad. Sci. Hungar.*, xi (3–4) : 417–463.

VAILLANT, L., 1890.—Histoire naturelle des annelees marins et d'eau douce. 3 (2). Hirudiniens : 477–542. Roret. Paris.

KEY TO LETTERING ON FIGURES

a.g.m., anterior ganglionic mass; a.int., anterior intestine; ant.ce., anterior caecum; br., gill; c.g.p., common genital pore; c.int., circumintestinal loop; cr., crop; d.int.s., dorsal intestinal sinus; div., intestinal diverticulum; d.v.m., dorsoventral muscle; g., somital ganglion; g.ap., genital aperture; g.p., common genital papilla; int., posterior intestine; m.d., male median muscular duct; m.p., mouth-pore; m.t.ph., m. teniens pharyngis; nep., nephridium; ov., ovary; p.c., postcaecum; p.g.m., posterior ganglionic mass; ph., pharynx; prb., proboscis; re., rectum; r.s., seminal receptacle; sal.g., salivary gland; s.int.s., subintestinal sinus; s.s.o., somital sense organ; s.v., seminal vesicle; t., testis; t.m., terminal mass of male system; v.d., vas deferens. Note: Somites are indicated by Roman numerals. All scales in millimetres.

GEOLOGY OF THE MT. TENNYSON AREA, SOUTH OF YETHOLME, N.S.W.

B. J. WATTS

Department of Geology and Geophysics, University of Sydney

(*Communicated by Associate-Professor T. G. Vallance*)

(Plate IX)

[Read 26th March, 1969]

Synopsis

South of Yetholme, N.S.W., stratified rocks of probable Silurian to Devonian age have been metamorphosed to hornblende hornfels facies within the aureoles of the Bathurst Granite and one of its satellites. A western succession of strongly foliated sediments and volcanics is separated by a major structural break from a concentrically folded, unfoliated eastern succession with abundant calcareous sediments. A narrow, north-trending belt of Ordovician to Silurian mafic igneous rocks forms a structurally high basement for the eastern succession.

The geosynclinal Hill End Trough sequence west of Sofala and the geanticlinal stratigraphy at Limekilns, separated by the Wiagdon Thrust (Packham, 1958, 1968) are respectively correlated with the Yetholme western and eastern successions on a petrological and stratigraphic basis.

INTRODUCTION

The small township of Yetholme, some 15 miles east of Bathurst (Fig. 1) is situated on a dissected plateau surface about 3,800 feet above sea level, drained by tributaries of the westward flowing Fish River, part of the Macquarie River system. To the south and south-west of Yetholme the elevation of the country sharply falls to the level of the Bathurst Plains (about 2,500 feet) occupied by deeply weathered rocks of the Bathurst Granite.

In the present paper attention is drawn chiefly to the nature and status of the stratified rocks in the Yetholme area. Although most of these rocks occur within the contact aureoles of the Bathurst Granite and an associated body, the Durandal Stock it has been possible to recognize two distinct stratified sequences with fundamentally different sedimentary facies and structural features. A thick north-south trending western sucession of turbidite deposits and volcanics is separated from a relatively thin calcareous eastern succession by a major structural break, the Wiagdon Thrust. The thermal metamorphism of these stratified rocks has produced hornblende hornfels facies mineralogy within the already low-grade regionally metamorphosed succession.

Previous geological investigations in the Yetholme area were concerned mainly with economic potential of molybdenite-bearing skarn rocks at Mt. Tennyson and Andrews (1916) provides a brief account of the early mining history together with a general map of the small mineralized area. In more recent work the western part of the area has been described by Williams (1961) and Mackay (1964) gives a detailed account of the Yetholme granite together with a broad outline of the regional geological setting.

Field locations within this paper refer to the grid reference (GR) on the 1 : 63,360 Bathurst and Oberon military sheets and specimen numbers refer to catalogued rocks and thin sections in the collection of the University of Sydney.

Stratigraphy and Petrology

In establishing the complete succession at Yetholme it is necessary to refer to the stratigraphy and petrology of specific areas to the north. The restricted outcrop between two granitic masses and complete lack of fossils in these contact metamorphic rocks has made correlation on a comparative basis essential.

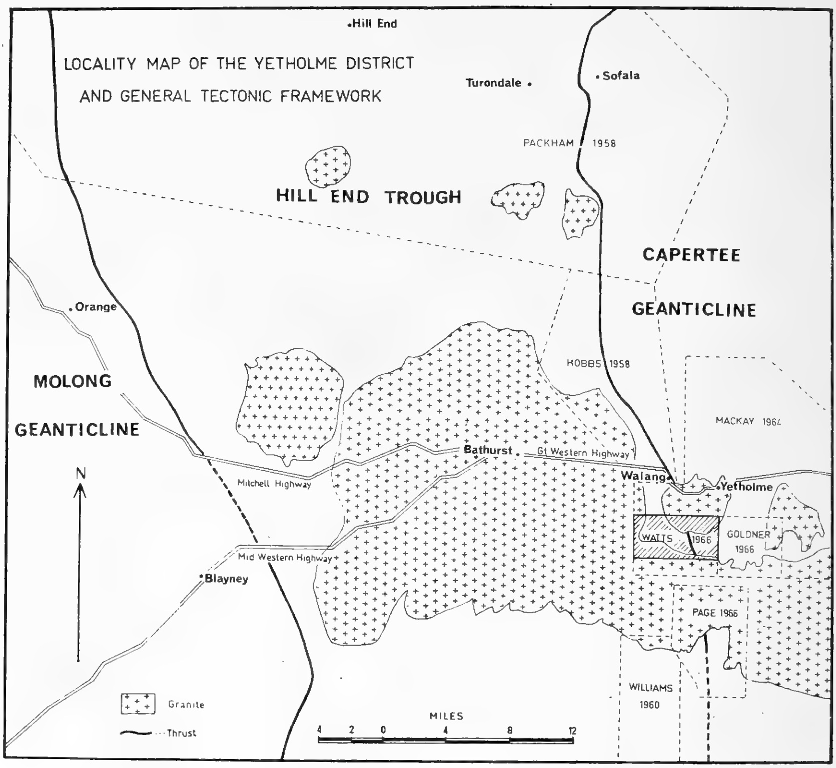


Fig. 1.

West of the Wiagdon Thrust, the stratigraphy which can be recognized in the contact aureole at Yetholme (Fig. 2), is closely related to that defined by Packham (1958) in the Sofala-Turondale area where an essentially conformable geosynclinal sequence ranging from Ordovician to Devonian is exposed particularly along the Turon River. Part of the Limekilns stratigraphy (Packham, 1958) to the east of the Wiagdon Thrust is also considered here (Table 1 provides a comparision of these sequences). Accordingly the stratigraphic nomenclature used is that of Packham (1958, 1966, 1968) in the regional compilation of the Bathurst sheet 1:250,000 geological map.

The Western Succession

Sofala Volcanics

South-west of Yetholme the narrow belt of Sofala Volcanics includes a variety of contact metamorphosed pyroclastic, intrusive and possibly flow rocks with mafic to ultramafic mineralogy. Brecciated rocks which retain igneous textures of both coarse grained strongly porphyritic rock types and fine grained volcanics are common. However textural indication of original igneous character is generally lacking in fine grained strongly foliated rocks

TABLE 1

	Unit	Sofala-Turondale		Yetholme			
		Thickness		Thickness	Western succession	Thickness	Eastern succession
Crudine Group	Waterbeach Formation	1690′	Shaly rocks far more abundant than sandy ones. Tuffaceous rocks absent. Conglomerates absent		Not represented		
	Turondale Formation	2020′	Mainly tuffs, shaly bands prominent towards the top. To the south conglomerate occurs in the upper part. Massive tuffs basally	2500′	Felspathic tuffs and/or greywackes with minor dacitic volcanics interbedded with slates becoming more prominent higher in the succession. Bed of cobble conglomerate is prominent towards the top	1200′	Coarse felspathic tuffs and/or greywackes; calcareous and conglomeratic basally. Overlain and underlain by pelitic lithologies
	Cookman Formation	1500′	Quartz-rich greywackes, occasional grits and conglomerates interbedded with slates. Quartzite-like subgreywacke basally	? 850′	Quartz-rich subgreywacke and greywacke interbedded with slates. Grades upward into more felspathic greywacke		
	Chesleigh Formation	3500′	Massive basal subgreywacke. Interbedded slate and subgreywacke gives way to greywacke and interbedded tuff horizons. Silts and slates in uppermost beds	? 600′	Highly cleaved silts and slates		
	Bell's Creek Volcanics	1500′	Rhyolitic tuffs and lavas. Tuffs basally then rhyolite and finally more tuffs	? 9000′ +	Faulting probably invalidates estimate of thickness. Fine-grained quartz-rich foliated rocks. ? Tuffs comprise most of the formation. Minor rhyolites probably occur one-third of the way up the section		
	Tanwarra Shale	250′	The junction with the Sofala Volcanics is obscured by structural disturbance of the Wiagdon Thrust. Basal conglomerate contains limestone and andesite detritus. Above is limestone and calcareous sandy shale. Shales comprise the remainder	? 500′	These rocks are strongly disturbed, commonly lenticular, and have been grouped with the Bell's Creek Volcanics. Calcareous bands with sandy shale are common. Shaly lithologies are interlayered with fine-grained siliceous rocks of the Bell's Creek Volcanics		
	Sofala Volcanics	7000′ +	The type section for this formation is east of the Wiagdon Thrust. Lower part contains fine-grained dark sediments. Low-grade altered tuffs and andesitic breccias are sporadically present in the lower part, but are abundant in the upper part, where coarse-grained mafic intrusives are common	? 800′	This formation occurs east of the Wiagdon Thrust and within the thrust zone. Tuffs, andesitic breccias and coarse-grained intrusives with mafic and ultramafic mineralogy are developed		

that contain various amphibole-rich assemblages. All these rocks with a general north-south trend, are essentially intercalated and the thickness exposed is about 800 feet. Local zones of strong foliation and kink folding, particularly along the western boundary, indicate the position of the Wiagdon Thrust against psammo-pelitic schists and foliated acid rocks of the Bells Creek Volcanics. The eastern boundary may also be faulted against massive pelitic material but the lack of foliation or deformation in the latter perhaps suggests an unconformable relationship.

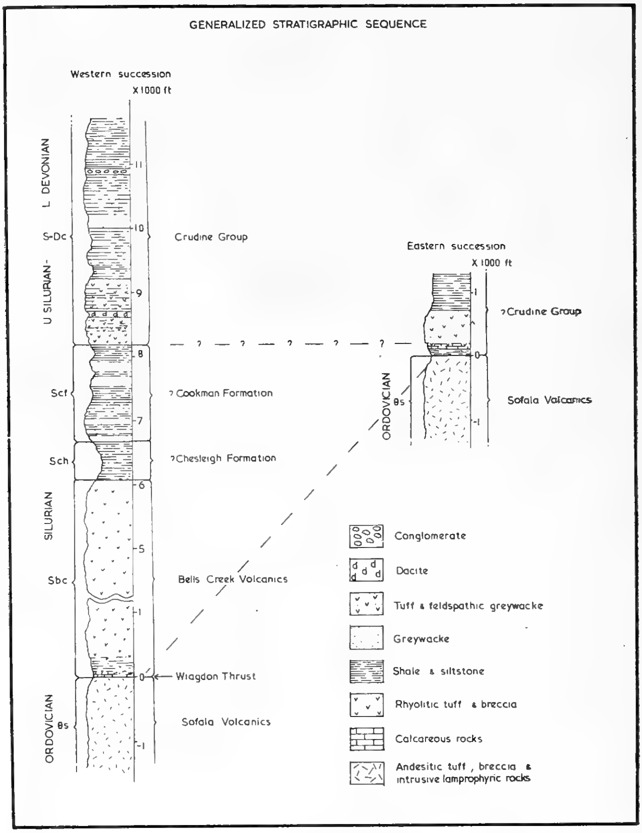


Fig. 2.

The following rock types are, in general, those most characteristic of this unit at Yetholme. A more detailed petrological and chemical study is currently in progress.

Fine grained dark green rocks which retain traces of original igneous textures and mineralogy probably represent volcanic products including flows, fine grained tuff and breccia. Fragmental rocks as a rule can be distinguished in the field, the angular fragments ranging from approximately 2 cm. to 5 cm. across. At GR 785593 they are flattened parallel to the locally developed foliation. Mineral assemblages have essentially adjusted to the hornblende hornfels facies metamorphism except where relict clinopyroxene grains rimmed with amphibole remain in the lithic fragmental material. This pyroxene is zoned and/or twinned, and relict glomeroporphyritic structures have been observed. Pseudomorphous metamorphic amphibole has, in some cases, preserved the characteristic euhedral to subhedral pyroxene grain shapes. However such assemblages as tremolite-olivine (-spinel-phlogopite) are commonly developed and subradiating to decussate amphibole laths form the main textural feature with ragged olivine poikiloblasts developed in an elongate fashion parallel to the foliation. Green spinel granules, where present, are most abundantly associated with the olivine. In the matrix of many breccias (e.g. 33831) relict pyroxene is characteristically lacking and large (up to 1·5 mm.) densely poikiloblastic olivine grains have developed with tremolite, spinel and minor plagioclase. Such mineral assemblages are also characteristic of rocks containing no apparent textural relics.

Coarse grained metamorphosed mafic rocks with blastophenocrysts (up to 4 mm.) of amphibole and/or relict clinopyroxene suggesting a parent of perhaps lamprophyric character (cf. Basnett, 1942 and Colditz, 1948) are found both massive and brecciated. The euhedral to subhedral blastophenocrysts are easily distinguished in hand specimen as comprising up to 70% of some rocks. Traces of possible primary brecciation are suggested by angular fragments up to about 4 cm. across, in a matrix with similar textural and mineralogical features to that of the fragmental material. The relict pyroxene is commonly zoned and glomeroporphyritic as in the finer grained rock types. Zoning is marked by various concentrations of finely divided brown opaque granules. However a pale green pyroxene remarkably clear of inclusions is also present mainly as single euhedral to subhedral crystals. Both pyroxene types are considerably altered to amphibole (probably actinolite) peripherally and along cracks and cleavages. Most original phenocryst sites are, however, now occupied by pale green to colourless amphibole similar to that produced by contact metamorphism in the matrix material.

Relict plagioclase occurs only in 33840 as glomeroporphyritic aggregates and single laths containing inclusions of radiating actinolite. The blastoporphyritic texture and the mineralogy of this rock suggest that it originally may have been andesitic. However no relict groundmass minerals remain. Instead one finds generally a mat of decussate amphibole laths.

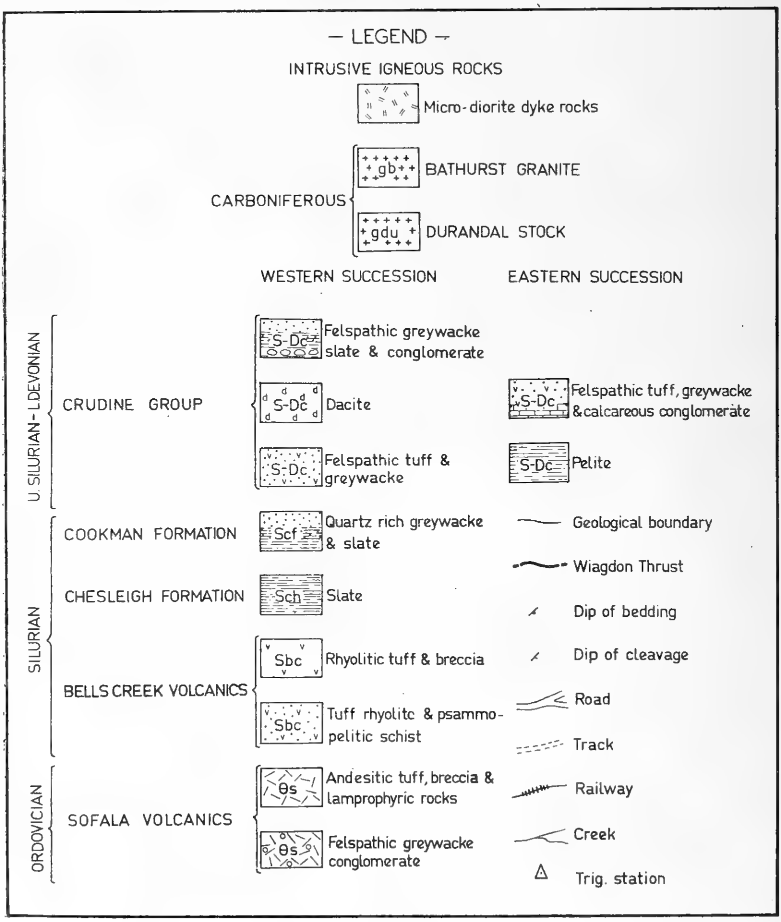
Rocks which now contain cordierite and anthophyllite are included within these volcanics. However they only retain textures related to foliation and kink folding. This is especially so in coarser grained types where amphibole needles are mimetic to a previous foliation. More commonly, however, the amphibole is subradiating to decussate. Cordierite, anthophyllite and quartz is the most widely developed assemblage (together with occasional minor biotite). Coarse grained clinochlore-anthophyllite-spinel rocks lacking all textural signs of original character have been observed and cummingtonite-bearing assemblages are also represented. Detailed work on the nature and significance of these Mg-rich rocks is in progress.

Minor calc-silicate rocks consisting of garnet, diopside, plagioclase and wollastonite are associated with these mafic and ultramafic rocks. At GR 770602 a small body containing the manganese-rich silicates rhodonite, bustamite, tephroite and garnet may form the continuation of a wollastonite-diopside-garnet bearing band at the eastern margin of these volcanics.

An occurrence of foliated conglomerate at GR 780588 is included within this unit because of its close association with these mafic rocks and limited exposure (Plate IX). This conglomerate has a matrix of detrital plagioclase laths apparently of volcanic origin. Fine grained siliceous and calc-silicate pebbles (10 mm. to approx. 30 mm. across) are now oval shaped in section and flattened parallel to the foliation.

Distribution of the main rock types.—The abundant coarse grained rocks bearing numerous large amphibole and pyroxene blastophenocrysts appear to be intercalated with the finer grained lithologies. There is a tendency, however, toward concentration of finer grained rocks along the western boundary of the Sofala Volcanics and to the south-east, adjacent to the main Bathurst Granite. Cordierite-anthophyllite rocks occur in a narrow band along the Wiagdon Thrust from the northern granite contact to the south and a small exposure of this rock type is also found at GR 772600. It is important to note that cordierite-anthophyllite rocks occur to the south of the Bathurst Granite in the area described by Page (1966) and also to the north of the Durandal Stock. These occurrences lie directly along strike with the band of cordierite-anthophyllite rocks west of Mt. Tennyson. Strongly foliated lenses of the calc-silicate lithologies apparently associated with the rocks of igneous origin are concentrated along both eastern and western margins.

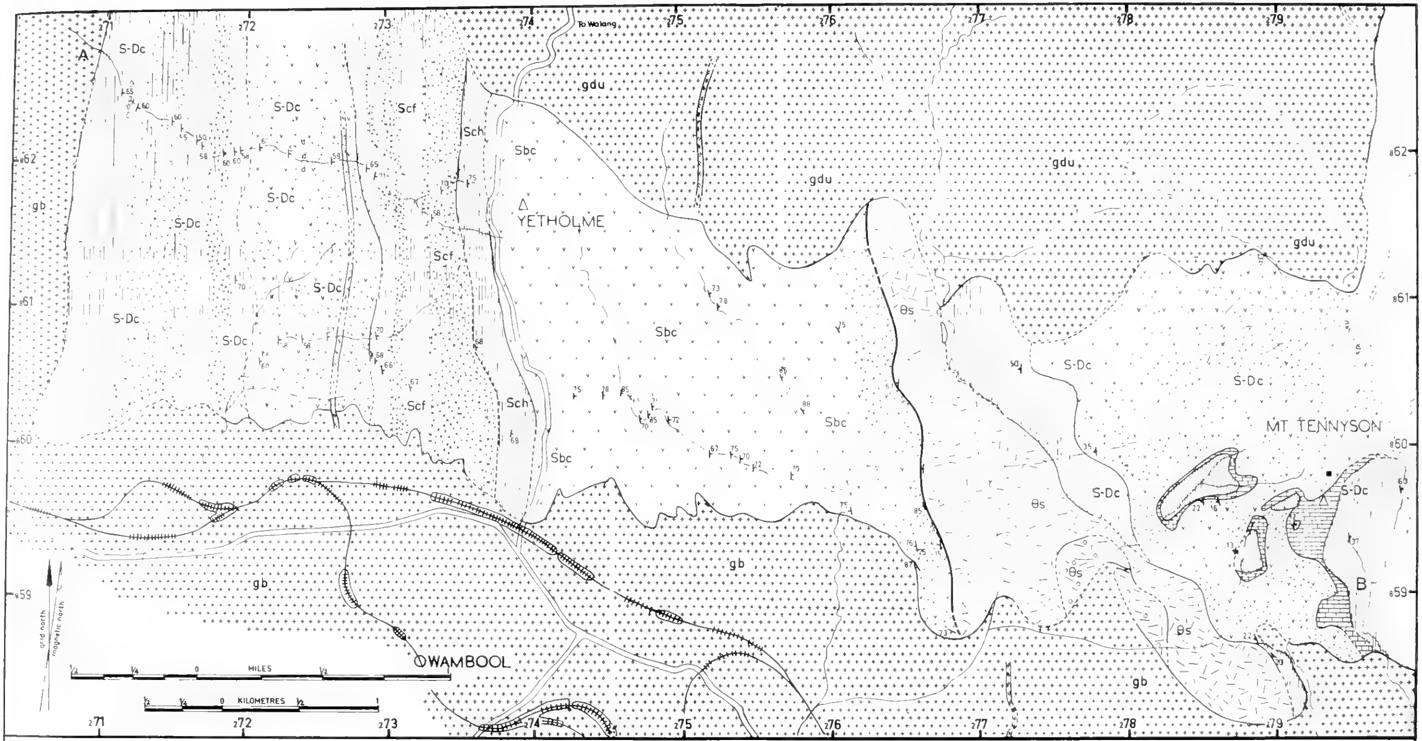
Regional correlation.—The distinctive petrographic character of the coarser grained amphibole and pyroxene-rich igneous rocks can be recognized north of Walang (Hobbs, 1958) and further to the north at Sofala (Packham,



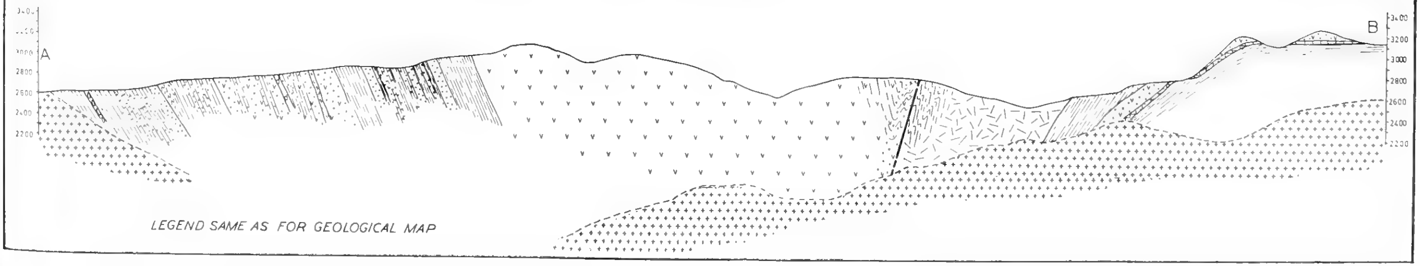
Legend to Plate IX.

PLATE IX

GEOLOGY OF THE MT. TENNYSON AREA SOUTH OF YETHOLME



SECTION A-B



1958). Considerable low grade mineralogical reconstitution within these rocks has produced chlorite, quartz, albite, carbonate, epidote and actinolite and more rarely prehnite- and pumpellyite-bearing assemblages.

As in the Yetholme breccias, strongly porphyritic fragments are common in the Sofala Volcanics at Sofala. The majority of the phenocrysts here are similarly pale green clinopyroxene and the plagioclase present is generally extensively altered to carbonates with white mica and chlorite. The vesicles developed in these porphyritic fragments contain chlorite-albite assemblages, occasionally with epidote and calcite and the matrix material consists of crystal and lithic tuff containing pyroxene, amphibole and smaller rock fragments together with the patchy alteration minerals calcite, prehnite, chlorite, quartz, albite and rarely pumpellyite.

Extensively altered fine grained tuffs or flow rocks at Sofala generally contain mafic to ultramafic low grade alteration associations including chlorite, amphibole, sphene, quartz and carbonate. Such low grade alteration, particularly along the Wiagdon Thrust has presumably taken place prior to essentially isochemical thermal metamorphism of the Yetholme rocks.

In the lower part of the Sofala Volcanics of the type section to the east of Sofala, abundant dark grey to black fine grained (commonly brecciated) sediments occur together with lithologies containing andesitic and sedimentary cobbles in a fine grained sedimentary matrix. In this part of the succession sedimentary structures and upper Ordovician fossils are suggested by Packham (1958) to represent a deep water environment. South of the Bathurst Granite, Page (1966; Fig. 1) has identified fine grained dark pelitic lithologies associated with mafic rocks similar in mineralogy and texture to those at Yetholme. However fine grained pelitic lithologies are not characteristic of the latter. The upper part of the Sofala succession contains breccias mainly with angular blocks of andesitic material and abundant minor intrusions of lamprophyric rock types. Limestone blocks have also been noted at Sofala by Packham (1958), who suggested their presence may be related to shallowing by orogenic movement.

Thus the sequence characteristic of the middle and upper part of the type section is perhaps represented in the Sofala Volcanics at Yetholme and if they are also time equivalent then an upper Ordivician to lower Silurian age may be indicated.

Bell's Creek Volcanics

The Bell's Creek Volcanics occur west of the Sofala Volcanics and consist of a rather monotonous, strongly foliated succession of rocks with extremely felsic mineralogy. Relatively fine grained strongly deformed rocks with a characteristic lenticular layering are common. All textures indicating the nature of original rock type have generally been obliterated by deformation, and recrystallization effects imposed during contact metamorphism. However a few weakly foliated rocks contain relict textures that suggest former acid volcanic character. Minor rocks of pelitic and psammo-pelitic composition are strongly foliated and retain no original textural features. Any estimation of true thickness of this unit (Fig. 2) is probably invalidated by repeated faulting. The eastern boundary of these rocks against the mafic Sofala Volcanics is the Wiagdon Thrust, and the western boundary, against strongly foliated pelitic rocks, may also be faulted. However kink folding is not apparent along the latter. The most characteristic rock types of the Bell's Creek Volcanics south-west of Yetholme are described below.

Fine grained lenticular foliated rocks which probably represent acid volcanics contain sparsely distributed small blastophenocrysts of quartz and plagioclase. The quartz is commonly euhedral and rarely retains textures of resorption. Glomeroporphyritic textures can be recognized in some small plagioclase aggregates. However no former textures remain in the surrounding material which is fine grained and felsitic, consisting mainly of quartz and plagioclase with minor microcline and biotite. The latter has developed parallel to the previous foliation. Unfoliated fine grained rocks are generally more leucocratic than biotite-bearing types and contain little suggestion of original porphyritic character. Patches with slightly coarser grainsize show the same textural relations as the surrounding granoblastic material.

Brecciated examples are represented within the layered acid rocks that comprise the main part of this unit. However brecciation is often difficult to recognize when the fragments have been rendered completely lenticular within a petrographically identical matrix. Biotite tends to occur with the granoblastic quartz and felspar of the surrounding medium rather than within the fragmental material, which is slightly more siliceous. Strongly brecciated rocks at GR 766588 contain typically augen-shaped siliceous fragments (approximately 6 cm. max. direction) that are mineralogically similar to the matrix. The proximity of this example to the strongly deformed fault zone may indicate tectonic derivation rather than original pyroclastic vulcanism.

Large plagioclase blastophenocrysts up to 3 mm. in length are rarely evident in some fragments and commonly glomeroporphyritic structure has been observed. Smaller "microlites" of former plagioclase in more or less random orientation are apparent only in plane polarized light where recrystallized elongate granular aggregates are now similar to the micro-hornfelsic enclosing medium.

The light brown to buff mica schists composed mainly of quartz, muscovite and biotite with minor plagioclase may also contain cordierite. The textural features of these rocks largely depend on the impressed structural elements and the foliation is further deformed by a strain-slip cleavage in examples such as 33890. Psammo-pelitic schists concentrated within the fault zone contain a considerable amount of quartz and commonly cordierite is lacking.

Calc-silicate rocks, which bear no original textures, are mainly lenticular and mineral assemblages are essentially similar to those in other formations. However a vesuvianite-garnet-plagioclase-quartz association is developed at GR 742597.

Distribution of the main rock types.—The pelitic lithologies with minor lenses of calc-silicate rock are strongly foliated and concentrated along the Wiagdon Thrust at the eastern boundary of this unit. These rocks, particularly the fine grained foliated rocks, are abundant for about 600 to 800 feet upwards into the lighter coloured quartz rich banded acid volcanics and thin pelitic layers are sporadically intercalated with the volcanics in this part of the unit. Several small discontinuous lenses of brecciated rocks also occur in this eastern part of the succession and massive fine grained quartz rich hornfelses outcrop in almost cliff forming exposures (at GR 753605) above these relatively thin brecciated examples.

Lenticular, layered rocks comprise the major part of the sequence and are developed above the thin pelitic bands which decline in abundance westwards from the thrust zone.

Regional correlation.—The petrographically similar fine grained acid volcanic rocks mapped by Hobbs (1958) above mafic volcanic and intrusive rocks north of Walang, are considerably outside any thermal effects imposed by the Bathurst Granite. Textures indicate the main rock type to be an acid tuff consisting of fine grained quartz and felspar in which are set small, often euhedral crystals of quartz. These rocks are massive in outcrop and strongly jointed; thus cleavage development associated with faulting probably initiated the lenticular and finely banded nature of the rock types comprising the main part of the unit at Yetholme.

In the Sofala-Turondale area (Packham, 1951, 1958) the Tanwarra Shale is interbedded with the Sofala Volcanics at its base and the Bell's Creek Volcanics at the top. It consists of calcareous shale with siliceous shale and minor lenses of limestone and is substantially foliated in the vicinity of Sofala. Graptolites indicate a Silurian age for the Tanwarra Shale (Packham, 1958). The overlying Bell's Creek Volcanics west of Sofala consists of fine grained acid tuffs and lavas rich in quartz, orthoclase and dark biotite.

The rocks within the thrust zone at the base of the quartzo-felspathic unit at Yetholme may thus be the Silurian Tanwarra Shale assuming that petrological and stratigraphic similarity is a valid basis for correlation.

Some parts of the Sofala-Turondale succession defined by Packham are apparently not represented to the south in the contact metamorphosed succession at Yetholme where primary sedimentary features become extremely difficult to recognize. However direct correlation with lower grade units north of Yetholme (Hobbs, 1958; Mackay, 1962) is possible for a small part of the sequence.

? *Chesleigh Formation*

This formation at Yetholme is thought to be represented by a massive pelitic lithology that appears to bear faulted relations with adjacent beds. The thickness exposed is about 600 feet and no intercalation with neighbouring units is evident. These fine grained buff coloured slates consist only of quartz and micas with occasional porphyroblasts that have largely retrogressed to micas. Cordierite is only locally developed. A lenticular compositional layering parallel to the original foliation is composed of quartz rich layers alternating with mica rich layers. This layering is gently deflected around the large pseudomorphed porphyroblasts that may represent former andalusite crystals. Two small calc-silicate lenses exposed towards the northern extremity of this unit (at GR 738623) consist of wollastonite-garnet-diopside assemblages with epidote and plagioclase.

This part of the succession may doubtfully be correlated with the lower part of the Chesleigh Formation in the Sofala stratigraphy. The upper part of the Chesleigh Formation as represented west of Sofala appears to be absent at Yetholme.

? *Cookman Formation*

Interbedded coarse and fine grained greywackes, together with slates, are exposed for approximately 1,500 feet of the succession above the fine grained foliated rocks perhaps belonging to the Chesleigh Formation. The boundary with the latter unit is easily defined as the lowest, 60 feet thick bed of quartz-rich greywacke and the top of this unit is the boundary of a thick slate band with the first occurrence of a massive felspathic tuff of the overlying Crudine Group. Three main rock types characterize this unit.

A poorly sorted rock containing angular detrital grains (about 0·5 mm. across) that have a more or less even distribution throughout the matrix, has been moderately affected by the regional cleavage. Of the detritus quartz and felspar are approximately equally developed. The felspar, dominantly sodic andesine, is extremely clouded (e.g. 33924). The matrix which consists mainly of fine grained quartz and micas is not tectonically differentiated into layers of different mineralogical composition as are the finer grained shaly lithologies of this unit. Graded bedding, commonly developed on a small scale within these relatively fine grained quartz rich ricks involves only small differences in grainsize and indicates that the beds are in fact, overturned. Dip of bedding is approximately 70° towards the east and is essentially parallel to the slaty cleavage. These sediments probably belong to a deep water suite (Packham, 1954) and may be classified as sublabile greywackes.

A considerably coarser grained labile greywacke contains detritus from 0·5 mm. to 1·5 mm. across, and the degree of sorting is higher than for that described above. The matrix, which only constitutes about 30% of the rock, contains a small amount of micaceous material with recrystallized quartz and felspar and small laths of bluish-green metamorphic hornblende. The detritus is similar to that described above. However, fairly angular clear quartz grains about 1·5 mm. across are rather distinctive in hand specimen.

The fine grained slates interbedded with the above lithologies are similar to those developed in the Chesleigh Formation below.

Distribution of the main rock types.—The three main lithologies throughout this unit are interbedded (Fig. 2) on the scale of 60 to 80 feet, with some beds consisting of alternating fine grained quartz rich greywacke and slate several inches to a foot thick. The detritus of coarser grained members becomes slightly more felspathic towards the top of this formation, where slaty lithologies are more prominent.

Regional correlation.—The upper part of this formation can be directly correlated with the southern part of the area mapped by Hobbs (1958) and Williams (1961), where it consists of fine grained quartz rich greywacke regularly interbedded with black shale. Graded bedding is common in parts of the formation together with slumping and flow casts. These features are also present west of Sofala (Packham, 1958) where this formation consists dominantly of slate with interbedded fine to medium grained quartz-rich subgreywacke and sublabile greywacke. Here a thick shale band defines the top of this formation against the overlying coarse grained tuffaceous rocks of the Crudine Group, as at Yetholme. Lithological similarity together with a somewhat similar distribution of rock types is considered sufficient reason to correlate Yetholme rocks with the Cookman Formation west of Sofala.

Crudine Group

This group at Yetholme is marked by the development of massive felspathic tuff directly above the thick upper slate band of the Cookman Formation. The upper part of this group at Yetholme is characterized by a paucity of tuffaceous rocks, slates becoming more abundant than coarser grained rocks. One thin conglomerate horizon is present towards the top of the 1,800 feet of sequence exposed. The top of this unit is not represented as it is truncated by granite. Outcrop is generally poor in the vicinity of GR 712626 where numerous thin tongues of granite and quartz have been intruded parallel to the regional foliation. The following rock types are present within this group.

Coarse grained felspathic rocks in which the average grainsize is about 1·2 mm. are taken to represent felspathic greywackes and tuffs. The detritus is chiefly volcanic and abundant relict plagioclase (An_{30-35}) is lath shaped and more rarely glomeroporphyritic. Small granules of epidote are contained in some clouded plagioclase laths. Perthitic alkali felspar is less common and fairly large embayed quartz grains up to 2 mm. form less than 5% of the detritus. It is difficult to estimate the percentage of matrix compared with detritus in some of these rocks, since bluish-green, subradiating aggregates of metamorphic amphibole are abundant and commonly project into the felspar grains obscuring former textures.

Blastoporphyritic rocks containing coarse relict plagioclase laths and occasional rounded and embayed grains of quartz in a fine grained "groundmass" of recrystallized plagioclase and quartz perhaps represent dacitic flows. The plagioclase is present as both single crystals and glomeroporphyritic aggregates and two size ranges are apparent: large grains from 3 mm. to 5 mm. and abundant smaller laths from 0·5 mm. to 1·5 mm. Any evidence of flow or vesiculation has been obliterated by recrystallization and formation of biotite, hornblende and minor epidote. The development of microcline is commonly limited to the recrystallized groundmass material.

Fine grained greyish slates commonly containing cordierite and biotite represent interbedded pelitic lithologies within this dominantly volcanic unit. The properties of these rocks are similar to those of the slates in the ? Chesleigh Formation.

A coarse cobble conglomerate at GR 712624 consists mainly of severely flattened but well rounded quartzite cobbles up to 5 inches across (long dimension) and smaller biotite-muscovite schist pebbles (about 2·5–1 inch, maximum dimension) set in a fine grained schistose matrix containing cordierite, biotite, muscovite and quartz. This assemblage is typical of the fine grained pelitic lithologies near the western contact with the Bathurst Granite.

Distribution of the main rock types.—The felspathic tuffs and/or greywackes are the most common rock types developed. About 800 feet of these massive rocks occur basally but give way to small thicknesses of interbedded fine grained slaty material higher in the succession. About 80 feet of porphyritic dacitic rocks overlie the "tuffs". These are overlain by 400 feet of felspathic tuffaceous greywacke with thin beds of knotted slate. Above this about 800 feet of massive slate is present with thin bands of interbedded felspathic tuffaceous or greywacke sediments developed in the central 200 feet of the main pelitic lithology. Inverted graded bedding in the fine grained pelites dips at approximately 60° to the east.

Massive, strongly foliated and in some cases mesoscopically folded rocks comprise the remainder of this unit and the growth of contact metamorphic minerals precludes the identification of previous textural elements. The thin band of coarse cobble conglomerate occurs close to the western granite contact within the dominant pelitic lithology.

Regional correlation.—The type section of the Crudine Group near Turondale (Packham, 1958, 1968) is similar to the succession of volcanic derivatives and flows west of Yetholme. The lowest part of the formation is composed almost entirely of tuffaceous material with relatively scarce slate and fine grained sandstones. The basal conglomerate present at Turondale is absent at Yetholme. However, the overlying tuffaceous rocks consisting of quartz, felspar, chlorite and epidote are petrologically similar to the Yetholme rocks. They are hard and massive and graded bedding is common. Interbedded fine grained greywackes and slates are developed above the tuffaceous sediments. These are followed by more massive tuffaceous rocks and then dominantly slate and silt with minor greywacke for the rest of the unit.

The upper part of the lower formation (the Turondale Formation) of the Crudine Group south of the type section, however, contains conglomerates up to several hundred feet thick. The pebbles are mainly quartzite, quartz porphyry, limestone and shaly rocks. The quartzite pebbles range from "less than an inch to six to eight inches along their greatest dimension" (Packham, 1968). The conglomerate band west of Yetholme, although fairly thin, and developed close to the granite contact, is similar in most respects to that developed south of the type section at Turondale, and probably represents an important marker horizon for the correlation of this unit with the upper part of the Turondale Formation of the Crudine Group in the Sofala-Turondale stratigraphy.

Thus it appears that most of the Turondale Formation of the lower Crudine Group is represented in the Yetholme succession 30 miles to the south of the type section.

THE EASTERN SUCCESSION

Only three units occur to the east of the Wiagdon Thrust in the area under discussion. These rocks may be equivalent to the Crudine Group of the western succession. However such correlation at Yetholme could only be of a most general nature based on lithological similarity. The regional geology of the eastern succession is not entirely clear in this vicinity as compared with the Limekilns stratigraphy of Packham (1968).

? Crudine Group

At Yetholme coarse grained tuffaceous rocks together with greywackes and fine sediments are more massive than those belonging to the western sequence. Sedimentary structures are generally lacking and individual beds are difficult to distinguish. However a fine layering which may be interpreted as bedding is well-developed in the pelitic lithologies. An extensive molybdenite-bearing skarn horizon occurs at the base of the greywacke and tuffaceous rocks and appears to be a former calcareous conglomerate horizon. The mineralogy and chemistry of these rocks are present subjects of investigation. Cleavage is characteristically absent from this succession which shows gentle concentric folding.

About 40 feet of a banded pelitic lithology is exposed basally and the individual sub-parallel bands are about 1 cm. to 0·5 cm. thick. Alternating quartz-rich and cordierite-rich units define this layering in rocks now consisting mainly of cordierite, biotite and quartz. Although this metamorphic assemblage is typical of a pelite, much material may be fine grained tuff (Mackay, 1961).

The sudden appearance of a calcareous cobble conglomerate marks the base of the following 600 feet of massive tuffs and greywackes. The thickness of the conglomerate varies considerably from about 5 feet to about 40 feet and in the basal section consists mainly of a wollastonite-bearing rock with garnet, diopside and quartz. The wollastonite occurs in subrounded patches, commonly 3 to 6 cm. across and rarely up to 3 feet across. These perhaps represent former pebbles and cobbles between which diopside-garnet assemblages are developed. Wollastonite is absent from the overlying conglomerate and garnet-quartz-calcite-diopside is the main association represented. The pebbles and cobbles in this upper part are strongly zoned and commonly retain volcanic textures; quartz rich inclusions and pelitic lithologies are also represented. Molybdenite mineralization is associated with this upper conglomerate and is localized mainly within the garnet-quartz-calcite-diopside skarn.

In the greywackes and tuffs above the basal conglomerate quartz and felspar constitute most of the detrital material. The average grainsize is between 0·5 mm. and 1·5 mm. and is consistent throughout the lateral and stratigraphic extent of this lithology. The quartz grains are extremely angular to euhedral and many are deeply embayed (e.g. 33992). The euhedral crystals commonly show double terminations, fracturing and displacement. The plagioclase detritus is clouded and angular; however some plagioclase is distinctly subhedral to euhedral. Of the detrital material the proportion of quartz to labile components is as high as 70: 30 in some rocks. However rocks containing only plagioclase detritus are also abundant.

The matrix material consists of fine-grained granoblastic quartz and felspar, rarely with cordierite, and constitutes approximately 30% of most rocks. In slightly more calcareous lithologies the finer grained fraction includes metamorphic diopside but the coarse-grained fraction is similar to that described above.

Well-rounded acid volcanic and pelitic pebbles which occur in these tuffaceous arenites at GR 781592 vary in size from about 4 cm. to 1 cm. across and generally consist of a microfelsite with relict textures suggesting an acid volcanic source.

The upper limit of these coarse-grained rocks is well defined against a pelitic lithology mineralogically similar to that developed below. Only 600 feet of this lithology is exposed and its western boundary against the mafic rocks of the Sofala Volcanics is faulted or perhaps represents an unconformity. This unit is more extensively exposed to the east (Mackay, 1964; Goldner, 1966) where two distinct conglomerate members break a monotonous series of shales with rare fine quartz-rich tuffaceous rocks. A conglomerate band about 20 feet thick occurs at GR 790586 on the western side of Mt. Tennyson where it consists of small (1 cm. to 3 cm.) well rounded pebbles set in a matrix of banded pelitic material. Fine grained quartz-rich pebbles are most abundant together with pebbles containing granoblastic quartz-plagioclase-biotite assemblages and pelitic lithologies now represented by purplish cordierite-biotite rocks.

Small calc-silicate lenses at the western boundary of this unit with the Sofala Volcanics contain wollastonite-garnet-diopside assemblages. The manganese-bearing rocks previously mentioned may actually be associated with the rocks of this unit rather than with the mafic rocks of the Sofala Volcanics. This situation is unclear, however, due to poor outcrop.

Intrusive Rocks

The Durandal Stock

An essentially equidimensional body, named by Mackay (1964) after the property Durandal, this stock consists of the following three lithologies: a leucocratic granite with only sparsely developed potash felspar "megacrysts", a "megacrystalline" granite and a fine grained marginal phase. The non-genetic term "megacryst" was adopted by Mackay (1964) and "normal" granite was defined as containing less than 1% megacrysts. The latter generally occurs toward the central part of the stock.

The fine grained marginal granite consists mainly of an equigranular (i.e. about 0·5 mm.) quartz, plagioclase and potash felspar aggregate. The potash felspar in most cases is finely perthitic and the plagioclase is strongly zoned. A few elongate subhedral biotite grains are commonly altered to chlorite, and minor apatite is enclosed by or associated with the biotite. Myrmekitic intergrowths are common and fan-like projections locally extend into adjacent potash felspar grains. Quartz phenocrysts (up to 2 mm.) are rarely present. These are anhedral against the enclosing finer grained material as described above. Plagioclase phenocrysts are of a similar size and also anhedral. Modally, quartz forms about 40% and the percentage of potassic felspar and plagioclase is similar, indicating that these rocks are micro-adamellites. The modal mineral composition of this rock type appears to be extremely constant.

Megacrystalline granite contains megacrysts up to 6 cm. but usually 3 cm. to 4 cm. long. These are strongly perthitic orthoclase, containing small, irregular biotite flakes, quartz and plagioclase. Intricately sutured margins enclose quartz and felspar blebs. Myrmekitic intergrowths are also common at the boundaries of such grains. The granite between the megacrysts is usually quite granular. However in some examples it may be porphyritic in quartz and plagioclase. Large (up to 6 mm.), slightly embayed quartz grains and smaller (about 4 mm.) zoned plagioclase phenocrysts (about An_{27} centrally) which are commonly glomeroporphyritic, are enclosed in a groundmass of quartz, plagioclase and potash felspar with an average grainsize of about 0·5 mm. Biotite, magnetite and sphene are accessory. The approximate modal percentages are 40% quartz, 32% plagioclase, 25% potash felspar and 3% sphene, biotite and magnetite. This granite with gradual loss of megacrysts grades imperceptibly into "normal" granite containing less than 1% megacrysts.

Small allotriomorphic granular xenoliths (up to 5 cm.) contain quartz, plagioclase, potash felspar and biotite with euhedral sphene. The plagioclase shows normal progressive and oscillatory zoning. The potash felspar is finely perthitic and the biotite is usually of similar dimensions to that of the surrounding granite. The small aplite veins and dykes, and long, narrow microdiorite dykes are similar to those in the Bathurst Granite to the south.

The Bathurst Granite

The Durandal Stock is narrowly separated from the main Bathurst Granite which outcrops over 500 square miles and extends from Hartley to Newbridge. Upper Devonian rocks are the youngest intruded by the Bathurst Granite (Mackay, 1964; Goldner, 1966) and the age of part of the granite (near Hartley) has been dated as Middle Carboniferous (Evernden and Richards, 1962).

In the area to the south of Yetholme all the stratified rocks are intruded by the Bathurst Granite, the overall contact relationships being strongly transgressive. However, to the west of the Wiagdon Thrust the contact assumes a sheeted character with narrow tongues of granite parallel to the well-developed regional foliation. To the east, broad curving tongues of granite preferentially intrude selected lithologies.

The granite at Yetholme appears to be particularly uniform. It is porphyritic, but only in one locality (739595) does megacrystalline granite, in the sense of Mackay, occur. A fine grained marginal phase of similar petrographic character to that of the Durandal Stock locally intrudes the foliated rocks in a sheeted manner and is also sporadically developed along the eastern contact.

Biotite (-hornblende) adamellite is most widely developed with a grainsize of approximately 4 mm. and allotriomorphic granular texture. Modally this consists of about 30% quartz, 35% potassic felspar and 30% plagioclase with 5% biotite. The potassic felspar is finely perthitic orthoclase with lesser microcline. Minor intergrowths of quartz mark grain boundaries of potassic felspar against plagioclase. The latter shows strong normal progressive zoning and occurs as subhedral somewhat irregular laths. Large grains of muscovite and chloritized biotite are common accessories together with euhedral sphene and apatite.

Aplite dykes are commonly joint controlled (e.g. GR 588765). The aplite consists of granular quartz, plagioclase and potash felspar with biotite practically absent. The grainsize is fairly constant from about 0·1 mm. to 0·5 mm. and the approximate modal composition is quartz 40%, plagioclase 25% and potash felspar 35%. The potash felspar is again finely perthitic (33887) and rarely myrmekite is present at grain boundaries. Apatite is euhedral and associated with the sparse biotite grains.

A small occurrence of micrographic pegmatite occurs at GR 780591. The quartz "runes" are embedded in microcline and also appear to extend into the small plagioclase laths adjacent to the microcline.

Two types of inclusion are present in this granite. Well rounded granitic xenoliths up to 5 feet across but more commonly 3 to 6 inches, contain noticeably more biotite than the surrounding granite and are finer grained with strongly zoned plagioclase. The quartz grains are irregular, and potash felspar constitutes considerably less of the felspar fraction than plagioclase. Biotite constitutes up to 10% of some inclusions and occurs in subradiating and decussate aggregates commonly 3 cm. across (33850). Apatite is a constant accessory in these inclusions.

At GR 726599 in a small granite quarry, rafts of strongly metamorphosed foliated rocks up to 40 feet (maximum direction) are enclosed by the granite. These are horizontally elongate and only one rock type appears to be present. This is now a biotite-plagioclase-hornblende-quartz-microcline rock in which the biotite accentuates an original foliation and hornblende forms subradiating clusters. It is not possible to indicate the formation from which these xenoliths were derived.

Basic dykes

Long narrow basic dykes have been intruded parallel to the north-south regional trend of the country rocks and in some cases can be traced into the granite. A characteristic outcrop of small rounded boulders can be followed for distances probably exceeding one mile. They are about 20 feet to 50 feet across. Such dykes intrude both the Durandal Stock and the Bathurst Granite.

All the dyke rocks are extremely similar with an intergranular texture and average grainsize of about 0·5 mm. Plagioclase is glomeroporphyritic and is mainly An_{30}. However in most cases it is altered to patchy calcite and sericite with minor epidote. A few large anhedral to subhedral phenocrysts of augite are present. The elongate plagioclase laths of the groundmass, comprising about 40% of the rock, are interspersed with laths of brown amphibole. A small number of interstitial quartz grains are also present. The common accessories of these microdioritic dyke rocks include small euhedral sphene granules, apatite and peppery magnetite euhedra. In some rocks rounded patches of calcite up to 5 mm. across are present and probably fill amygdales. These rocks have thus undergone considerable low grade adjustment. Deuteric alteration or adjustment due to burial at depth are possible causes.

STRUCTURE

The structural basis for the division of the stratigraphy into two separate successions reflects the strongly developed tectonic elements west of the Wiagdon Thrust, compared with the gently folded massive rocks of the eastern succession. Similarly a discussion of the structure will also be divided into two sections.

The Western Succession

The western structural block of the area mapped by Hobbs (1958; Fig. 1) is the northern continuation of sediments occurring to the west of the Wiagdon Thrust at Yetholme and structural features of the sediments are essentially similar.

The most prominent s-surface developed is a slaty cleavage, characteristic of the finer grained lithologies, and is closely parallel to the few observed examples of true bedding. This regional cleavage has a strike of about 340° and the dip is constantly east at reasonably high angles, i.e. about 70°. However the regional cleavage fans near the Wiagdon Thrust first becoming vertical then dipping at high angles towards the west. Although the slaty cleavage pre-dates thermal effects, extensive recrystallization, especially of biotite, has emphasized the earlier textures.

There is no evidence in this area as to whether the development of this cleavage accompanied folding of a primary lithological layering. On a regional scale, the fan-like attitude of the foliation may be axial plane to a much larger folded structure, the scale of which does not allow interpretation within the mapped area. Such intense cleavage development is commonly related to reasonably appressed folding (Turner and Weiss, 1963).

A strain-slip cleavage is only developed locally within the fine grained lithologies and consists of alternating mica-rich and quartz-rich bands. Large flakes of contact metamorphic white mica have developed, accentuating this cleavage. At GR 766588 the strain-slip cleavage is well developed, deforming the slaty cleavage and cutting the latter at a reasonably high angle. (The strain-slip cleavage dips at 75° to 125°; the slaty cleavage dips at 85° to 245°.) In other localities the development of strain-slip cleavage is gradational to rocks exhibiting only slaty cleavage. In most rocks strain-slip cleavage is completely absent.

The most conspicuous layering observed in the area is of unrecognizable stratigraphic significance and is probably of metamorphic origin. It may represent a transposed lamination. Flat lenses, which vary considerably in size and thickness are characteristic of the Bells Creek Volcanics. Generally they are in the order of about 20 cm. long and from 1 mm. to about 3 cm. in width. In the lenticular quartz-rich material foliation is generally not obviously developed mesoscopically. The layering developed within fine pelitic lithologies is a finer differentiation lamination and in a few rocks isolated hinges of folds can be discerned on a small scale. Lenticles flattened in the plane of the slaty cleavage are finally produced.

True bedding especially in fine grained lithologies is thus not easily recognized in these foliated rocks. Bedding was probably never present within the Bell's Creek Volcanics. However in medium grained rocks, beds vary from about two feet to a few inches thick. At GR 719620 the intersection of bedding with slaty cleavage indicates that the beds are overturned. Graded bedding also suggesting that the succession is inverted is mainly developed on a small scale with many thin graded beds developed in the one unit.

A prominent lineation in the foliated acid rocks west of the Wiagdon Thrust is defined by a linear preferred orientation of biotite grains. This lineation is essentially a mineral streaking which pitches about 75° north in the plane of the slaty cleavage. The lineation developed within the finer grained lithologies appears as a fine crenulation on slaty cleavage surfaces. It may represent the intersection of an incipient strain-slip cleavage with slaty cleavage. On a much larger scale the long axes of deformed pebbles in the conglomerate at GR 712624 also define a lineation. Another lineation defined by small crenulations is rarely developed on the surface of the quartz rich pebbles in this conglomerate.

Folding occurs most commonly in the slaty cleavage in areas of maximum deformation—that is, along the Wiagdon Thrust and at GR 718622 where kink folds with shallow plunges are developed. Within the Wiagdon Thrust small, shallowing plunging concentric folds are developed with asymmetry towards the west. To the east of these kink folding is common. Axial planes have variable orientation and fan about the fold axis.

The Eastern Succession

Bedding, the most important structural element, is gently concentrically folded into a broad anticlinal structure the subhorizontal meridional axis of which occurs on the eastern side of Mt. Tennyson. Small flexures slightly complicate the structure (Plate IX).

The effect of the intrusion of the Bathurst Granite is such that the slaty cleavage has changed its gross orientation throughout the entire area as compared with observations to the north (Hobbs, 1958). The steep westerly dip changes gradually southwards to vertical and then to 50° or 60° north-east near the granite contact (Hobbs, 1969). This change, he states, has apparently been accomplished by large scale kink folding.

SUMMARY AND CONCLUSIONS

Owing to confined outcrop of these strongly contact metamorphosed rocks between the Bathurst Granite and Durandal Stock, the stratigraphic succession is elucidated mainly by comparison of lithology, lithological distribution and structure in areas to the north.

Two sequences can be recognized—a western succession and an eastern succession separated by a narrow continuous thrust zone. Primary textural features are poorly preserved in rocks of the western succession and the well developed slaty cleavage in some finer lithologies has been further deformed by a strain-slip cleavage. In the eastern succession bedding is the main structural element and has been concentrically folded into a broad anticlinal structure. Original textural features are usually visible and the penetrative cleavage of the western succession is lacking. Some rock types are common to both divisions but it is difficult to tell whether the sequences are time-equivalent since correlation is not possible across the thrust zone. The main difference between them is thus tectonic style.

In the western sequence the oldest exposed rocks are the Ordovician to Silurian Sofala Volcanics. They are altered dark-green rocks originally perhaps of andesitic composition, now with mafic and ultramafic mineralogy. These rocks appear to include flows, pyroclasts and related porphyritic intrusive rocks. The unit has faulted relations with adjacent beds, but is thought to form a structurally high area where the thinner eastern succession of Silurian to ? Devonian calcareous sediments with acid volcanics is developed. To the west, foliated pelitic and minor calc-silicate lithologies grade into the foliated acid rocks of the Bell's Creek Volcanics. A thick succession of felsic to intermediate volcanic rocks and unfossiliferous greywacke and slate stratigraphically above the Bell's Creek Volcanics, is related to that described by Packham (1958, 1968) and possibly comprises part of the Chesleigh Formation, the Cookman Formation and part of the Crudine Group.

In the eastern sequence the lowest exposed banded pelitic lithology is overlain by greywacke and tuff which is conglomeratic at the base. This conglomerate is distinctly calcareous and a molybdenite-bearing skarn has been produced by contact metamorphism. A pelite above the greywacke and tuff is also banded and contains relatively thin conglomeratic horizons at a number of levels. The eastern boundary of this unit may be unconformable or faulted against the mafic rocks of the Sofala Volcanics.

On a regional scale the foliated western succession forms part of the Hill End Trough geosynclinal sequence (Packham, 1960, 1962, 1968) whereas the eastern succession is believed to comprise part of the relatively thinner marine succession of the Capertee Geanticline. The Wiagdon Thrust, extending from north of Mudgee to south of Yetholme, a distance of over 60 miles (Packham, 1968), marks the boundary between these fundamentally different sedimentary and structural terranes and coincides with the Ordovician to Silurian volcanic province now represented by altered mafic volcanic rocks of the Sofala Volcanics. To the west of the Hill End Trough, the Molong Geanticline (Fig. 1) with abundant calcareous lithologies is also characterized by andesitic and basaltic igneous activity concentrated along a narrow thrust zone (Smith, 1966).

The Carboniferous Bathurst Granite and the Durandal Stock appear to be contemporaneous plutons and their present levels of exposure are probably quite near the roofs of both bodies. However vast differences in rock types are apparent, "megacrystalline" granite being almost entirely restricted to the Durandal Stock, and only one small occurrence near the margin of the main Bathurst Granite. On a regional scale, the Bathurst Granite outcrops over 500 square miles and cuts directly across the Hill End Trough, separating the more strongly deformed southern areas (Binns, 1958; Hopwood, 1958; Williams, 1961; Page, 1966; Fig. 1) from those to the north.

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References

Andrews, E. C., 1916.—The molybdenum industry in New South Wales. *N.S.W. geol. Surv., miner. Resour.*, 24.

Basnett, E. M., 1942.—Studies in metamorphism and assimilation in the Wellington district, New South Wales. II. The dynamic and contact metamorphism of a group of ultrabasic rocks. *J. Proc. roy. Soc. N.S.W.*, 73: 161-189.

Binns, R. A., 1958.—The geology of the Cow Flat district near Bathurst, N.S.W. Unpubl. B.Sc., Hons. thesis, Univ. Sydney.

Colditz, M. J., 1948.—The petrology of the Silurian volcanic sequence at Wellington, New South Wales. *J. Proc. roy. Soc. N.S.W.*, 81: 180-197.

Evernden, J. F., and Richards, J. R., 1962.—Potassium-argon ages in Eastern Australia. *J. geol. Soc. Aust.*, 9: 1-49.

Goldner, P. T., 1966.—The geology of the Mt. Tennyson-Tarana quarry area. Unpubl. B.Sc., Hons. thesis, Univ. Sydney.

Hobbs, B. E., 1958.—The geology of the area to the north-east of Bathurst, N.S.W. Unpubl. B.Sc., Hons. thesis, Univ. Sydney.

————, in Packham (1969)—Geology of New South Wales. *Journ. geol. Soc. Austr.* 15 (in press).

Hopwood, T. P., 1960.—Geology of an area south-east of Bathurst. Unpubl. B.Sc., Hons. thesis, Univ. Sydney.

Mackay, R. N., 1964.—The Yetholme Granite. Unpubl. Ph.D. thesis, Univ. Sydney.

Packham, G. H., 1954.—Sedimentary structures as an important feature in the classification of sedimentary rocks. *Amer. J. Sci.*, 252: 466-476.

————, 1958.—Stratigraphic studies in the older Palaeozoic rocks of the Tasman Geosyncline in central-western N.S.W. Unpubl. Ph.D. thesis, Univ. Sydney.

————, 1960.—Sedimentary history of part of the Tasman Geosyncline in south-eastern Australia. *Int. geol. Congr.*, 21 (12): 74-83.

————, 1962.—An outline of the geology of New South Wales. 36th Meeting Aust. & N.Z. Assoc. Adv. Sci., Sydney, A Goodly Heritage: 24-35.

————, 1966.—Bathurst 1: 250,000 geological series sheet *S1 55-8* (Geol. Surv. N.S.W.).

————, 1968.—The lower and middle Palaeozoic stratigraphy and sedimentary tectonics of the Sofala-Hill End-Euchareena region, N.S.W. Proc. Linn. Soc. N.S.W., 93: 111-163.

Page, R. W., 1966.—The geology of the Diamond Hill area south-west of Tarana, N.S.W. Unpubl. B.Sc., Hons. thesis, Univ. Sydney.

Smith, R. E., 1966.—The geology of Mandurama-Panuara. *J. Proc. roy. Soc. N.S.W.*, 98: 239-262.

Watts, B. J., 1966.—Geology of the Mt. Tennyson area south of Yetholme N.S.W. Unpubl. B.Sc., Hons. thesis, Univ. Sydney.

Williams, C., 1961.—The geology of the Walang-Napoleon Reefs area. Unpubl. B.Sc., Hons. thesis, Univ. Sydney.

Williams, I. R., 1960.—Geology of the Wisemans Creek district, central tablelands, N.S.W. Unpubl. B.Sc., Hons. thesis, Univ. Sydney.

SPOROZOITE RATE IN *ANOPHELES FARAUTI* LAVERAN RELATED TO TYPES OF CATCH AND SEASONAL CONDITIONS

MARGARET SPENCER*

[Read 30th April, 1969]

Synopsis

Comparison of the sporozoite rates obtained from five different types of catch of *Anopheles farauti* Laveran made by standard methods and with standard apparatus indicates that in estimating sporozoite rate caution should be exercised with window-trap catches and catches of mosquitoes resting indoors in the daytime. It is recommended that dissections for sporozoite rate in this vector species should be carried out on anophelines caught in the act of biting during all-night catches as this directly combines attack rate and sporozoite rate and should be carried out over a sufficient period of time.

INTRODUCTION

Monthly and quarterly variations in sporozoite rate for this species were given in a previous paper (Spencer, 1965), but in this paper little reference was made to variations observed in different types of catch.

In establishing a biting pattern and a pattern of nocturnal activity for *An. farauti* in hamlets, the following types of catch were carried out, as shown in Table 1—(1) all night biting, (2) daytime resting out-of-doors, (3) daytime resting indoors, (4) night-time resting on and in houses, (5) window-trapping, (6) catches in garden areas.

These catches were made in four small coastal hamlets, Uiaupolo, Bwalalea, Muduia and Mapamoiwa, of Fergusson Island, D'Entrecasteaux Islands, Papua.

An. farauti dominated the anopheline community to an extent shown by the fact that in one period when 2548 *An. farauti* were taken in the catches, we recovered during that time and in that locality only 25 adult *An. punctulatus,* 16 *An. subpictus* and 1 *An. annulipes.* The composition of the anopheline population of the entire island group has been previously described (Spencer, 1960 and 1965).

METHODS

Standard methods and apparatus were used. We developed a battery-operated suction device for collecting adult mosquitoes which was of great benefit to the collectors (Spencer, T., 1962).

OBSERVATIONS

A. TYPES OF CATCH. Observations are set out in Table 1.

(1) *Hamlet all night biting catch.* It is considered that this is the most representative type of catch, directly combining attack rate and sporozoite rate. The S.R. from these catches were 0·85% and 1·18%, close to the overall average of 0·8% in 6456 dissections.

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* 1 George St., Tenterfield, N.S.W. 2372

(2) *Resting on and in houses at night-time.* The two samples gave an average S.R. of 1·59% and 0·9%, close to the overall average of 0·8%.

(3) *Daytime resting out-of-doors catch* gave an average S.R. of 1·5%, a comparable result to the biting and night-resting catches. This is interesting because the best sample for obtaining the human blood index indicating anopheline blood preferences for exophilous mosquitoes is from this type of catch.

TABLE 1

Types of catch, time periods, and sporozoite rates observed for An. farauti, *Fergusson Island, D'Entrecasteaux Group, Papua, between June, 1957, and June, 1959 (prespray)*

Type of catch	Place	Time period	Number dissected	+	%	95% confidence limits*
All night biting 6 p.m.–6 a.m.	All hamlets	June, 1957–Aug., 1958	1,288	11	0·85	0·404–1·5%
All night biting 6 p.m.–6 a.m.	All hamlets	Jan.–Aug., 1958	678	8	1·18	0·506–2·32%
Daytime resting out-of-doors	All hamlets	Jan.–Aug., 1958	341	5	1·5	0·48–3·48%
Daytime resting indoors	All hamlets	Jan.–Aug., 1958	106	4	3·8	1·05–9·47%
Nighttime resting on houses	Bwalalea	March and April, 1959	440	7	1·59	0·63–3·28%
Nighttime resting on houses	Bwalalea	March–June, 1959	774	7	0·9	0·354–1·86%
Window traps	Bwalalea	March–June, 1959	2,733	8	0·29	0·14–0·63%
Garden areas	All hamlets	Jan.–July, 1958	96	0	0	0–3·77%
Total			6,456	50	0·8	

* The confidence limits are from *Geigy Scientific Tables*, Sixth Edition, 1962, published by Geigy Pharmaceuticals.

(4) *Resting indoors in the daytime catch.* This has a considerably higher average S.R. (3·8%) than the all-night biting catch, which was a larger series taken at the same time. This adds some support to Metselaar's (1957) contention that more older and sporozoite-positive females are found indoors in the daytime than appear in biting catches on human bait. More could be done to explore this possibility (using Polovoda's method), especially if this type of catch is to be used to establish a sporozoite rate.

(5) *Window-trap catch.* In a large series the average S.R. was 0·29%. In the same period of time in the same locality a very much higher average S.R. (0·9%) occurred in the night-time resting series. These two series are definitely from the same anopheline population, but there is small probability that they will be equally representative samples of that population. On the other hand Peters and Standfast (1960, for *An. punctulatus*) found their highest sporozoite rate among mosquitoes caught in traps. Obviously this also needs further exploration.

(6) *Garden areas.* In spite of the fact that we obtained no sporozoite-positive anophelines in a limited series of catches, the possibility of their occurrence in these areas cannot be ignored.

B. Seasonal conditions. Observations are set out in Tables 2 and 3.

As has been observed commonly elsewhere in tropical areas, there is considerable monthly variation in sporozoite rate; in our observations 1958 is the more typical year, as 1957 was unusually dry and adverse to mosquito longevity. It can be seen that it is possible to dissect hundreds of a vector species within an area of highly endemic malaria without finding a single sporozoite-positive mosquito. The S.R. was often roughly in inverse proportion to the mosquito density.

Of interest was the coincident or approximately coincident appearance of sporozoite-positive anophelines in the one hamlet in two different types of catch. Note (Table 3) the appearance of sporozoite-positive mosquitoes in Bwalalea on June 9th (biting and resting), in Mapamoiwa on June 16th (resting outdoors) and June 18th (resting indoors) and June 23rd (resting) and June 25th (biting) at Uiaupolo.

Discussion

(1) A breakdown of the types of catch indicates clearly that caution must be exercised with window-trap catches and catches of mosquitoes resting indoors in the daytime, at least with the exophilous *An. farauti.* The window-trap catch may tend to include a larger proportion of younger anophelines which possibly are not old enough to have matured sporozoites. Window-trap catches therefore may neither be truly representative of the mosquito population as a whole, nor contain the epidemiologically important fraction; equally daytime indoor-resting catches may not be truly representative, containing a greater fraction of sporozoite-positive mosquitoes than the population at large.

The writer considers that under the conditions of coastal Papua-New Guinea window-traps should be regarded only as a useful apparatus for sampling the anopheline species present, and their times of leaving houses, and that dissections for sporozoite rate should be carried out on anophelines caught in the act of biting during all-night catches.

(2) Care must be taken in assessing the effect of seasonal conditions (particularly rainfall) upon the mosquito population. If conditions are adverse for adults (e.g. particularly dry), the average duration of life may be shortened, resulting possibly in lower observed sporozoite rates. On the other hand under favourable breeding conditions high dilution of the population with flocks of recently-emerged mosquitoes would also give low observed sporozoite rates.

The question therefore arises as to the minimum size of the sample that is necessary to assess a sporozoite rate and the time-period over which the sample should be made. On statistical grounds, the sample should be not less than 1000 mosquitoes in any locality for any given type of catch (Table 2 shows clearly the wide confidence limits where small numbers are involved). The time-period should cover at least one "population cycle"—this being one full rise and fall in numbers as shown by nightly catches or bi-weekly catches or whatever sampling is judged to be sufficient for the purpose. It will include the highs and lows in numbers of nulliparous and multiparous mosquitoes, and thus the fluctuations in sporozoite rate, and will be clearly shown if detailed records are kept of the total numbers taken in the individual

TABLE 2

Results of salivary gland dissections of mosquitoes taken in all-night biting catches, 6 p.m.–6 a.m., June, 1957–August, 1958, Fergusson Island, D'Entrecasteaux Group, Papua (Breakdown of line 1, Table 1)

Month	Dissected	Number + sporozoites	% +	95% confidence limits
1957 :				
June	189	1	0·529	0·01 – 2·9%
July	65	2	3·08	0·37 –10·68%
August	97	0	0	0·0 – 3·73%
September	100	0	0	0·0 – 3·62%
October	83	0	0	0·0 – 4·35%
December	76	0	0	0·0 – 4·74%
Total	610	3	0·49	0·099– 1·425%
1958 :				
January	206	0	0	0·0 – 1·8%
February	37	4	10·81	3·03 –25·42%
March	15	0	0·0	0·0 –21·8%
April	111	1	0·9	0·02 – 4·9%
May	103	0	0·0	0·0 – 3·5%
June	91	2	2·2	0·27 – 7·7%
July	79	1	1·27	0·03 – 6·8%
August	36	0	0·0	0·0 – 9·7%
Total	678	8	1·18	0·506– 2·32%
Total 1957–1958	1,288	11	0·85	0·404– 1·5%

TABLE 3

Sporozoite-positive An. farauti *mosquitoes appearing in different types of catch showing coincidence in time both in the same hamlet and in different hamlets (Fergusson Island, D'Entrecasteaux Group, Papua) (prespray)*

Place	Date	Circumstances	Caught	Dissected	+
Uiaupolo hamlet	11.2.58	Night-biting in hamlet	130	30	4
	11.2.58	Daytime resting indoors	19	16	1
	23.6.58	Daytime resting outdoors	10	9	1
	25.6.58	Night-biting in hamlet	102	61	1
	14.7.58	Night-biting in hamlet	37	29	1
	16.7.58	Daytime resting indoors	5	5	1
Bwalalea	10.3.58	Daytime resting outdoors	69	56	1
	9.6.58	Night-biting in hamlet	14	13	1
	9.6.58	Daytime resting outdoors	26	24	2
Mapamoiwa	27.2.58	Night resting indoors	15	13	1
	13.3.58	Daytime resting indoors	11	11	1
	16.6.58	Daytime resting outdoors	4	3	1
	18.6.58	Daytime resting indoors	3	3	1
Muduia	10.4.58	Night biting in hamlets	68	21	1

adult catches from which the dissections are made. Samples for nulliparity ratio can be assessed by Detinova's method.

These population cycles for *An. farauti* on Fergusson Island occupied approximately a month, from one rockbottom low to the next. If, due to human factors (absence of infected people),* no sporozoite-positive mosquitoes occur during one population cycle then dissection obviously must be continued until an acceptable result is obtained or observations must extend to include a more representative human population.

A knowledge of biting patterns, nocturnal activity and age-composition of anopheline populations intimately associated with human population units gives both the entomologist and the epidemiologist a confident appraisal of the true interrelationship of the anopheline and the human communities. It will not have to be done in every situation; once carried out in certain key localities, prediction could be made from aerial photographs, contour maps and known patterns of rainfall.

Recommendations

It is recommended that dissections for sporozoite rate in this vector species should be carried out on anophelines caught in the act of biting during all-night catches. Samples should be not less than 1000 and the time-period should cover at least one full "population cycle". Combination of catches from several small hamlets is legitimate if the human population moves freely between them, and may in fact be essential for an accurate picture. These suggestions relate to tropical coastal areas of Papua-New Guinea in which *An. farauti* is the major vector. They may also be valid for Highlands areas, and for subcoastal areas where *An. punctulatus* is the dominant vector.

Acknowledgements

It is a pleasure to acknowledge the helpful advice of my husband, Dr. T. Spencer, and the always interested co-operation and hard work of the indigenous staff of the Malaria Section's D'Entrecasteaux Islands Pilot Project who collected the basic data. This paper is published with the permission of the Director of Public Health, Territory of Papua and New Guinea.

References

METSELAAR, D., 1957.—Pilot project of residual insecticide spraying in Netherlands New Guinea. (Thesis, Leyden.)

PETERS, W., and STANDFAST, H., 1960.—Studies on the epidemiology of malaria in New Guinea, Part 2. *Trans. Roy. Soc. trop. Med. & Hyg.*, 54 (3): 249.

SPENCER, T., and SPENCER, M., 1960.—Malaria assessment methods, including anopheline species distribution list for the D'Entrecasteaux Islands, Papua. *Papua N. Guinea med. J.*, 4: 55.

SPENCER, M., 1965.—Malaria in the D'Entrecasteaux Islands Papua with particular reference to *Anopheles farauti* Laveran. PROC. LINN. SOC. N.S.W., 90 (1): 115.

SPENCER, T., 1962.—Suction device for catching mosquitoes. *Papua N. Guinea med. J.*, 6 (1): 32.

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* The richest source of gametocytes in this area is infants and children up to 10 years of age.

A PRELIMINARY LIMNOLOGICAL SURVEY OF THE WOOLI LAKES, NEW SOUTH WALES

B. V. Timms*

Sciences Department, Avondale College, Cooranbong, N.S.W.

[Read 30th April, 1969]

Synopsis

Near Grafton there are two freshwater lakes, Hiawatha and Minnie Water, which were formed by coastal sand dunes blocking two depressions in the Fitzroy Beds. In both lakes the slightly acid water has less than 100 p.p.m. of total dissolved solids and is dominated by Na and Cl ions. The lakes are polymictic. The fauna and flora is poor in variety, but in some groups is rich in numbers. The zooplankton is dominated by *Calamoecia tasmanica*, but *Mesocyclops leuckarti* and *Bosmina meridionalis* are also present. A comparison of these lakes with typical sand dune lakes in northern N.S.W. and southern Queensland shows that the modes of origin are different, leading to different water chemistry, which probably accounts for the interesting differences in the zooplankton.

INTRODUCTION

Near the coastal township of Wooli and about 40 km. east of Grafton by road in the North Coast District of N.S.W. lie two freshwater lakes, Lake Hiawatha and Lake Minnie Water (Fig. 1). They are situated close to the sea (the eastern shore of Hiawatha is only 2 km. from the coastline) and separated from it by sand dunes. The lakes are similar to those of the coastal acidic sand-dune series studied by Bayly (1964), but there are important differences.

METHODS

The lakes were visited on two occasions in 1967—August 24–25 and December 30–31. Temperatures were measured with a resistance thermometer at 1 m. intervals until the bottom of the lake was reached. Readings were taken at five different places in each lake and were made in the mid-morning. The methods of water analyses and the plankton nets were the same as those used in Timms (1967). Parts of this report, particularly the sections on physiography and fish, are based on the unpublished data of other workers (see acknowledgements).

PHYSIOGRAPHY

The two lakes lie in two depressions in a north-south line between Silurian Fitzroy Beds of shales, slates and phyllites in the west and recent siliceous sand-dunes to the east. McElroy's map (1962) of the area is inaccurate in that it shows the lakes completely surrounded by Quaternary deposits. The sand-dunes form a continuous ridge running roughly in a north-south direction reaching an altitude of 100 m. immediately north-east of Lake Minnie Water. The two depressions are separated by a bar of Fitzroy Beds which varies in height from about 20 m. in the east to about 30 m. in the west above sea-level. It is probable that the lakes lie on the same

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* Present address, Monash University, Clayton, Victoria, 3168.

Beds in the west and in the centre, while in the eastern part they lie over the base of the sand-dunes (Fig. 2).

Lake Hiawatha is 315·6 hect. in area and 16·8 m. above sea-level, while Lake Minnie Water is 51·4 hect. in area and 19·8 m. above sea-level. No permanent streams flow into the lakes with most of the water entering by seepage and by surface runoff from the western ridge. During normal and subnormal rainfall periods Lake Minnie Water has no overflow, but during exceptionally wet periods it overflows into Lake Hiawatha. The latter lake has a semi-permanent overflow in the south-east corner. This outflow passes into swamps and then into the Wooli River. In both lakes the water level is known to vary no more than 1 m., even in times of severe drought. The maximum depth in Hiawatha is 11 m. and in Minnie Water, 9 m. The average yearly rainfall for the area is of the order of 1·25 m.

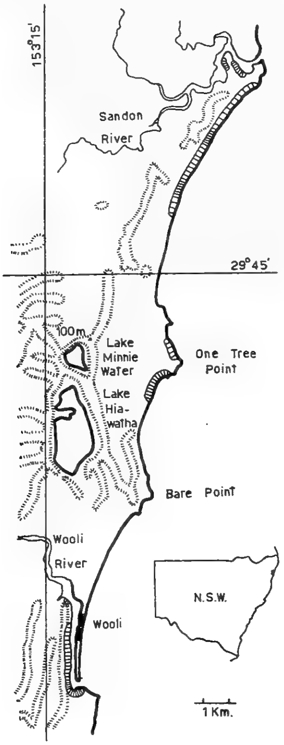

Fig. 1. Locality map of the Wooli Lakes showing the lakes with respect to various physiographical features. Outcrops of organically-bound sand are shown as hatched areas. In these the closer the lines then the more extensive the outcrop.

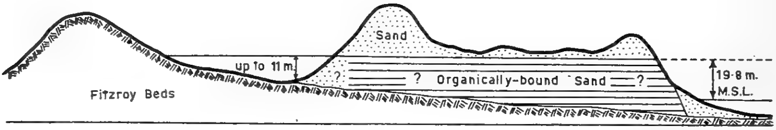

Fig. 2. Diagramatized and idealized profile through Lake Hiawatha from the western ridge to the coast. The relationship between the lake and sea level and between the rock base, organically-bound sand and sand dunes is shown.

The physiography of the littoral areas in both lakes is variable. Basically three types can be distinguished: (i) a gently sloping littoral area of a clayey material studded in places with claystone outcrops—found wherever the lakes directly abut the Fitzroy Beds; (ii) sandy littoral area—associated with the sand-dunes on the eastern shore of both lakes; gently sloping in Hiawatha, but much steeper in gradient in Minnie Water; (iii) a peaty littoral area found wherever there are swampy areas near the lake edge—gradient is variable and in places the peat layer is undercut giving rise to an abrupt drop of 2–3 m. beyond the edge. The peaty littoral area is well developed and extensive in Minnie Water, but in Hiawatha it is limited to a small area at the northern end.

Some information is available on the nature of the benthic substrata in the lakes. Over the claystone it is generally of a colloidal ooze nature, though in places it is gravelly. The benthic material is sandy in the eastern section of the lakes. In the deepest part of Hiawatha there is an accumulation of leaves and reed debris to a depth of almost a metre.

Apparently there is no published information on the method of origin of the Wooli Lakes. The lakes were probably due to building up (possibly in Pleistocene and Recent geological time) of a dune barrier upon the truncated deposits of an old (Pleistocene) swamp now about 17 m. above sea-level. Evidence for the old swamp is seen in the outcropping of peat and organically-bound sand to the north, east and south of the lakes. This material probably acts as a water table in the eastern side of the lakes and is responsible for the retention of water between the dunes and Fitzroy Beds.

PHYSICAL AND CHEMICAL FEATURES

The temperature profiles for the two lakes are shown in Fig. 3. In winter the lakes were isothermal and no doubt in complete circulation. In summer there was only 1° difference between the bottom and surface temperatures in both lakes, and so it is probable that during the night the lakes are in complete circulation. Thus, it would appear that the lakes are polymictic. The main contributing factor to this condition is thought to be the exposure of the lakes to wind, though the clear water would allow heating to some considerable depth.

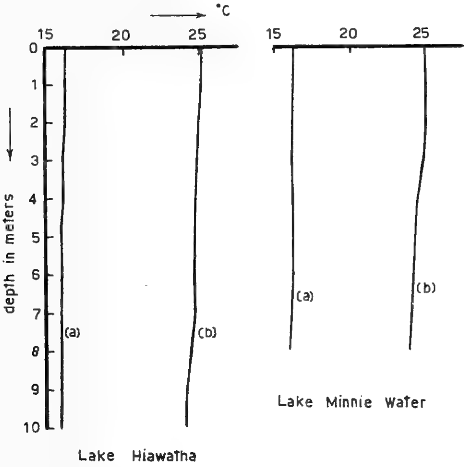

Fig. 3. Temperature profiles for the Wooli Lakes. Winter profiles are marked (a) and summer profiles are marked (b).

Both lakes contain clear water with Secchi Disc readings of 473 cm. (August) and 337 cm. (December) for Lake Minnie Water, and 420 cm. (August) and 560 cm. (December) for Lake Hiawatha. From afar off the lakes appeared bluish, but Minnie Water tended towards a light humic brown colour on the summer trip.

Both lakes are acidic, and average pH values from a number of readings over the years are 6·2 for Minnie Water, and 6·5 for Hiawatha. The values for total dissolved solids for the August trip are given in Table 1. The December values are 74 p.p.m. for Minnie Water, and 67 p.p.m. for Hiawatha. The decreased values recorded on the summer trip were no doubt associated with the rise in water level in both lakes because of the abundant summer rains.

TABLE 1

Percentage composition of cations and anions and T.D.S. in p.p.m. in coastal sand dune lakes

Locality	Na	K	Ca	Mg	Cl	HCO$_3$	SO$_4$	T.D.S.
Lake Minnie Water ..	80	1	5	14	77	17	6	79
Lake Hiawatha ..	80	1	5	14	72	18	10	69
Mean of 19 Qld–N.S.W. lakes*	78	2	4	16	82	2	16	39

* From Bayly (1964).

TABLE 2

Chemical composition of coastal acidic lake water

Locality	Na	K	Ca	Mg	Total ionic concentration (m-equiv./l)		Cl	HCO$_3$	SO$_4$
	in p.p.m.				Summation of Cations	Summation of Ions	in p.p.m.		
Lake Minnie Water* ..	13·8	0·2	0·8	2·4	0·85	0·88	27·0	6·1	1·9
Lake Hiawatha* ..	14·5	0·2	0·8	2·6	0·89	0·93	27·7	6·7	3·8
Mean of 19 Qld–N.S.W. coastal acidic lakes†	11·8	0·6	0·5	1·2			19·1	1·6	5·1
Range of values in the 19 Qld–N.S.W. lakes† ..	7·9 26·3	0·3 1·2	0·2 0·8	0·7 2·8			12·5 43·3	Nil 3·0	2·4 12·5

* Water sample taken on 24th August, 1967.
† From Table 1, Bayly (1964).

Tables 1 and 2 show the chemical composition of the water of the Wooli Lakes. As would be expected from their origins, the water chemistry of the two lakes is very similar. Sodium completely dominates the cations and chlorine the anions, the most common condition in Australian lakes (Williams, in Weatherley, 1967). As discussed later, there are important similarities and differences between the water chemistry of the Wooli Lakes and that of the coastal sand dune lakes studied by Bayly (1964).

BIOLOGICAL FEATURES

Around the shores of both lakes, emergent hydrophytes are abundant, though they are sparse in areas where there is outcropping rock. On all types of littoral shores (see earlier) there is a pure stand of the sedge *Lepironia articulata* (Retzius) on the outer edge and often continuing right to the shoreline. In places this species was found to be growing in water up to 3 m. deep. Other common emergent plants growing in the littoral region include a spike-rush *Eleocharis sphacelata* (Brown) and a pipe-wort *Eriocaulon scariosum* (Smith). Only two submergent species of hydrophytes were found. Thus there were numerous plants of *Restio pallens* (Brown) on some areas of the clayey shoreline of Hiawatha, and *Nitella* sp. (cf. *N. tasmanica* (Muhlenberg)) grew abundantly in parts of the littoral area in Minnie Water.

In Minnie Water the bottom was covered by a dense mat of hydrophytes. Two species, *Chara fibrosa* (Agardh) and *Utricularia flexuosa* (Vahl) were present, and from the limited number of dredgings taken it was apparent that each species occurred as pure stand and that *Utricularia flexuosa* grew on areas near peaty shorelines, and *Chara fibrosa* grew elsewhere in the lake. No macroscopic plants were found in the benthic zone of Hiawatha. No obvious reason could be seen for this difference.

TABLE 3

Percentage composition of planktonic crustacean species in the Wooli lakes

Locality and date of collection		*Calamoecia tasmanica*	*Mesocyclops leuckarti*	*Bosmina meridionalis*
Lake Minnie Water	24. 8.1967	99·8	0·1	0·1
	31.12.1967	99·7	0·2	0·1
Lake Hiawatha	24. 8.1967	98·0	—	2·0
	31.12.1967	97·1	0·3	2·6

In the present work, no observations were made on fish, but a team from the State Fisheries Department under Dr. A. A. Racek collected fish (and decapods) from Lake Hiawatha intermittently during the period 1954–57. The unpublished data resulting from these collections are presented in Table 4. The freshwater catfish *Tandanus tandanus* is very common in the lake and in September, 1956, its commercial exploitation was attempted. At the time a 7 lb. sea mullet was caught. It was a ripe female which apparently did not spawn because it is known that in such circumstances the gonad is resorbed unless the fish reaches the sea.

No list of birds is available and the general opinion is that both lakes support a meagre variety of birds. My own observations are few. Thus, on both the summer and winter trips small numbers of black cormorant (*Phalacrocorax carbo* Linnaeus), little pied cormorant (*P. melanoleucos* Vieill) and black duck (*Anas superciliosa* Gmelin) were observed on both lakes. A few dusky moorhen (*Gallinula tenebrosa* Gould) were observed on both lakes in summer only while at the same time a number of a species of tern (*Sterna* sp.) were observed fishing in Lake Hiawatha.

In both lakes the limnetic zooplankton consists of three species of crustaceans, namely *Calamoecia tasmanica tasmanica* (Smith), *Mesocyclops leuckarti* (Claus), and *Bosmina meridionalis* (Sars). As shown in Table 3, *C. tasmanica* is the dominant species, and the only difference between the two lakes is the higher proportion of *B. meridionalis* in Hiawatha. The only phytoplankton species noted was *Botrycoccus* sp. No rotifers were observed, nor was the dipteran larva *Chaoborus*. An unidentified water mite was found in the August collection from Minnie Water.

Among the few insects observed were a number of corixid bugs and some larvae of Odonata and Trichoptera. Although snails and prawns were specifically looked for in the littoral area none were found. However, many specimens of an atyid prawn, *Caridina* sp. (of the *"nilotica"* group of species) was collected from the benthic region of Lake Minnie Water, it being associated with the masses of *Chara fibrosa* brought up with the anchor. Four littoral species of entomostracans were collected. These are *Eucyclops serratulus* (Fisher), *Paracyclops fimbriatus, Mesocyclops* sp., cf. *leuckarti* group and *Acroperus harpae* (Baird). None were common, being represented by only a few individuals in three five-minute collections at each lake.

TABLE 4

*List of fishes found in Lake Hiawatha**

Fish		Notes
Latin name and author	Common name	
Tandanus tandanus Mitchell	Freshwater catfish	Common in lake
Anguilla australis Schmidt	Short-finned eel	In outlet
Mugil cephalus Linn.	Sea mullet	Possibly introduced by local fishermen
Pseudomugil signifer Kner.	Blue eye	Only two specimens found in lake
Melanotaenia fluviatilis (Castelnau)	Rainbow fish	Abundant along eastern shore
Galaxias attenuatus (Jenyns)	Common jolly-tail	In outlet
Carassiops galii Ogilby	Fire-tailed gudgeon	Abundant along eastern shore
Gambusia affinis (Baird and Girard)	Mosquito fish	In most of the lake's areas
Retropinna semoni (Weber)	Australian smelt	In outlet
Ambassis agassizi Steindachner	Chanda perch	In lake and outlet
Rhadinocentrus ornatus Regan	Porthole fish	Only one specimen found in lake

* Unpublished data, Dr. A. A. Racek.

Racek's team recorded four species of Decapoda from Lake Hiawatha and its outlet. They are *Atya striolata* McCulloch and McNeill and *Cherax* n. sp. (to be described by Riek in a forthcoming paper) from the outlet, and *Paratya australiensis* Kemp and *Caridina* sp. (of the *"nilotica"* group of species) from the weeded parts of the lake. Despite an organized search, no Spongillidae, Ectoprocta, Lamellibranchiata or Palaemonidae were found in the lake. Thus by combining Racek's and the author's observations, it can be seen that there are no Mollusca in the lakes.

DISCUSSION

Hutchinson (1957) has discussed and catalogued the various methods of origin of lakes. The Wooli Lakes provide a modified example of Type 60—the formation of a lake in a valley dammed by wind-blown sands. Thus, in the present instance, two depressions have been dammed by sand dunes, organically-bound sand within the dunes acting as control for the water-table. Jennings (1957) has cited some similar examples on King Island (Tasmania) where water is held in depressions between siliceous sand-dunes and granite hills by a layer of organically-bound sand.

The coastal acidic sand dunes in south-east Queensland and north-east New South Wales, and some lakes on King Island are formed in a different way, and, as pointed out by Bayly (1964), one that receives little mention in the limnological literature. In these cases the lakes occur in depressions within sand dunes, the water being withheld by an impervious seal of organically-bound sand.

There is a high degree of similarity in these two modes of origin, and thus one would expect to find similar but slightly different water chemistry between lakes of different mode of origin with the same area. Brand (1967) found this to be the case on King Island, and as shown below, this is so with the Wooli Lakes and the coastal acidic sand dune lakes of south-east Queensland and north-east New South Wales.

If the water chemistry of the Wooli Lakes and of the coastal acidic sand dune series studied by Bayly (1964) are compared, the following points emerge. Thus, the pH is acidic in both series, but is higher in the Wooli Lakes (an average of 6·35 compared to an average of 4·8, and a range of 4·1 to 6·0 in the coastal acidic sand dunes series (calculated from Bayly, 1964). The higher pH is probably associated with the relatively higher amount of bicarbonate in the Wooli Lakes (see Table 2 and later).

The average values for T.D.S. of 76·5 p.p.m. and 68 p.p.m. for Minnie Water and Hiawatha respectively are well above the average for the coastal acidic sand dune series (39 p.p.m.) but within the range 26–84 p.p.m. (calculated from Bayly, 1964) recorded for that series.

Table 2 shows the chemical composition of the water of the Wooli Lakes compared with the mean values and range of values for 19 coastal sand dune lakes in south-east Queensland and north-east New South Wales (Bayly, 1964). It can be seen that there are differences in the ionic composition between the two groups. While the values for Na and Cl are well within the range exhibited by the coastal sand dune lakes, and the values for K, Ca, Mg and SO_4 are near the extremes found in the same lake series, the amount of HCO_3 in the Wooli Lakes is much higher. As shown in Table 1 the proportions of the major cations are much the same in the two series (note that there is a small difference in the relative proportion of Ca and Mg in the two) but the proportions of major anions are quite different. As stated before, much of the water entering the lakes is by seepage from the sand dunes and it can be reasonably expected that this water is of much the same nature as that entering the coastal sand dune lakes. The higher amount of HCO_3 in the Wooli Lakes can only be attributed to water that has run off the western ridge.

The only limnetic entomostracan species found in the coastal acidic sand dune series is *Calamoecia tasmanica tasmanica*. The same species is present in the Wooli Lakes, but in addition two further species are present, although in small proportions (see Table 3). It is believed that this difference in faunal characteristics is associated with the difference in water chemistry between the two series. It is now known (Brand, 1967) that *Calamoecia tasmanica* is able to survive in a much wider range of chemical conditions than previously thought, and in light of this, its presence and dominance in the Wooli Lakes is not surprising. Apparently, the Wooli Lakes provide a marginal habitat for *Mesocyclops leuckarti* and *Bosmina meridionalis*.

In many respects, a similar case of change in planktonic fauna with changing chemical conditions, has been presented by Brand (1967). Thus, in sand dune lakes on King Island *C. tasmanica tasmanica* is restricted to lakes of lower T.D.S. and Ca content, while *Boeckella symmetrica* Sars occurs mainly in lakes of higher T.D.S. and Ca content. A number of entomostracans penetrating into waters of low T.D.S. and Ca content were recorded; two of these were *Mesocyclops leuckarti* and *Bosmina meridionalis*.

Summing up, it can be seen that though there are many similarities between the Wooli Lakes and the more typical coastal acidic sand dune lakes, they are different in at least three important aspects—mode of origin, water chemistry, and zooplankton. The somewhat different, but nevertheless related, mode of origin accounts for the slight differences in water chemistry, which is probably the reason for the presence of the two additional species in the zooplankton of the Wooli Lakes.

Acknowledgements

I am grateful to the following persons who made information available: Dr. D. D. Francois, Director of N.S.W. State Fisheries; Mr. L. Fryer of Grafton; Mr. W. Hargraves of Wooli; Mr. L. Martin of Lismore; Dr. A. A. Racek, University of Sydney; Mr. N. Smith of Grafton, and Dr. J. Yaldwyn of Australian Museum. Thanks are also due to M. Tarbotton for help in the field. I also wish to acknowledge the help of the following taxonomists for their identifications: Prof. F. Kiefer of Germany for Cyclopoid Copepods; Mr. Mair of the National Herbarium, Sydney, for Aquatic Macrophytes; and Mr. N. N. Smirnov of U.S.S.R. for Chydoridae. Finally, I wish to thank Dr. I. A. E. Bayly, Mr. L. Martin, and Dr. W. D. Williams for their criticism of an early draft of the paper.

References

BAYLY, I. A. E., 1964.—Chemical and biological studies on some acidic lakes of the East Australian sandy coastal lowlands. *Aust. J. mar. Freshwat. Res.*, 15: 56-72.

BRAND, G. W., 1967.—Studies on some south-east Australian dune lakes, with special reference to the distribution of *Calamoecia tasmanica* Smith (Copepoda: Calanoida). Honours thesis, Monash University.

HUTCHINSON, G. E., 1957.—"A treatise on limnology," Vol. I. New York: John Wiley & Sons, xiv + 1015 pp.

JENNINGS, J. N., 1957.—Coastal dune lakes as exemplified from King Island, Tasmania. *Geogr. J.*, 123: 49-70.

McELROY, C. T., 1962.—The geology of the Clarence Moreton Basin. Memoirs of the Geological Survey of N.S.W., Geology No. 9: Mines Department of N.S.W.

TIMMS, B. V., 1967.—Ecological studies on the Entomostraca of a Queensland pond with special reference to *Boeckella minuta* Sars (Copepoda: Calanoida). *Proc. Roy. Soc. Qld.*, 79: 41-70.

WILLIAMS, W. D., 1967.—"Chemical characteristics of lentic waters" in "Australian Inland Waters and Their Fauna." Edit. A. H. Weatherly. Canberra: A.N.U. Press, xv + 287 pp.

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SPECIES OF *ATTENUATELLA* STEHLI (BRACHIOPODA) FROM NEW SOUTH WALES

John Armstrong and Peter Telford
Department of Geology, University of Queensland

(Plate x)

(*Communicated by Professor T. G. Vallance.*)

[Read 25th June, 1969]

Synopsis

Attenuatella convexa Armstrong and *Attenuatella* sp. cf. *A australis* Armstrong and Brown are recorded from the Farley Formation in the Sydney Basin, New South Wales thereby strengthening the correlation of the fauna in this unit with Dickins Fauna II in Queensland. *Attenuatella multispinosa* Waterhouse from the Gilgurry Mudstone in northern New South Wales is considered to be closest to *A. incurvata* Waterhouse from the AG 4 Limestone in New Zealand. Species occurring in the Gilgurry Mudstone with *A. multispinosa* include *Strophalosia ovalis* Maxwell, *Cancrinella magniplica* Campbell, *Ingelarella* sp. cf. *I. mantuanensis* Campbell, and *Notospirifer* sp. cf. *N. minutus* Campbell. The occurrence of *Attenuatella multispinosa* with these species supports the correlation of the fauna in the Gilgurry Mudstone with New Zealand faunas that contain *A. incurvata.*

Introduction

The occurrence of *Attenuatella convexa* Armstrong and *Attenuatella* sp. cf. *A. australis* Armstrong and Brown in the Farley Formation is the first record of the spiriferid *Attenuatella* in the Sydney Basin. Waterhouse (1967*a*) has described *Attenuatella multispinosa* Waterhouse from the Gilgurry Mudstone in northern New South Wales and representatives of *Attenuatella* are quite common in Queensland (Armstrong and Brown, 1968; Armstrong, 1968). The fauna occurring with *Attenuatella convexa* and *Attenuatella* sp. cf. *A. australis* in the Farley Formation includes *Anidanthus springsurensis* (Booker) (UQF52687–8) recorded by Armstrong, Dear, and Runnegar (1967, p. 90), *Ingelarella ovata* Campbell (UQF54448), and *I. branxtonensis* (Etheridge) (UQF54449–50). Farley Formation is the amended name proposed by Booker (1960, p. 15) for rocks which David (1907, 1950) included in his Farley Stage. Species occurring at other localities in the Farley Formation are listed by Armstrong *et al.* (1967, p. 90). Many of these species are characteristic of the fauna of the Tiverton Formation (i.e. Fauna II of Dickins, 1964) in Queensland, and for this fauna Armstrong *et al.* (1967, p. 91) suggest a lower Artinskian (Aktastinian) age. In Queensland *Attenuatella convexa* is known from two localities (Armstrong, 1968) at both of which there is a diverse Fauna II. The occurrence of *Attenuatella convexa* in the Farley Formation strengthens the correlation of the fauna in this unit with Fauna II in Queensland.

A number of specimens of *Attenuatella multispinosa* Waterhouse have recently been collected from two localities (UQL3270 and UQL3272) in the Gilgurry Mudstone in northern New South Wales. Each of these localities is at approximately the same stratigraphic level. The fauna from a locality (UQL3271) near the base of the Gilgurry Mudstone about 1,700 feet stratigraphically below UQL3270 includes *Cancrinella magniplica* Campbell (UQF54427), *Strophalosia ovalis* Maxwell (UQF54431–32), and *Notospirifer* sp. cf. *N. minutus* Campbell (UQF54416). Faunas from approximately the same stratigraphic level as the localities which yielded the specimens of

A

Attenuatella multispinosa include *Ingelarella* sp. cf. *I. mantuanensis* Campbell (UQF56068 from UQL3318; UQF56066 from UQL3317) and *Notospirifer* sp. cf. *N. minutus* Campbell (UQF56067 from UQL3317).

Repositories and localities.—Mentioned and figured specimens which are retained in the collections of the Australian Museum, Sydney and in the Department of Geology, University of Queensland are designated by a number prefixed by AMF and UQF respectively. Localities indexed at the latter institution are denoted by a number prefixed by UQL.

All of the localities in the Gilgurry Mudstone which are mentioned in the text are on the Drake 1: 63,360 map (1946 reproduction). The descriptions and grid references of the localities on this map are as follows:

UQL3270: on east side of Slaty Creek, 400 yards at 35° east of north from the Sandy Hill to Drake road crossing of Slaty Creek. 356E 173N.

UQL3271: hill slope on north side of Slaty Creek about 1900 yards at 30° east of north from the Sandy Hill to Drake road crossing of Slaty Creek. 363E 186N.

UQL3272: road cutting on the road from Sandy Hill to Drake at 398E 152N.

UQL3317: in creek 200 feet north of the road from Sandy Hill to Drake at 375E 162S.

UQL3318: exposures in small creek which is first creek, to the south of the Drake to Sandy Hill road crossing of Crooked Creek, to enter Crooked Creek from the east. 308E 157S.

The locality from which the Farley Formation specimens of *Attenuatella* were collected is UQL3265 which is the north western corner of Portion 74, Parish Pokolbin, County Northumberland, New South Wales.

SYSTEMATIC DESCRIPTION

Phylum BRACHIOPODA Duméril, 1806
Order SPIRIFERDIA Waagen, 1883
Subfamily AMBOCOELIINAE George, 1931
Genus *Attenuatella* Stehli, 1954

Attenuatella Stehli, 1954. *Attenuatella* Stehli; Chernyak, 1963. *Attenuatella* Stehli; Waterhouse, 1964. *Attenuatella* Stehli; Waterhouse, 1967*a*. *Attenuatella* Stehli; Armstrong and Brown, 1968. *Attenuatella* Stehli; Waterhouse, 1968. *Attenuatella* Stehli; Armstrong, 1968. *Attenuatella* Stehli; Beznosova, 1968.

Type species.—(original designation) *Attenuatella texana* Stehli, 1954, Pl. 25, figs 31–33, from the Lower Leonardian Bone Spring Formation, Texas.

Other species and specimens.—*A. acutirostrus* (Krotova, 1885), Pl. 4, fig. 24. *A. stringocephaloides* (Chernysheva and Likharev) *in* Likharev and Einor, 1939, Pl. 13, fig. 5a, b. *A. attenuata* (Cloud, 1944), Pl. 17, figs 22–25. *A. stringocephaloides* (Chernysheva and Likharev); Chernyak, 1963, Pl. 42, figs 3, 4. *A. taimyrica* Chernyak, 1963, Pl. 42, figs 5–9. *A. incurvata* Waterhouse, 1964, Pl. 20, figs 1–12, Pl. 21, figs 1–9. *A. multispinosa* Waterhouse, 1967*a*, Pl. 24, figs 1–7. *A. australis* Armstrong and Brown, 1968, Pl. 8, figs 1–16. *A. altilis* Waterhouse, 1968, Pl. 2, figs 2–12, 15. *A. convexa* Armstrong, 1968, Pl. 142, figs 1–12, 19. *A.* sp. cf. *A. incurvata* Waterhouse; Armstrong, 1968, Pl. 142, figs 13–18. *Attenuatella* sp. A. Armstrong, 1968, Pl. 142, figs 20–23. *Attenuatella* sp. Landis and Waterhouse, 1966, Pl. 1, figs 1–5. *Attenuatella* sp. Landis and Waterhouse, 1966, p. 144. *Attenuatella* sp. Armstrong, 1968, Pl. 142, figs 24–26. (?) *A. elgae* Beznosova, 1968, Pl. 29, figs 1–3. A. sp. cf. *A. australis* Armstrong and Brown, (herein). *A. convexa* Armstrong, (herein). *A. multispinosa* Waterhouse, (herein).

ATTENUATELLA CONVEXA Armstrong, 1968.

Specimens.—UQF54451–53, UQF54455–58 from the Farley Formation in the Sydney Basin, New South Wales at UQL3265 in the north-western corner of Portion 74, Parish Pokolbin, County Northumberland.

Description.—The shell of the Farley specimens is gently bi-convex and variably transverse. Ventral valves are relatively broad and they bear a narrow but distinct sulcus for their entire length. Flanks of the ventral valves are smooth and towards the commissure are rather steep. The dorsal valve is semicircular in outline although the length of the cardinal margin is slightly less than the greatest width of the valve. One dorsal valve is gently convex (Pl. X. fig. 4). Another is gently convex rostrally but is flattened around the margins of the valve (Pl. X, fig. 5). However the internal mould of the latter specimen is flattened dorso-ventrally suggesting that this dorsal valve was originally also gently convex. On the posterior part of this valve (Pl. X, fig. 5) there is a shallow median furrow. Both the ventral and the dorsal valves of the Farley specimens are covered with numerous growth lamellae along which the small spines on the shell are sometimes located; between eight and ten spines per millimetre occur along a growth lamella.

In the ventral valve in the posterior part of the delthyrium there is a small delthyrial plate depressed below the level of the area. The teeth are strong and bulbous. The sockets in the dorsal valve are large and along the inner side of each one there is a robust inner socket ridge. Narrow, less strong ridges lie along the outer margins of the sockets. The crural bases arise from the floor of the valve at the anterior ends of the inner socket ridges. No adductor muscle scars are preserved in the dorsal valves of the Farley specimens but on the internal moulds (UQF54451 and UQF54457) of two valves there are the impressions of a tuberculate cardinal process. The area of attachment of the muscles in the ventral valve is low in comparison with that of most species of *Attenuatella*. It is not an elevated platform with steep sides, but like the ventral muscle fields of Queensland specimens of *Attenuatella convexa* it is characteristically elongate, lying on the floor of the valve posteriorly and being a low rounded elevation anteriorly (Pl. X, fig. 9).

Remarks.—Like specimens of *Attenuatella convexa* from Queensland the Farley specimens possess a low, massive ventral umbo, a broad ventral valve, a distinct ventral sulcus, a gently convex dorsal valve, and quite coarse spines.

One specimen (Pl. X, figs 1, 2) of *Attenuatella* from the Farley Formation at UQL3265 is characterized by a relatively elongate shell and a gently reflexed dorsal valve which is concave in its adult growth stages. The ventral muscle platform is not distinctly elevated but otherwise the specimen is closest to *Attenuatella australis* Armstrong and Brown (1968).

Age.—*Attenuatella convexa* and *A. australis* occur in faunas which are correlatives of Dickins's (1964) Fauna II and for this fauna Armstrong *et al.* (1967) have deduced a lower Artinskian (Aktastinian) age.

ATTENUATELLA MULTISPINOSA Waterhouse, 1967*a*

Specimens.—Several internal and external moulds of ventral and dorsal valves (UQF54417–24, UQF54433–45, UQF54447) from UQL3270. The specimens are preserved in a dark siltstone and are from the upper part of

Voisey's (1936, pp. 159, 160) Upper Division of the Drake Series. For the 1,000 feet of rocks which constitute the upper part of his Upper Division, Voisey (1958, p. 180) proposed the name Gilgurry Mudstone. Additional specimens of *Attenuatella multispinosa* (UQF54425–26, UQF54428–30) from the Gilgurry Mudstone are from UQL3272.

Remarks.—The main distinguishing features of *Attenuatella multispinosa* are its fine spines and the ridges along the margins of the platform of muscular attachment in its ventral valve (Waterhouse, 1967*a*). Waterhouse records spine concentrations of between ten and twenty per millimetre on his specimens of *A. multispinosa*. The specimens of *Attenuatella* from UQL3270 possess narrow elongate ventral valves with imperceptible sulci and reflexed dorsal valves. On some of these ventral valves (i.e. UQF54419, UQF54437 from UQL3270) the spines number between 12 and 16 per millimetre. On a ventral valve (UQF54428) from UQL3272 there are between 14 and 20 spines per millimetre. On any particular ventral valve the finest spines occur on the flanks of the valve near the cardinal extremities. In three ventral valves (UQF54433, UQF54439–40) from UQL3270 there are ridges along the margins of the posterior end of the muscle platform, but in other ventral valves the preserved platforms of muscular attachment are without such ridges (UQF54420, UQF54425–6, UQF54430, UQF54434). However, not all of Waterhouses's specimens of *A. multispinosa* have ridges along the edges of the platform of muscular attachment in the ventral valve (Waterhouse, 1967*a*, Pl. 24, figs 1, 2, & 4). The Gilgurry specimens of *Attenuatella* from UQL3270 and UQL3272 can confidently be assigned to *A. multispinosa*.

Species of *Attenuatella* which have a convexi-concave dorsal valve are *A. incurvata* Waterhouse, *A. multispinosa* Waterhouse, and *A. australis* Armstrong and Brown. The last species has a more prominent ventral sulcus than either of the preceding species and it generally has coarser spines than *A. multispinosa*. *Attenuatella incurvata* and *A. multispinosa* are very similar species. Waterhouse (1967*a*) distinguished them on the basis of the size of their superficial spines and the degree of development of the ridges along the margins of the platform of muscular attachment in their ventral valves. Along concentric lines on its shell, *Attenuatella incurvata* may have six to eight spines per millimetre (Waterhouse, 1964, p. 111), ten to 13 spines per millimetre (Landis and Waterhouse, 1966, p. 145), or ten to 14 spines per millimetre (Waterhouse, 1967*a*, p. 171). As noted previously, marginal ridges are variably developed on the ventral muscle platforms of the Gilgurry specimens of *Attenuatella,* so that the characteristics of the external ornament and of the ventral muscle platform of the Gilgurry specimens would not seem to enable confident separation of *A. multispinosa* from *A. incurvata*. Should the spines of *A. incurvata* number up to 14 per millimetre, many of the specimens of *Attenuatella* from the Gilgurry Mudstone (i.e. those lacking muscle platform ridges) would be inseparable from the New Zealand species.

In any case *Attenuatella multispinosa* is particularly close to *A. incurvata* and its occurrence in the Gilgurry Mudstone will lend support to a correlation of the fauna in this unit with faunas in which *A. incurvata* occurs elsewhere. In New Zealand *Attenuatella incurvata* occurs in the AG4 Limestone in the Arthurton Group, and in the Pine Bush Formation in the Kuriwao Group (Waterhouse, 1964). The species occurring with *A. multispinosa* in the Gilgurry Mudstone are characteristic of Fauna IV of Dickins (1964; see Runnegar, 1967), and the similarity of *A. multispinosa* to *A. incurvata* supports Runnegar's (1967) and Runnegar and Armstrong's (in press) correlation of Fauna IV with Waterhouse's (1967*b*, p. 166) New Zealand faunas that contain *A. incurvata*.

References

ARMSTRONG, J., 1968.—The unusual brachial skeleton of *Attenuatella convexa* sp. nov., *Palaeontology*, 11: 783-792.

ARMSTRONG, J. and BROWN, C. D., 1968.—A new species of *Attenuatella* (Brachiopoda: Spiriferida) from the Permian of Queensland. *Mem. Qd. Mus.*, 15: 59-64.

ARMSTRONG, J., DEAR, J. F., and RUNNEGAR, B., 1967.—Permian ammonoids from eastern Australia. *J. geol. Soc. Aust.*, 14: 87-97.

BESNOSOVA, G. A., 1968.—*in* SARYCHEVA, T. G., Brakhiopody Verkhnego Paleozoya Vostochnogo Kazakhstana. *Trudy Paleont. Inst.*, 121: 1-212 (Upper Palaeozoic brachiopods from eastern Kazakstan).

BOOKER, F. W., 1960.—Studies in Permian sedimentation in the Sydney Basin. *Tech. Rep. Dep. Mines N.S W.*, 5 (for 1957): 10–62.

CHERNYAK, G. E., 1963.—in V. I. USTRITSKIY and G. E. CHERNYAK. Biostratigrafiya i Brakhiopody verkhnego paleozoya Taymyra. *Trudy nauchno-issled. Inst. Geol. Arkt.*, 134: 1–139. (Biostratigraphy and branchiopods of the upper Permian of Taimyr).

CLOUD, P. E., 1944.—Permian Brachiopoda. *in* KING, R. E., DUNBAR, C. O., CLOUD, P. E., and MILLAR, A. K.—Geology and palaeontology of the Permian area northwest of Las Delicias, south western Coahuila, Mexico. *Spec. Pap. geol. Soc. Am.*, 52: 1–72.

DAVID, T. W. E., 1950.—The geology of the Hunter River Coal Measures, New South Wales. *Mem. geol. Surv. N.S.W.*, 4.

————, 1950.—"The geology of the Commonwealth of Australia." London. Edward Arnold and Co.

DICKINS, J. M., 1964.—Appendix *in* MALONE, E. J., CORBETT, D. W. P., and JENSEN, A. R., 1964.—Geology of the Mount Coolon 1: 250,000 Sheet area. *Rep. Bur. miner. Resour. Geol. Geophys. Aust.*, 64: 1–87.

DUMÉRIL, A. M. C., 1860.—"Zoologie analytique ou méthode naturelle de classification des animaux." Paris. Allais.

GEORGE, T. N., 1931.—*Ambocoelia* Hall and certain similar British spiriferida. *Q. Jl. geol. Soc. Lond.*, 87: 30–61.

KROTOVA, P., 1885.—Artinskiy yarus. Geologopaleontologicheskaya monografiya Artinskogo peschanika. *Trudy Obshch. Estest. imp. Khar'kov. Univ.*, 13 (5): 1–314. (Artinskian stage. Geological-palaeontological monograph of the Artinsk sandstones).

LANDIS, C. A., and WATERHOUSE, J. B., 1966.—Discovery of Permian fossils in the Eglinton Volcanics, Southland. *Trans. r. Soc. N.Z. Geol.*, 4: 139–146.

LIKHAREV, B. K., and EINOR, O. L., 1939.—Materialy k poznaniyu verkhnepaleozoyskikh faua Novaya Zemli, Brachiopoda. *Trudy arkt. nauchno-issled Inst.*, 127: 1–245. (Contributions to the knowledge of the upper Palaeozoic faunas of Novaya Zemlya, Brachiopoda).

RUNNEGAR, B., 1967.—Preliminary faunal zonation of the eastern Australian Permian. *Qd. Govt. Min. J.*, 68: 552–556.

RUNNEGAR B., and ARMSTRONG, J., in press. Comments on Series and Stages in the Permian of New Zealand. *Trans. r. Soc N.Z.*

STEHLI, F. G., 1954.—Lower Leonardian Brachiopoda of the Sierra Diablo. *Bull. Am. Mus. nat. Hist.*, 105: 261–358.

VOISEY, A. H., 1936.—The upper Palaeozoic rocks in the neighbourhood of Boorook and Drake, N.S.W. PROC. LINN. SOC. N.S.W., 61: 155–168.

————, 1958.—Further remarks on the sedimentary formations of New South Wales. *J. Proc. r. Soc. N.S.W.*, 91: 165–189.

WAAGEN, W. H., 1883.—Salt Range fossils, Part 4 (2) Brachiopoda. *Mem. geol. Surv. India Palaeont. indica*, ser. 13, 1: fasc. 2, 391–546.

WATERHOUSE, J. B., 1964.—Permian Brachiopoda of New Zealand. *Bull. geol. Surv. N.Z. Palaeont.*, 35: 1–287.

————, 1967*a*.—A new species of *Attenuatella* (Brachiopoda) from Permian Beds near Drake, New South Wales. *Rec. Aust. Mus.*, 27: 167–173.

————, 1967*b*.—Proposal of Series and Stages for the Permian of New Zealand. *Trans. r. Soc. N.Z.* 5: 161–180.

————, 1968.—The classification and descriptions of Permian Spiriferida (Brachiopoda) from New Zealand. *Palaeontograph.*, 129: 1–94.

EXPLANATION OF PLATE X

All Figures × 5 except Figure 5 which is natural size.

Figs 1, 2. *Attenuatella sp.* cf. *A. australis* Armstrong and Brown; 1, dorsal view of the latex cast of a dorsal valve and the umbo of its conjoined ventral valve. 2, ventral view of the internal mould of the shell which yielded the external mould from which the cast in Figure 1 was taken. UQF54454 from the Farley Formation at UQL3265.

Fig. 3. *Attenuatella convexa* Armstrong; Latex cast of the exterior of a ventral valve. UQF54457 from the Farley Formation at ULQL3265.

Fig. 4. *A. convexa* Armstrong; dorsal view of a latex cast of a dorsal valve and part of its conjoined ventral valve. UQF54451 from the Farley Formation at UQL3265.

Figs 5–7. *A. convexa* Armstrong; 5, 6, dorsal views (natural size and × 5 respectively) of a latex cast of a dorsal valve and its conjoined ventral valve. 7, dorsal view of the internal mould of the shell which yielded the external mould from which the cast in Figures 5 and 6 was taken. UQF54457 from the Farley Formation at UQL3265.

Figs 8, 9. *A. convexa* Armstrong; 8, latex cast of the exterior of a ventral valve. 9, internal mould of the ventral valve whose exterior is illustrated in Figure 8. UQF54452 from the Farley Formation at UQL3265.

Fig. 10. *Attenuatella multispinosa* Waterhouse; dorsal view of the latex cast of a dorsal valve and the umbo of its conjoined ventral valve. UQF54441 from the Gilgurry Mudstone at UQL3270.

Fig. 11. *A. multispinosa* Waterhouse; lateral view of the latex cast of a shell. UQF54423 from the Gilgurry Mudstone at UQL3270.

Fig. 12. *A. multispinosa* Waterhouse; Internal mould of a ventral valve. UQF54434 from the Gilgurry Mudstone at UQL3270.

Figs 13–15. *A. multispinosa* Waterhouse; latex casts of the exteriors of three ventral valves. UQF54419 from UQL3270, UQF54437 from UQL3270, and UQF54428 from UQL3272 respectively, all from the Gilgurry Mudstone.

Fig. 16. *A. multispinosa* Waterhouse; latex cast of the exterior of a dorsal valve. UQF54417 from the Gilgurry Mudstone at UQL3270.

Fig. 17. *A. multispinosa* Waterhouse; internal mould of a ventral valve. AMF42105 from the Gilgurry Mudstone. See also Waterhouse, 1967*a*, Pl. 24, Fig. 3.


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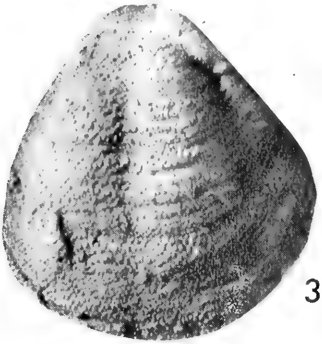
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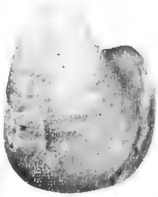
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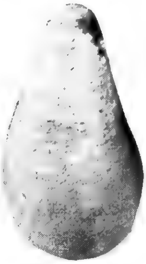
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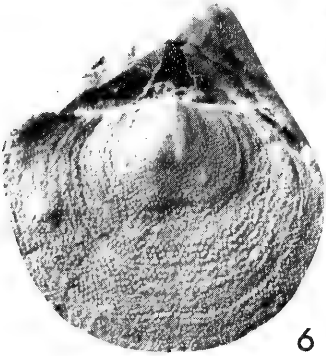
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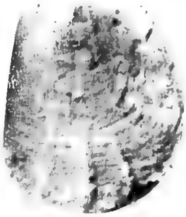
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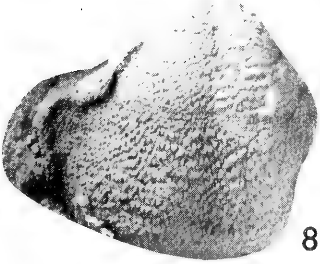
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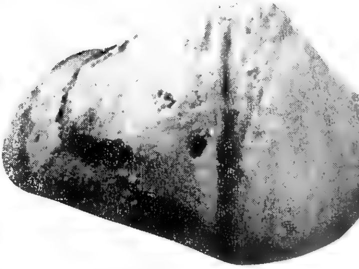
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17

Species of *Attenuatella* Stehli (Brachiopoda)

CRINIA TASMANIENSIS (ANURA: LEPTODACTYLIDAE): GEOGRAPHIC DISTRIBUTION, MATING CALL STRUCTURE, AND RELATIONSHIPS

M. J. Littlejohn
Department of Zoology, University of Melbourne
Parkville, Victoria, 3052

(Text Figures 1–2).

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Synopsis

Geographic distribution, mating call structure, and breeding biology of *Crinia tasmaniensis* are described and compared with Tasmanian populations of *C. signifera.* The two species, which are extensively sympatric, are presumed to be reproductively isolated at the premating level by differences in mating call structure, and also appear to be isolated at the postmating level. *C. tasmaniensis* is clearly a member of the *C. signifera* complex, but does not show a close relationship to the three species groups currently recognized within the complex. Accordingly it is suggested that *C. tasmaniensis* be placed in a fourth group.

Introduction

The *Crinia signifera* complex includes ten species and has been divided into three species groups (superspecies) on the basis of distribution, life history, genetic compatibility, and mating call structure (Main, 1957, 1962; Littlejohn, 1961; Littlejohn and Martin, 1965*b*; Straughan and Main, 1966). The *C. signifera* group includes *C. signifera* Girard, *C. glauerti* Loveridge and *C. riparia* Littlejohn and Martin. The *C. insignifera* group includes *C. insignifera* Moore, *C. parinsignifera* Main, *C. pseudinsignifera* Main, *C. sloanei* Littlejohn and *C. subinsignifera* Littlejohn. *C. tinnula* Straughan and Main constitutes the third group (Straughan and Main, 1966). The affinities of the remaining taxon, *C. tasmaniensis* (Günther), have yet to be considered.

Two species of the *Crinia signifera* complex, *C. signifera* and *C. tasmaniesis,* occur in Tasmania, the latter being endemic to that island (Littlejohn and Martin, 1965*a*). The status of *C. tasmaniensis,* about which there had previously been some doubt, was confirmed by Blanchard (1929), who also provided information on the morphology and biology of this species. Parker (1940) gives a detailed description of the adult morphology of *C. tasmaniensis,* which differs from *C. signifera* in its lack of tarsal folds, less granular belly, smooth throat in males, and commonly by the presence of bright red patches on the concealed portions of the flanks and hind limbs. Embryonic development, larval morphology, and larval biology of *C. tasmaniensis* are described by Martin (1967), and of mainland *C. signifera* by Moore (1961) and Martin (1965). A general account of *C. signifera,* including adult morphology, is provided by Moore (1961).

Moore (1954) noted the sympatric occurrence of the two species near Derwent Bridge, and found that in three *in vitro* crosses between *C. signifera* females (Sydney, N.S.W.) and *C. tasmaniensis* males (Derwent Bridge), the resulting progeny were haploids, all of which eventually died, the last as larvae of 10 mm. length. G. F. Watson (pers. comm.) crossed a female *C. signifera* from three miles NW of Derwent Bridge with a male *C.*

tasmaniensis from nine miles E of Marrawah and found that all the resulting embryos were abnormal and died before hatching. These results indicate a level of genetic incompatibility which, together with the sympatric occurrence of the two forms, further confirms the status of *C. tasmaniensis.*

Sympatric species of anuran amphibians generally have distinctive mating calls, and the differences in call structure are presumed to operate as premating reproductive isolating mechanisms. Experimental documentation of this function has now been provided for a reasonable number of hylid frogs (see references in Littlejohn and Loftus-Hills, 1968), and for five species of the *Crinia signifera* complex (Straughan and Main, 1966; Lindgren, 1963, in Main, 1968). In closely related, morphologically similar (cryptic) species, the mating call is often the only characteristic which will allow certain identification (Littlejohn, 1968). The basic structure of the calls may also assist in the establishment of phylogenetic relationships, particularly in cryptic species groups. However, such characteristics must be used with caution, because their role as premating reproductive isolating mechanisms renders them liable to maximal selection for divergence in sympatry (Littlejohn, 1968). Mating calls of all known species of the *C. signifera* complex, except *C. tasmaniensis,* have now been described (Littlejohn, 1957, 1958, 1959; Littlejohn and Martin, 1965*b*; Straughan and Main, 1966).

The aims of the present paper are: (i) to summarize information on geographic distributions and extent of sympatry of *C. tasmaniensis* and *C. signifera* in Tasmania; (ii) to describe the mating call of *C. tasmaniensis* and to compare it with that of *C. signifera* in its role as a presumed premating isolating mechanism; (iii) to consider other aspects of breeding biology in relationship to the maintenance of efficient reproductive isolation; and (iv) to review available information and suggest phylogenetic affinities of *C. tasmaniensis.*

Materials and Methods

Field work in Tasmania was carried out during the following periods: October 25 to November 8, 1960; December 14 to 20, 1960; October 26 to November 8, 1961; April 2 to 5, 1963; and November 20 to 25, 1967.

Distributional data were derived from three sources: (i) specimens in the Research Collection, Department of Zoology, University of Melbourne; (ii) field observations on mating calls during the breeding seasons; and (iii) published records. Only localities additional to those where specimens were obtained are listed in the sections on call records.

Calls were tape recorded in the field using either an EMI L2B, or a Nagra III BH tape recorder, and a Reslo DPH, or a Beyer M 88 dynamic microphone. Wet bulb air and water temperatures were measured at positions close to calling frogs and the appropriate temperature, depending on whether the frog was calling in air or water, used as the effective temperature (presumed to approximate that of the frog). Tape recordings were analysed on an audiospectrograph (Kay Model 6061-A Sona-Graph), and a double beam cathode ray oscilloscope (Cossor Model 1049 Mk IV) and continuously recording 35 mm. camera (J. Langham-Thompson Series 205), with playback on either a Nagra III BH, Truvox R 6, or Uher 4000 Report S tape recorder. Overall speed variations (record—playback) were within ± 1·5% of the nominal tape speed (19 cm./sec.). Frequency responses of all components were reasonably linear within the range 50–7000 Hz. (based on manufacturers' specifications). Three calls of each individual were analysed on the oscilloscope and one of these on the audiospectrograph. The use of these two techniques permitted a relatively complete description of the acoustic signals.

Data from only three call samples of *C. tasmaniensis* are presented in Table 1, although several others were obtained. The particular samples, which come from widely separated stations, were selected because effective temperatures were within 2·0°C. of 10·0°C. (a convenient and established standard) allowing a general comparison to be made without correction for possible temperature effects.

GEOGRAPHIC DISTRIBUTION

CRINIA TASMANIENSIS

Specimens: 6 miles WNW of Smithton; 9 and 10 miles E of Marrawah; 1 mile S of Oonah; 5 miles S of Parrawe; 1 mile SW of Beaconsfield; 4 miles SE of Frankford; Mt. Barrow road, 4 miles below summit; Mt. Barrow (4637 feet); 4 miles W of St. Helens; 5 and 12 miles S of Golden Valley; Great Lake, east side; Rosebery; West Strahan; 16 miles E of Queenstown; Little Navarre River, Lyell Highway; Lake St. Clair, 3 miles NW of Derwent Bridge; Florentine Valley, near Maydena; Mt. Wellington (3000 feet); 8 miles N of Sorell.

Call records: Smithton area; Forest; 14 miles SW of Smithton; 15 miles E of Marrawah; Wynyard area; 1 mile N of Yolla; 2 miles S of Parrawe; 12 miles NW of Frankford; 8 miles S of Beaconsfield; Pioneer; 29 miles NW of St. Helens; 20, 14, and 8 miles N of Tullah; Tullah area; 1 mile S of Renison Bell; 6 miles W of Zeehan; 4 miles E of Zeehan; 9 miles SE of Zeehan; 7 miles S of Deloraine; Breona area; Queenstown; 6 miles E of Queenstown; King William Saddle; Wombat Moor.

Literature records: Wilmot, Cradle Valley, Lake Fenton, Mt. Wellington, Port Arthur (Blanchard, 1929); Ulverstone, Cradle Valley, Lake Fenton, National Park, Summit of Mt. Wellington, between Port Arthur and Roger's River (Parker, 1940); near Derwent Bridge (Moore, 1954); Ridgley (900 feet), Highclere (1200 feet), Black Bluff, Pine Lake, Lake St. Clair (2400 feet), Tarraleah, Tunnack, Woodsdale (1800 feet), Wombat Moor (3400 feet), Mt. Wellington (4166 feet), Murdunna, Eaglehawk Neck (Hickman, 1960); 4 miles S of Parrawe, Wombat Moor, Mt. Wellington (Martin, 1967).

CRINIA SIGNIFERA

Specimens: 10 miles E of Marrawah; 4 miles SE of Latrobe; 1 mile S of Nunamara; Pioneer; 4 miles W of St. Helens; Longford; 3 miles N of Breona; Great Lake, east side; 7 miles E of Poatina; 12 miles SE of Cressy; Campbelltown; 10 and 12 miles E of Campbelltown; Lake St. Clair, 3 miles NW of Derwent Bridge; Orford; 8 miles NE of Sorell; Sandy Bay; Clifton Beach.

Call records: Marrawah Beach; 6 and 10 miles E of Marrawah; 17 miles WSW of Smithton; Forest; 5 miles WNW of Detention River; 4 miles NW of Sassafras; 12 miles NW of Frankford; Frankford area; 1 mile SW of Beaconsfield; Exeter; 12 miles NNE of Launceston; 3 miles W of Bridport; 4 and 7 miles S of Deloraine; Carrick; 6 miles S of Cressy; 15 and 18 miles SE of Cressy; Storys Creek area; 6 miles N of Avoca; Avoca; 1 mile S of Cleveland; 7 miles NW of Campbelltown; Lake Leake area; Swansea area; 12 miles S of Swansea; 1 mile E of Strahan Beach; Jericho area; 2 miles S of Triabunna; 4 miles E of Buckland; Wombat Moor; 2 miles N of Sorell; 2 miles N of Dunalley; 8 miles SE of Dunalley; 8 miles N of Port Arthur; 6 miles W of Geevestown.

Literature records: Russell River Valley near National Park, Eaglehawk Neck (Blanchard, 1929); Ulverstone, near Devonport, Launceston, George's Bay, National Park, Eaglehawk Neck (Parker, 1940); near Derwent

TABLE 1

Physical characteristics of mating calls of Crinia tasmaniensis. *Means are given with ranges in parentheses*

Locality	Sample size	Effective temp. (°C.)	Call duration (msec.)	Note duration (msec.)	Number of notes	Note repetition rate (notes/sec.)	Pulse repetition rate (pulses/sec.)	Dominant frequency (Hz)
10 miles E of Marrawah ..	3	10·0	416 (383–447)	35 (32–40)	7·1 (7–8)	14·8 (12·0–16·0)	205 (175–221)	2230 (2000–2350)
4 miles W of St. Helens ..	5	11·25	349 (317–370)	32 (31–34)	6·3 (6–7)	16·6 (15·3–17·9)	208 (184–226)	2800 (2600–3200)
Florentine Valley, near Maydena	9	12·0	402 (310–513)	37 (31–43)	6·6 (5–8)	15·3 (13·0–17·2)	206 (171–258)	2820 (2450–3400)

Bridge (Moore, 1954); Tunnel Hill, Launceston, Perth, Pine Lake, Great Lake, Fingal, Bronte Park, Steppes, Ross, Tunbridge, Strahan, Lake St. Clair, Brady's Marsh, Tarraleah, Oatlands, Parattah, Lake Tiberias, Tunnack, Woodsdale, Wombat Moor, National Park, Howrah, Sandy Bay, Murdunna (Hickman, 1960); Arthur River, Ulverstone, Launceston, Lake St. Clair, Derwent Bridge, National Park, Eaglehawk Neck, Cox Bight (Moore, 1961); 4 miles E of Frankford, Longford, 7 miles E of Poatina, Campbelltown, Orford, Hobart area (Littlejohn, 1964).

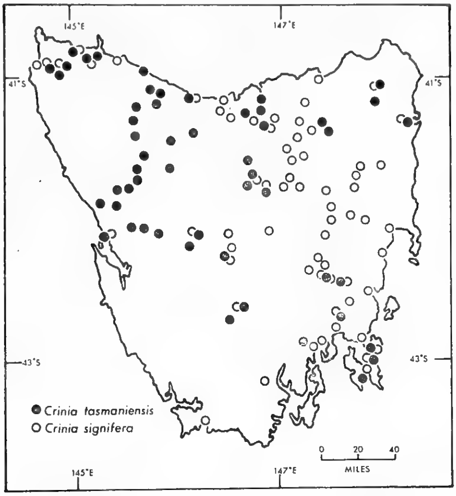

Fig. 1. Geographic distribution of *Crinia tasmaniensis* and *C. signifera* in Tasmania (based on localities listed in text).

Comments on Distribution: Locality data listed in the foregoing sections are summarized in Fig. 1. Both species are common and wide-ranging through much of Tasmania and occur in extensive sympatry across the north, in the central highlands, and in the south east. Only *C. tasmaniensis* has been found in the western highlands, and in an area northward to the coast between Burnie and Wynyard. Only *C. signifera* occurs in the midlands and apparently through to the central eastern coast. *C. signifera* occurs near sea level to 43° 30′ South Latitude (Cox Bight), and *C. tasmaniensis* to at least 43° 00′ South Latitude (Eaglehawk Neck). Both species have been found at nearly 4000 feet near Breona (41° 45′ South Latitude), and at 3382 feet on Wombat Moor (42° 40′ South Latitude). Only *C. tasmaniensis* has been found at 4000 feet on Mt. Wellington (42° 55′ South Latitude) (J. L. Hickman, pers. comm.).

MATING CALL STRUCTURE

CRINIA TASMANIENSIS

The mating call may be described as a slowly and irregularly repeated, quavering "bleat". It consists of a series of pulse trains (notes), each having an envelope with a gradual rise in amplitude (about 30 msec.) and an abrupt delay of about 5–8 msec. (Fig. 2). There is generally a concentration of energy at one peak (dominant frequency) within the range 2000 to 3500 Hz., although calls of three individuals showed a secondary peak 650–800 Hz. below the dominant. Values for the principal acoustic characteristics are summarized in Table 1. An oscillogram of a mating call is presented in Fig. 2.

A second type of acoustic signal (possibly associated with territoriality) was also encountered in two areas: 9–10 miles E of Marrawah, and 1 mile SW of Beaconsfield. An individual producing typical mating calls would occasionally make a longer call of differing temporal structure, but sometimes with the first part being similar to that of the mating call (i.e. transitional) or else rather variable, then settling down to a more regular pattern of quasi-periodic single pulses, or groups of two to four pulses (Fig. 2b). The pulse (or pulse group) repetition rate in this phase of the call is about 22–23 pulses/sec. The pulse duration is about 9–12 msec. with a sharp attack (less than two msec.), and a more gradual decay (about 5 msec.), resembling a pulse in the mating call of *C. signifera*.

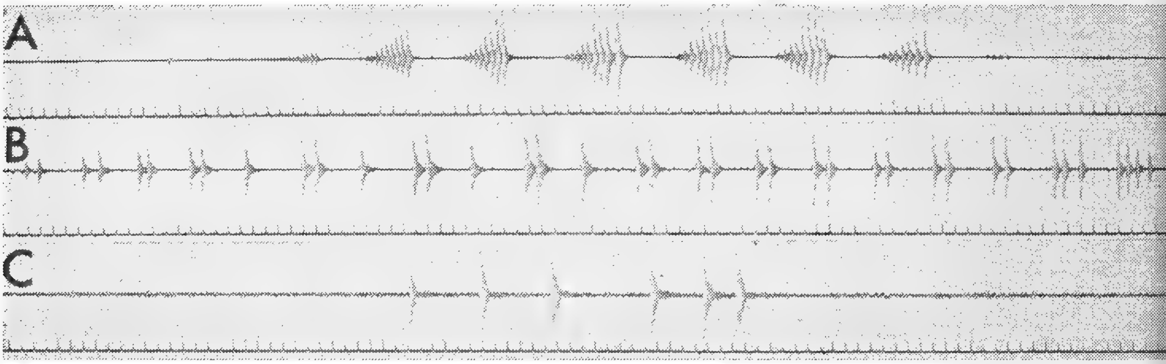

Fig. 2. Oscillograms of representative acoustic signals. The time marker below each trace indicates 10 msec. intervals. A: mating call of *Crinia tasmaniensis;* B: "territorial call" of *C. tasmaniensis;* C: mating call of *C. signifera.* The above three calls were recorded in a sympatric chorus, 10 miles E of Marrawah, at an effective temperature of 10·0°C.

CRINIA SIGNIFERA

The mating call of this species may be described as a short, rapidly repeated "chirp" or "crick". It consists of a train of pulses (pulse duration about 8–15 msec.) which have sharp attacks (less than two msec.) and more gradual decays (about 5–10 msec.). The pulses within a call are not periodic, but occur more frequently towards the end of a call. An oscillogram of a call is presented in Fig. 2c.

Selected physical characteristics of mating calls of 85 individuals from Tasmania, at an effective temperature of 10·0°C., were depicted graphically by Littlejohn (1964), and were based on the following data (means with ranges in parentheses):

Call duration (msec.)	232 (114–361)
Pulses per call	6·2 (4–9)
Pulse repetition rate (pulses/sec.)	23·1 (14·5–35·1)
Call repetition rate (calls/min.)	82 (40–127)

Littlejohn (1964) did not study the spectral structure of the calls but indicated that the dominant frequency was about 2550 Hz. Spectrographic analysis of mating calls of 10 individuals from a sympatric site, 10 miles E of Marrawah (effective temperature: 10·0°C.), indicated that a wide frequency band with two energy peaks was present; the lower peak had a mean of 2360 Hz. (range: 2100–2500), and the upper peak had a mean of

2940 Hz. (range: 2450–3400). The lower peak was of higher intensity in calls of six individuals, while the two were about equal in the remainder.

Comments on Mating Call Structure: The mating calls differ strikingly in their temporal structure (duration and amplitude modulation) both qualitatively and quantitatively. The differences are greater than those seen in other sympatric pairs of species that are included in the same species group of the *C. signifera* complex, e.g. *C. parinsignifera* and *C. sloanei* or *C. pseudinsignifera* and *C. subinsignifera* (Littlejohn, 1958, 1959). However, they are comparable to call differences between sympatric species belonging to different species groups, e.g. *C. glauerti* and *C. pseudinsignifera,* or *C. signifera* and *C. parinsignifera* (Littlejohn, 1958, 1959).

The similarity of dominant frequencies in the sympatric samples is of interest, for this could result in reduced efficiency of communication in mixed-species choruses through "acoustic jamming" (Littlejohn, 1965). Because of the extent of temporal dissimilarity, it is not clear whether specificity of the acoustic signal-response system depends mainly on one, or on a combination of differences.

COMPARATIVE BREEDING BIOLOGY

Habitats: Temporary ponds, low swampy seepages, and shallow rocky streams were utilized by both species for breeding sites.

Calling Positions: *C. tasmaniensis* males call from concealed positions on land at the edge of water, or while floating and supported by emergent vegetation. *C. signifera* males generally call from concealed positions on the banks and close to the edge of the water. No species-specific aggregations were noticed in the sympatric breeding sites; rather, there appeared to be a mosaic distribution with calling males of each species in close proximity.

Calling Seasons: Both species were heard calling in strong choruses during the period October 26–November 8, and less intensely during the periods November 20–25, and December 14–20. Neither species was heard calling during the period April 2–5, although areas where both species occur were visited.

Calling Temperatures: Effective calling temperatures ranged from 7·0 to 18·0°C. for *C. tasmaniensis,* and from 4·5 to 16·5°C. for *C. signifera.* The calling temperature ranges are almost certainly wider than indicated by these limited field data.

Times of Oviposition: A gravid female *C. tasmaniensis* was collected near Maydena on October 29, 1960, and embryos in the early yolk plug stage were seen on Wombat Moor on November 3, 1961. Martin (1967) collected early embryos of *C. tasmaniensis* on Mt. Wellington on October 11, 1965.

C. signifera females with uterine eggs were collected on Wombat Moor on November 3, 1961, and at Lake St. Clair on November 22, 1967. An amplexed pair of *C. signifera* was taken at Sandy Bay on December 20, 1960.

Comments on Breeding Biology and Reproductive Isolation: The two species occur in extensive sympatry and overlap in all aspects of their breeding biology except mating call structure. It seems that efficient reproductive isolation is achieved through the operation of this premating isolating mechanism (and the associated specific female phonotaxis). The results of the *in vitro* crosses (Moore, 1954; Watson, pers. comm.) indicate a high degree of genetic incompatibility; thus there is little likelihood of gene exchange between the taxa should the premating isolation ever break down.

RELATIONSHIPS

Moore (1954) suggested that *C. tasmaniensis* and *C. signifera* were derived from a common stock through a double invasion into Tasmania. An ancestral form spread into Tasmania across a Bass Strait land bridge during the lower sea level of a Pleistocene glacial period. The Tasmanian population was then isolated by the higher sea level of an interglacial period and underwent differentiation. The mainland stock again entered Tasmania during a later glacial period and the two forms remained distinct, with *C. tasmaniensis* today representing the earlier invader and *C. signifera* the later invader. It was not then known that *C. signifera* (*sensu lato*) included several cryptic species in south eastern Australia, or that species groups would subsequently be recognized.

Martin (1967) considered that *C. tasmaniensis* was clearly a member of the granular-bellied group of species (the *C. signifera* complex) because of the close similarities in adult and larval morphology, and aquatic oviposition and development. Main (1968), on the mistaken assumption that *C. tasmaniensis* had terrestrial oviposition, placed it in the *C. laevis* complex (smooth-bellied species with terrestrial oviposition and advanced embryonic development before hatching, or suppression of the free-swimming larval stage). The similarities to the *C. laevis* complex (relatively large eggs, and relatively advanced stage of development at hatching) were considered by Martin (1967) to represent independent adaptations to differing ecological conditions.

The mating call structure of *C. tasmaniensis* is more comparable to that of the *C. signifera* complex, than that of the *C. laevis* complex (Littlejohn and Martin, 1964, and unpublished observations). Straughan and Main (1966) did not use call structure when assessing the relationships of *C. tinnula*, and provide only meagre data (one audiospectrogram) for further consideration. However, they did note the close resemblance between the mating call of *C. tinnula* and that of *C. sloanei,* from which it appears to differ only in having a slightly higher dominant frequency. The pattern of organization into the pulse groups seen in the mating call of *C. tasmaniensis* is characteristic of the *C. insignifera* species group (and presumably of the *C. tinnula* group), but the pulses of the "territorial call" are similar to those of the *C. signifera* species group. The mating call of *C. tasmaniensis* bears a superficial resemblance to that of *C. pseudinsignifera* (Littlejohn, 1959, 1961) in that it is composed of a series of pulse groups (notes); but the envelope shape and mode of amplitude modulation differ and suggest convergence. In sum, a consideration of call structure cannot aid in determining the closer relationships of *C. tasmaniensis.*

Straughan and Main (1966) used the level of genetic incompatibility (measured through *in vitro* hybridization tests) as a criterion for recognizing species groups in the *C. signifera* complex, presumably with inter-group crosses breaking down earlier, and more completely, than intra-group crosses. *In vitro* crosses between *C. tinnula* and *C. parinsignifera* or *C. signifera* revealed a high degree of genetic incompatibility (comparable to inter-group crosses) thus suggesting the separation of *C. tinnula* into a distinct group. Results of hybridization tests between *C. tasmaniensis* and members of the *C. signifera* species group (Moore, 1954; Main, 1957, 1968; Watson, pers. comm.) indicated a level of breakdown comparable to that seen in inter-group crosses. No crosses have been made between *C. tasmaniensis* and the *C. insignifera* species group.

An assessment of all these data (morphology, life history, call structure, and genetic incompatibility tests) leads to the provisional interpretation that *C. tasmaniensis* should be placed in a fourth species group. Perhaps it represents an early branch from the line which later gave rise to the other species groups of the *C. signifera* complex.

Acknowledgements

The support of research grants from the Australian Research Grants Committee, the Nuffield Foundation, the Society of the Sigma Xi, and the University of Melbourne is gratefully acknowledged. K. R. Campbell, N. V. Dobrotworsky, F. H. Drummond, J. L. Hickman, Patricia G. Littlejohn, J. J. Loftus-Hills and G. F. Watson assisted in the field. Laraine M. Howard prepared the distribution map. A. A. Martin read and criticized the manuscript.

References

Blanchard, F. N., 1929.—Re-discovery of *Crinia tasmaniensis*. *Austr. Zool.*, 5: 324–328.

Hickman, J. L., 1960.—Cestodes of some Tasmanian Anura. *Ann. Mag. nat. Hist.*, (13) 3: 1–23.

Littlejohn, M. J., 1957.—A new species of frog of the genus *Crinia*. *West. Austr. Nat.*, 6: 18–23.

————, 1958.—A new species of frog of the genus *Crinia* Tschudi from south-eastern Australia. Proc. Linn. Soc. N.S.W., 83: 222–226.

————, 1959.—Call differentiation in a complex of seven species of *Crinia* (Anura, Leptodactylidae). *Evolution*, 13: 452–468.

————, 1961.—Age and origin of some southwestern Australian species of *Crinia* (Anura: Leptodactylidae). Chapter in "*Vertebrate Speciation*" (ed. W. F. Blair). University of Texas Press.

————, 1964.—Geographic isolation and mating call differentiation in *Crinia signifera*. *Evolution*, 18: 262–266.

————, 1965.—Vocal communication in frogs. *Austr. nat. Hist.*, 15: 52–55.

————, 1968.—Frog calls and the species problem. *Austr. Zool.*, 14: 259–264.

Littlejohn, M. J., and Loftus-Hills, J. J., 1968.—An experimental evaluation of premating isolation in the *Hyla ewingi* complex (Anura: Hylidae). *Evolution*, 22: 659–663.

Littlejohn, M. J. and Martin, A. A. 1964.—The *Crinia laevis* complex (Anura: Leptodactylidae) in south-eastern Australia. *Austr. J. Zool.* 12: 70–83.

————, and ————, 1965*a*.—The vertebrate fauna of the Bass Strait Islands: 1. The Amphibia of Flinders and King Islands. *Proc. roy. Soc. Vict.*, 79: 247–256.

————, ————, 1965*b*.—A new species of *Crinia* (Anura: Leptodactylidae) from South Australia. *Copeia*, 1965: 319–324.

Main, A. R., 1957.—Studies in Australian Amphibia 1. The genus *Crinia* Tschudi in south-western Australia and some species from south-eastern Australia. *Austr. J. Zool.*, 5: 30–55.

————, 1962.—Comparisons of breeding biology and isolating mechanisms in Western Australian frogs. Chapter 31 in "*The Evolution of Living Organisms*" (ed. G. W. Leeper). Melbourne University Press.

————, 1968.—Ecology, systematics and evolution of Australian frogs. *Adv. Ecol. Res.*, 5: 37–86.

Martin, A. A., 1965.—Tadpoles of the Melbourne area. *Vict. Nat.*, 82: 139–149.

————, 1967.—The early development of Tasmania's endemic Anura, with comments on their relationships. Proc. Linn Soc. N.S.W., 92: 107–116.

Moore, J. A., 1954.—Geographic and genetic isolation in Australian Amphibia. *Amer. Nat.*, 88: 65–74.

————, 1961.—The frogs of eastern New South Wales. *Bull. Amer. Mus. nat. Hist.*, 121: 149–386.

Parker, H. W., 1940.—The Australasian frogs of the family Leptodactylidae. *Novit. Zool.*, 42: 1–106.

Straughan, I. R., and Main, A. R., 1966.—Speciation and polymorphism in the genus *Crinia* Tschudi (Anura, Leptodactylidae) in Queensland. *Proc. roy. Soc. Queensland*, 78: 11–28.

ANOTHER COLLECTION OF SCOLYTIDAE AND PLATYPODIDAE OF ECONOMIC IMPORTANCE FROM THE TERRITORY OF PAPUA AND NEW GUINEA

254. CONTRIBUTION TO THE MORPHOLOGY AND TAXONOMY OF SCOLYTOIDEA

KARL E. SCHEDL*

[Read 25th June, 1969]

Synopsis

In this paper six new species are described. The first, *Xylechinus papuanus*, n. sp. collected in flight, is a species of Scolytidae. The remainder are new species of Platypodidae: *Crossotarsus coxalis*, n. sp. in logs of *Syzygium* sp., *Podocarpus* sp., *Nothofagus* sp. and Hardwood sp.; *Platypus enormis*, n. sp. in bark of *Cryptocaria* sp.; *Platypus incertus* n. sp., in log of *Casuarina* sp.; *Platypus morigerus* n. sp., in stump of dead hardwood; and *Platypus truncatigranosus* n. sp., in logs of *Podocarpus* sp. and Hardwood sp.

INTRODUCTION

This is the third of a series of taxonomic papers on Scolytidae and Platypodidae collected from New Guinea. The specimens were sent for determination by Mr. B. Gray, Entomology Section, Department of Forests, Bulolo, New Guinea. The Section is currently engaged upon an extensive survey of bark and ambrosia beetles since they cause considerable economic loss in terms of destruction and degradation of logs and timber in the Territory of Papua and New Guinea. Further papers on these collections will be published, and details of distribution data recorded in a monograph (under preparation) on the Scolytidae and Platypodidae of the New Guinea region.

In this paper one new species of Scolytidae and five new species of Platypodidae are described. The numbers following the collector's name refer to the consignment number allocated to the specimens by Mr. Gray. The following abbreviations are used: L.A. (logging area); Estrn. Hlds. Dist. (Eastern Highlands District) and Wstrn. Hlds. Dist. (Western Highlands District).

DESCRIPTION OF NEW SPECIES

A. SCOLYTIDAE

XYLECHINUS PAPUANUS n. sp.

Dark reddish-brown, 1·63 and 1·87 mm. long, 2·2 times as long as wide, somewhat allied to *Xylechinus leai* Schedl from Queensland, but with quite different vestiture on the pronotum and the elytra.

Front aplanate to feebly impressed on a semicircular area below bearing slender scale-like hairs directed upwards to the median line, convex, silky shining, minutely punctulate and indistinctly punctured above. Antennal club large, about twice as wide.

Pronotum wider than long (23:19), base feebly bisinuate, widest near the base, sides subparallel on the basal fourth, thence gradually incurved, apex broadly rounded, with a few small asperities around the antero-lateral angles; disc rather feebly convex, subshining, minutely punctulate, regularly and rather coarsely punctured, the punctures bearing short, slender scales directed to the median line in the basal part of the disc. Scutellum not visible.

Elytra distinctly wider (25:23) and 1·8 times as long as the pronotum, sides parallel on the basal half, gradually incurved behind, apex moderate broadly rounded declivity commencing after the basal two-fifths, obliquely

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* Lienz, Osttirol, Austria.

convex; disc regularly and strongly striate-punctate, the striae rather deeply impressed, the strial punctures rather coarse near the base, indistinct behind, the interstices narrow, subcarinate, each one with a regular row of short, slender, inclined pale-yellow scales, the scales little shorter than the distances of indistinct punctures from which they arise, these punctures replaced by minute granules on the declivity.

Holotype in the collection of the Division of Entomology, CSIRO in Canberra; one *paratype* in the collection Schedl.

Locality: New Guinea, Long Island, L.A. Bulolo, Morobe District, in flight, 8.00 p.m., 4.x.1967, B. Gray (33).

B. PLATYPODIDAE

CROSSOTARSUS COXALIS n. sp.

Male.—Piceaus, 4·5 mm. long, 2·9 times as long as wide. Allied to *Crossotarsus pellicidus* Lea of the *Crossotarsi barbati* but much larger, the apical margin of the horizontal elytra rounded at the sides, the subperpendicular face of the declivity longer and opaque, the coxae of the hind legs extended to a horizontal plate of considerable length, divided medially by a narrow triangular emargination.

Front flat, separated from the vertex by a distinct angle, silky shining, minutely punctulate above a line connecting the insertions of the antennae, besides with rather coarse punctures bearing long semi-erect fuscous hairs, more shining and with several groups of minute setose punctures on a transverse band below, vertex irregularly punctured, medially with a longitudinal polished line.

Pronotum about as wide as long, femoral emarginations shallow, disc shining, minutely shagreened and with scattered very fine punctures, a few larger and setose ones along the anterior margin, median sulcus short.

Elytra feebly wider (11:10) and 1·8 times as long as the pronotum, widest behind the basal half, sides straight, feebly divergent, subparallel on the distal fourth; disc horizontal, apical margin transverse near the suture, rounded at the sides, with rows of very fine punctures in hardly impressed lines, interstices very wide, flat, each one with very fine scattered punctures, base of the third triangularly widened, somewhat elevated, connected at the base with the narrow fifth interstice, a small group of coarse punctures on the triangular elevation; the striae rather abruptly strongly impressed near the apical margin, the interstices becoming carinate and terminating in blunt short teeth projecting a short distance over the subperpendicular declivity face and each bearing a group of fuscous bristles, a few of these hairs also in continuation of the discal intervalles on the declivity, the apical margin of the latter broadly emarginate as in some *Platypi lunati.*

Hind coxae developed into horizontal plates of considerable length, medially divided by a narrow triangular emargination; abdomen dull, ascending, the last sternite feebly concave and distinctly punctured, ascending, sternites 2, 3 and 4 with a transverse row of long erect hairs, the second one with an additional seam of hairs on its anterior border.

Female.—a little larger, 4·8 mm. long, and somewhat more slender than the male. Front flat, shining, with a subcircular impression in the centre, anteriorly with some groups of small setose punctures, on the sides and above the impression with punctures of moderate size, bearing semi-erect fuscous hairs, convex towards the vertex, the latter polished, with a few setose punctures only. Pronotum similar to that of the male, but the median sulcus longer, the punctation largely reduced.

Elytra a little more than twice as long as wide, sides parallel on the basal four-fifths, apex transverse near the suture when viewed from above, postero-lateral angles rounded, declivity short, convex, restricted to the distal fifth of the elytra; disc brightly shining, minutely shagreened, with rows of extremely fine and remotely placed punctures, in impressed lines near the base, interstices very wide, each one with a few scattered fine punctures, the third feebly widened near the base and with a very few transverse regae; declivity rugosely punctured and with short pubescence, postero-lateral angles terminating in a minute triangular tubercle.

Hind coxae with the horizontal extensions much shorter than in *Copellicidus* Lea, the median emarginating narrower.

Holotype and *allotype* in the collection of the Division of Entomology, CSIRO in Canberra; *paratypes* in the collection of the Entomology Section, Department of Forests, Bulolo, TPNG and in collection Schedl.

Locality: New Guinea, Porotop Lutheran Mission Sawmill, Wstrn. Hlds. Dist., 11.viii.1967, in log of *Syzygium* sp. (10), in log of *Podocarpus* sp. (11), in log of *Nothofagus* sp. (13), and in log of hardwood sp., Coll. B. Gray. (14).

PLATYPUS ENORMIS, n. sp.

Male.—Reddish-brown, 3·5 mm. long, 4·3 times as long as wide. It is difficult to place this peculiar species in one of the known groups of the genus *Platypus* Herbst, but, provisionally, it might be kept in the *Platypi pseudospinulosi.*

Front subopaque, flat minutely punctulate, very densely reticulate-punctate, with remotely placed upward directed fine pubescence, gradually convex towards the vertex.

Pronotum longer than wide (33:24), widest behind the short but deep femoral emarginations, disc brightly shining, very finely and remotely punctured, median sulcus moderately long, surrounded by a small cordate patch of densely placed punctures.

Elytra about as wide and 1·7 times as long as the pronotum, brightly shining, horizontal, declivity abruptly perpendicular, disc with rows of minute remotely placed punctures in not impressed lines, the first row replaced by a narrow stria, the interstices wide and impunctate, the first and fifth narrowed behind and not reaching the declivity, interstices 2, 3, 4 and 6, distally drawn out into blunt and flat teeth surpassing the upper margin of the declivity, separated from each other by short impressed lines; declivity low, shining, crescent in outline, apical margin broadly concave, with a small tubercle on each side near the suture and rather long, slender and pointed lateral processes.

Coxae of the hind legs each one with a long and slender horizontal spine, abdomen ascending, feebly concave, the sternites very densely punctured.

Holotype in the collection of the Division of Entomology, CSIRO in Canberra; *paratypes* in the collection of the Entomology Section, Department of Forests, Bulolo, TPNG. and in collection Schedl.

Locality: New Guinea, Okasa Pine Forest, Estrn. Hlds. Dist., 23.viii.1967, in bark of *Cryptocaria* sp., Coll. F. R. Wylie and S. Auno (22).

PLATYPUS INCERTUS n. sp.

Male.—Piceous, 4·9 mm. long, 3·8 times as long as wide. More closely allied to *Platypus furcatus* Samps., but the elytra with rows of very fine punctures in hardly impressed lines, the apical processes longer and more slender, the seventh interstices on the sides of the declivity just before the commencement of the apical processes distinctly dentate.

Front large, flat, separated from the vertex by a more or less distinct angle, frontal face very densely and coarsely punctured, the punctures somewhat finer anteriorly, pubescence sparse on the anterior third and on the vertex.

Pronotum little longer than wide (41:37), widest at the angulate posterior limitation of the well-developed femoral emarginations; disc brightly shining, with very scattered minute punctation, a small irregularly placed group of larger punctures on each side of the long and fine median sulcus, another row of larger punctures bearing long fuscous hairs along the anterior margin.

Elytra but feebly wider (38:37) and twice as long as pronotum, general shape as is typical in the *Platypi oxyuri*, the sides parallel on little more than the basal half, obliquely narrowed behind, the distal processes of moderate length, trifid, similar as in *Platypus furcatus* Samps., sutural emargination well-developed, narrow and triangular; disc with rows of very fine, partly indistinct punctures in feebly impressed very narrow lines, interstices very wide and flat, with a few minute punctures here and there; declivital convexity commencing behind the basal three-fifths of the elytra, opaque, the striae and strial punctures obsolete, the interstices indicated by scattered fine punctures bearing long semi-erect hairs. Abdominal sternites with a sparse but long pubescence.

Holotype in the collection of the Division of Entomology, CSIRO in Canberra; *paratypes* in the collection of the Entomology Section, Department of Forests, Bulolo, TPNG. and in collection Schedl.

Locality: New Guinea, Wabag, Wstrn. Hlds. Dist., 9.viii.1967, in log of *Casuarina oligodon,* Coll. B. Gray (8).

PLATYPUS MORIGERUS, n. sp.

Male.—Reddish-brown, 3·9 mm. long, 3·7 times as long as wide. Another species of the *Platypi sulcati* more closely allied to *Platypus omissus* Schedl, but little larger, the patch of punctures surrounding the median sulcus of the pronotum very small, the elytra striate-punctate, the four tubercles of the elytral declivity larger and not as low down as in *P. omissus.*

Front opaque and feebly impressed above the insertions of the antennae, somewhat more shining, flat, minutely punctulate and remotely punctured below, a few setae on the sides of the upper part of the front and towards the convex vertex, on the latter with a transverse row of coarse setose punctures.

Pronotum feebly longer than wide (34:31), widest at the posterior angulate limitation of the shallow femoral emarginations, disc fairly shining, minutely chagreened in parts, remotely covered by punctures of varying size, a row of setose ones along the anterior margin, median sulcus moderately long, surrounded in its anterior half by a very small cordate patch of densely placed punctures.

Elytra as wide and not quite 1·9 times as long as the pronotum, sides parallel on more than the basal half, thence gradually incurved, apex rather broadly rounded, declivity commencing well behind the middle of the elytra, obliquely convex; disc shining, with rows of fine, partly confluent punctures in fine impressed lines, interstices very feebly convex, each one with some irregularly placed fine punctures more numerous near the striae, base of the third triangularly widened, with some punctures in the centre, connected with the narrow and also feebly elevated first interstices; on the upper more feebly convex part of the declivity the interstices becoming narrowly subcarinate and each one with a row of setose fine granules, a large upright tubercle on the fused interstices two and three, another one on the fifth interstices rather similar to the arrangement in *Platypus omissus* Schedl, the part of the declivity semicircular in outline, opaque, and minutely punctulate.

Female.—feebly larger and somewhat more slender, the upper opaque of the front more flat and more distinctly punctured, pronotum with the cordate patch of punctures much larger, wider than long, the base of the third interstices of the elytra more strongly elevated and covered with small granules, the declivity less opaque, the four tubercles much smaller, and the granules on the interstices above less distinct.

Holotype and *allotype* in the collection of the Division of Entomology, CSIRO in Canberra; pair of *paratypes* in the collection of the Entomology Section, Department of Forests, Bulolo, TPNG, another pair of *paratypes* in collection Schedl.

Locality: New Guinea, Awande, Estrn. Hlds. Dist., 24.viii.1967, in stump of dead hardwood, Coll. F. R. Wylie and S. Auno (23).

PLATYPUS TRUNCATIGRANOSUS n. sp.

Male.—Reddish-brown, 3·4 mm. long, 3 times as long as wide. Allied to *Platypus truncatipennis* Schedl, but the elytra sulcate-carinate on the distal half, the interstices not widened distally to form blunt teeth surpassing the upper limitation of the declivity, and the teeth on the declivital face merely indicated.

Front flat and opaque, minutely punctulate, finely and indistinctly punctured, the punctures bearing short erect hairs, a short median sulcus just below the centre, near the anterior margin more shining, the punctation coarser, the front separated from the vertex convex but distinct, the latter opaque, with a short median longitudinal carina.

Pronotum about as long as wide, widest at the posterior limitation of the short but deep femoral emarginations, this posterior angle drawn out into a very pointed prejection, disc brightly shining, covered by remotely placed punctures of varying size, median sulcus fine and moderately long.

Elytra feebly wider (34: 31) and 1·7 times as long as the pronotum, widest near the apex, the sides straight and with a seam of minute pointed granules, declivity restricted to the distal fifth of the elytra, truncate, subperpendicular and subcircular in outline; disc horizontal, sulcate-carinate in the distal half, the sulci minutely punctulate, therefore subopaque, gradually becoming deeper towards the declivity, fading out anteriorly and here replaced by rows of rather coarse punctures in more or less impressed lines, the interstices wide, rather shining and nearly impunctate near the base, gradually elevated and less opaque and, with a few minute pointed granules behind, more distinct on the alternate interstices, all of them abruptly ceasing on the upper margin of the declivity face, contained on the upper third of the declivity by short rows of uniseriate blunt tubercles and a dense plush of short reddish hairs, the lower part of the declivity face irregularly and densely granulate and covered with short slender scale-like setae, apical margin finely carinate up to the seventh interstices. Abdomen normal.

Holotype in the collection of the Division of Entomology, CSIRO, in Canberra; one *paratype* in the collection Schedl.

Locality: New Guinea, Porotop Lutheran Mission Sawmill, Wstrn. Hlds. Dist., 11.viii.1967, in hardwood sp. log, Coll. B. Gray (9: 11).

AUSTRALASIAN CERATOPOGONIDAE (DIPTERA, NEMATOCERA) PART XI:[1] THE AUSTRALIAN SPECIES OF *PELLUCIDOMYIA* MACFIE, AND A DESCRIPTION OF THE MALE GENERIC CHARACTERS

MARGARET L. DEBENHAM

School of Public Health and Tropical Medicine, University of Sydney, N.S.W.

(Text Figures 1–18)

[Read 25th June 1969]

Synopsis

In the present paper the previously undescribed male generic characters of *Pellucidomyia* are incorporated into the generic diagnosis. In addition, a new Australian species is described and the description of the only previously known Australian species (*Pellucidomyia leei* Wirth) is supplemented.

Genus PELLUCIDOMYIA Macfie

Pellucidomyia Macfie, 1939, Ruwenzori Exped., 1934–5, vol. 1, no. 5, Ceratopogonidae, p. 99. (Type: *Pellucidomyia ugandae* Macfie, monobasic.)

Macfiehelea Lane, 1946, *Rev. de. Ent. 17*: 208. (Type: *Macfiehelea oliveirai* Lane, monobasic.)

Diagnosis (based on Wirth, 1960):

Body densely white or blackish pollinose above. Head flattened anteroposteriorly, the unflattened portion with the same pollinosity as scutum; eyes bare, broadly separated; female with distal five, male with distal three, antennal segments markedly elongate, female antennal segments with sparse basal verticels, male with sparse antennal plume; palp 5-segmented, third segment not swollen, without sensory pit. Scutum conically produced anteriorly, without or with only a small, blunt anterior tubercule. Legs slender, femora unarmed, slightly club-shaped distally; fore legs short, mid legs longer, hind legs of female extremely elongated, of male only slightly elongated; in both sexes fore and mid fourth tarsal segment cordate to transverse, hind fourth tarsal segment cylindrical, very long and slender in female; fifth tarsal segment unarmed, inflated on fore leg, but not on mid and hind legs. Claws of female equal and simple or with a minute basal tooth on fore and mid legs; single, long, and with or without a basal barb on hind legs; claws of male equal on all legs. Wing venation similar to that of *Bezzia;* one radial cell; costa extending almost to wing tip; microtrichia absent or very small; macrotrichia absent. Abdomen of female without gland rods, with a pair of hair tufts ventrally on eighth segment; two large, and also sometimes one vestigial, spermathecae. Male genitalia: ninth tergite short and broad; aedeagus arched, expanded and setose medially, and with long anterior processes which articulate with the bases of the coxites; parameres broadly fused apically.

Australian species of Pellucidomyia

Most specimens were mounted in balsam on microscope slides. All measurements are based on slide specimens only, and are given in millimetres. Wing length is measured from the basal arculus. Morphological terms used are largely adopted from Wirth, 1952.

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[1] **Part X appeared in Vol. lxxxvii, p. 352.**

Abbreviations: USNM = United States National Museum, Washington; SPHTM = School of Public Health and Tropical Medicine, Sydney.

Key to Australian Species of Pellucidomyia

1. Legs largely whitish or yellowish, with dark brown bands .... leei Wirth
   Legs largely dark brown, all tibiae with a pale sub-basal band .... *dycei* n. sp.

PELLUCIDOMYIA LEEI Wirth

Pellucidomyia leei Wirth, 1960, *Bull. Brooklyn ent. Soc.*, 55 (1): 2–3.

This species was described from two females from Hartley's Creek, north of Cairns, Qld., 24.iv.1957. Here the description of the female is supplemented and the male and pupal characters newly noted, from a series of 14 females and 10 males from various localities in Queensland, New South Wales and Victoria.

Types: Holotype ♀ in USNM; 1 ♀ paratype in SPHTM.

Type Locality: Hartley's Creek, north of Cairns, Qld. (24.iv.1957, W. W. Wirth).

Female: Length 2·5–3·1 mm. (average 2·8 mm.), wing length 1·7–2·3 mm. (average 2·1 mm.), wing breadth approximately ⅓ wing length.

Eyes bare. Proboscis short, just under ⅓ the length of the head. Mandibular teeth 11–12. Palp dark brown, segment III not swollen, with 3 long sensillae on inner aspect of apical half. Palpal ratio 3·0. (Fig. 1.)

Palpal segment ..	I	II	III	IV	V
Length	0·019	0·038	0·057	0·041	0·049

Antennal segment II dark brown, yellow dorsally, segments III–IV dark brown, IV often paler basally, segments V–X brownish-white on basal half, brown on apical half, segments XI–XV brown, XI–XII with bases paler.

Antennal segment ..	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Length	0·012	0·057	0·057	0·057	0·053	0·053	0·057	0·053	0·182	0·186	0·182	0·197	0·228

Scutum without, or with a small, blunt, anterior tubercule. Fore femur yellowish, slightly brownish to dark brown distally, fore tibia whitish to yellowish, apex and sub-basal ⅓ brownish, mid femur yellowish, basal half and apex brown, tibia whitish to yellowish, basal fourth and apex light brown, hind leg whitish to yellowish, femur with base brown, proximal half brown dorsally, apical fourth dark brown to blackish, tibia with base narrowly and apex broadly dark brown, sometimes also with a broad pale brown sub-basal band. Fore tarsi pale brown, except V which is dark brown, mid tarsi whitish with apices pale brown, except IV–V, which are brown, hind tarsal segment I whitish with apex broadly light brown, II light brown, apex darker, III–IV brown, V pale brown, base and apex darker. (Figs 5, 7.)

Leg segment:		*Femur*	*Tibia*	*Tarsus*					*Tarsal*
				I	II	III	IV	V	*Ratio*
Length:	*Fore*	0·735	0·540	0·197	0·079	0·068	0·076	0·152	2·48
	Mid	1·185	0·825	0·380	0·148	0·076	0·064	0·121	2·56
	Hind	1·260	1·305	1·080	1·125	0·525	0·390	0·285	0·96

Claws of fore and mid legs paired, equal, with a minute internal basal tooth, in fore leg claws ½ as long as tarsal segment V, claws of mid leg slightly shorter than tarsus V. Claw of hind leg single, with a bifid basal tooth, claw as long as fifth tarsal segment.

Wing (Fig. 14) with microtrichia not visible; costal and radial veins pale yellowish, rest whitish, difficult to distinguish. No fringe on alula. Costal ratio 0·93. Haltere brown, apical half of club black.

Abdomen with tergites and sternites brown, terminal segments darker, pleural membranes greyish to light brown. Spermathecae (Fig. 11) three, two large, oval, without chitinised necks, 0·076 × 0·068 mm. and 0·072 × 0·053 mm., and one vestigial, oval to nearly tubular, 0·019 × 0·007 mm.

Male (description based on a selected specimen from the Merricumbene Cr.—Moruya R. series): Length 1·8 mm. (range 1·4–2·0 mm.), wing length 1·3 mm. (1·1–1·3 mm.), wing breadth approximately $\frac{1}{3}$ wing length.

The male differs from the female as follows:

Palpal ratio 2·0 (Fig. 2.)

Papal segment ..	I	II	III	IV	V
Length	0·015	0·026	0·038	0·026	0·030

Antenna (Figs 3–4) with segment II entirely dark brown, segments III–V brown, segments VI–XII brownish-white on basal half, brown on apical half, XIII–XV brown, XIII with base paler, antennal plume brown, sparse, reaching apex of segment XIII.

Antennal segment ..	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Length	0·087	0·053	0·049	0·049	0·045	0·045	0·045	0·045	0·057	0·079	0·121	0·182	0·197

Coloration of thorax and legs as in female, except mid femur may be brownish-white to light brown instead of yellowish. Hind leg not excessively elongated (Fig. 6).

Leg segment:		*Femur*	*Tibia*	*Tarsus*					*Tarsal Ratio*
				I	II	III	IV	V	
Length:	*Fore*	0·465	0·360	0·148	0·072	0·060	0·053	0·114	2·05
	Mid	0·645	0·465	0·239	0·098	0·064	0·041	0·091	2·42
	Hind	0·630	0·615	0·502	0·277	0·172	0·105	0·112	1·81

Claws all paired, equal, approximately $\frac{1}{2}$ the length of the fifth tarsal segment, each with minute internal basal tooth.

Wing with microtrichia apparent at magnification × 100. Costal and radial veins light brown, other veins very pale. Anterior edge of wing slightly fuscous. Costal ratio 0·80.

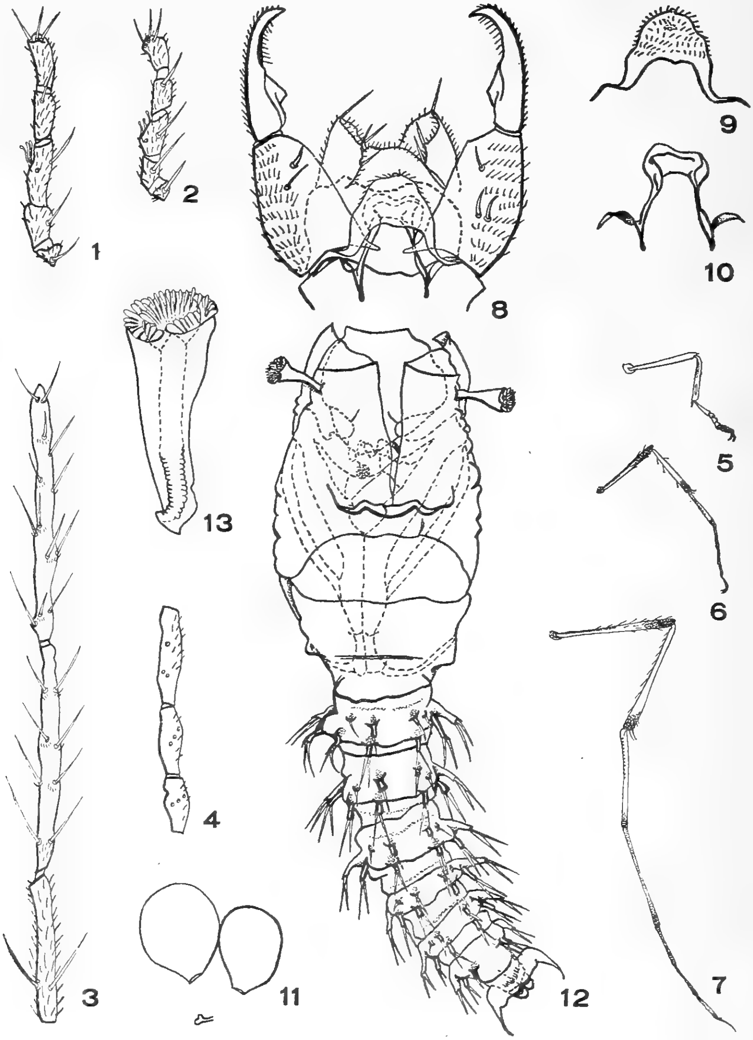
Abdomen blackish-brown. Hypopygium (Figs 8–10) including styles, brown. Aedeagus with an internal hook-like process just below apex. Ninth tergite broadly indented.

Pupa as illustrated (Figs 12–13). Thorax exceptionally bulbous, somewhat chironomid-like. Respiratory organ very short, funnel-shaped. Abdominal segments 3–7 similarly bristled, the tubercules arranged on each segment as follows: dorsally, two rows, the anterior row consisting of four tubercules, two on either side of the midline, the external ones smaller, and the posterior row consisting of four tubercules of approximately equal size, the inner pair directly beneath the inner pair of the anterior row, the external pair more lateral than the external pair of the anterior row; laterally, a single posterior row of three large tubercules, the most dorsal one being the largest; ventrally, a single row of six tubercules, three on either side of the midline, the outer one smallest. Glandular discs absent.

Distribution: *Eastern Australia.*

Specimens examined: Queensland—2♀♀, (in alcohol), Gillies Highway, 2m. W. of Little Mulgrave, 18.iv.1967, D. H. Colless; 2♀♀, Bramston Beach, nr. Innisfail, 30.iv.1967, rainforest fringe, D. H. Colless; 3♀♀, Innisfail

(1 Eubenangee Swamp, 12.xi.1963, 1 Morans Creek, 18.vi.1963, 1 Nino's Creek, mangrove swamp, 18.vi.1963), light trap, H. A. Standfast; 1 ♂, Ferny Grove, Brisbane, 23.xii.1954, net on creek bank, E. J. Reye. New South Wales—1 ♀, Bruxner Park, Coffs Harbour, 1.xi.1965, M. Upton; 2 ♀ ♀, Upper Kangaroo Valley, 23.xi.1960, D. H. Colless; 1 ♀, Kangaroo Valley, 23.iii.1961, D. H. Colless; 8 ♂ ♂, 1 ♀, bred from pupae, Moruya River-Merricumbene Creek, 2.iii.1964, A. L. Dyce and M. D. Murray; 1 ♀, Merricumbene Creek, 1.iii.1964, light trap, A. L. Dyce. Victoria—1 ♂, 1 ♀ (in alcohol), bred from pupae, Cabbage Tree Creek, 22.xi.1965, A. L. Dyce and M. D. Murray.



Figs 1–13. *Pellucidomyia leei*, Wirth. 1, ♀ maxillary palp × 165; 2, ♂ maxillary palp, × 165; 3, ♂ antennal segments XIII–XV, × 165; 4, ♂ antennal segments X–XII, × 165; 5, ♀ fore leg, × 12; 6, ♂ hind leg, × 12; 7, ♀ hind leg, × 12; 8, ♂ hypogium × 165; 9, ♂ aedeagus × 165; 10, ♂ parameres, × 165; 11, ♀ spermathecae × 165; 12, pupal case (dorsal view), × 40; 13, pupal respiratory organ, × 165.

The pupae of this species can be collected in widely differing habitats. Those of the Moruya River-Merricumbene Creek series were obtained about

1 mile up from the entry of the Merricumbene Creek into the Moruya River, in a temporary backwater formed in a sandy stretch of the river by leaf litter. In this situation they were protected by overhanging *Casuarina*, but were still exposed to sunlight for part of the day. They are floating pupae, and occur at the sand-water interface, being taken in samples from fairly coarse sand, algae and leaf litter. Other species taken in the same situation were *Culicoides bundyensis* Lee and Reye, *Culicoides victoriae* Macfie and *Culicoides dycei* Lee and Reye.

The pupae from Cabbage Tree Creek, on the other hand, were taken from a slow-running, deep-sided timbered creek which was almost completely shaded. The pupae were floated out from the organic mix at the creek margin. No other Ceratopogonidae were taken with these specimens.

PELLUCIDOMYIA DYCEI n. sp.

A large species with the legs almost entirely dark brown, very similar to *Pellucidomyia oliveirai* (Lane) from Brazil. Male unknown.

Types: Holotype ♀ and one ♀ paratype, in SPHTM.

Type Locality: Texas Station, Queensland (20.i.1952, suction light trap, A. L. Dyce).

Female: Length 2·68 mm., wing 1·60 × 0·54 mm. Body whitish pollinose. Head dark brown. Proboscis short, just over ⅓ as long as the head. Mandible with approximately 7 large and several small teeth. Palp brown, segment III not swollen, bearing 2–3 long sensillae on inner surface of apical half. Palpal ratio 2·2.

Palpal segment ..	I	II	III	IV	V
Length	0·019	0·030	0·041	0·030	0·041

Attena with segments II–IV dark brown, V–X whitish on basal half, light brown on apical half, segments XI–XV brown (Figs 16–17).

Antennal segment ..	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Length	0·087	0·045	0·038	0·038	0·038	0·038	0·038	0·045	0·121	0·117	0·117	0·110	0·114

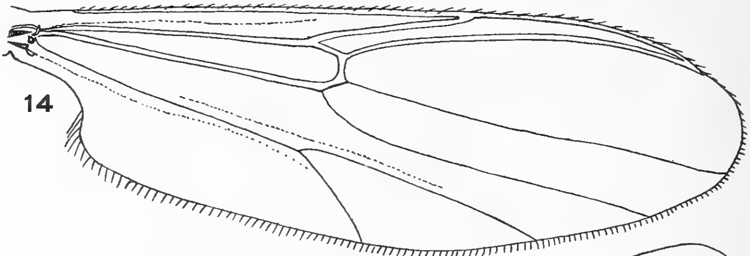
Thorax entirely dark brown, scutum with a very small, blunt anterior tubercule. All coxae and trochanters brown, femora dark brown, paler at base, tibiae dark brown, fore and mid tibiae with a narrow yellowish sub-basal band, hind tibia with a broader white sub-basal band. Tarsi whitish, in fore leg the apices of segments I–IV slightly brownish, segment V entirely dark brown, in mid leg segments I–IV with apices brownish, V entirely pale brown, in hind leg I with apex broadly brown, II–V light brown, each segment slightly darker than the preceding one, all with apices broadly darker brown. Fore tibia with a pale apical spine. Hind tibia slightly curved, with an apical comb of 2 long and 2–3 shorter spines.

Leg segment:		*Femur*	*Tibia*	*Tarsus*					*Tarsal Ratio*
				I	II	III	IV	V	
Length:	*Fore*	0·615	0·435	0·174	0·087	0·064	0·060	0·152	2·00
	Mid	0·930	0·530	0·338	0·114	0·079	0·057	0·095	2·97
	Hind	1·065	1·050	0·975	1·005	0·465	0·360	0·240	0·97

Claws of fore and mid legs equal, those of fore leg ½ as long as fifth tarsal segment, those of mid leg equal to fifth tarsal segment, claw of hind leg long (as long as the fifth tarsal segment), single, with a small bifurcate basal barb.

Wing (Fig. 15) very pale, veins whitish, difficult to distinguish. Costa almost reaching wing tip, costal ratio 0·93; length of radial cell 0·82 mm. Haltere dark brown, knob blackish.

Abdomen brown, pleural membranes pale blackish-brown. Cerci brown. Spermathecae (Fig. 18) three, two dark brown, large, elongate oval, with very short and narrow chitinised necks, 0·110 × 0·072 mm. and 0·102 × 0·060 mm., and one vestigial, oval, 0·011 × 0·009 mm., with a relatively long chitinised neck, 0·011 mm.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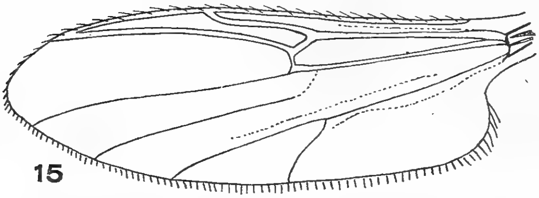
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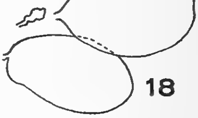
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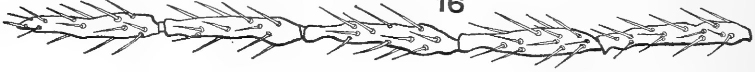
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Fig. 14. *Pellucidomyia leei*, Wirth. ♀ wing, ♂ 40.
Figs 15–18. *Pellucidomyia* dycei, n. sp. 15, ♀ wing, × 40; 16, ♀ antennal segments XI–XV, × 165; 17, ♀ antennal segments VIII–X, × 165; 18, ♀ spermathecae, × 165.

Distribution: Known only from the type locality. Both specimens were collected on the north bank of the Dumaresq River, which is an open river with a sandy bottom. The light trap was suspended over water trapped in a root hole of a tree which had fallen across the river. This water was stagnant and partly shaded.

This species can be distinguished from *P. oliveirai* by the dark brown fifth tarsal segment of the fore leg, the colour of the abdomen, *oliveirai* having segments III–VII mostly white, and the much smaller wing in relation to body length (wing 2 mm., body 2·2 mm in *oliveirai*). The female can further be distinguished by the larger hind tarsal ratio, 0·97 compared to 0·7 in *oliveirai*.

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References

LANE, J., 1946.—New Neotropical Ceratopogonidae (Heleidae). (Diptera, Nematocera). *Rev. de Entomologia*, 17 (1–2): 202–215.
WIRTH, W. W., 1952.—The Heleidae of California. Univ. Calif. Publ. Ent., 9: 95–266.
———, 1960.—The Genus *Pellucidomyia* Macfie (Diptera, Ceratopogonidae). *Bull. Brooklyn ent. Soc.*, 55 (1): 1–3.

AUSTRALASIAN CERATOPOGONIDAE (DIPTERA, NEMATOCERA) PART XII: THE STATUS OF THE GENUS *HETEROMYIA* SAY IN THE AUSTRALIAN REGION

MARGARET L. DEBENHAM
School of Public Health and Tropical Medicine,
University of Sydney, N.S.W.

(Text Figures 1–8)

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Synopsis

In the literature, four species from the Australian Region have been placed in the genus *Heteromyia* Say. In the present paper, the relationship between these species and the American species of *Heteromyia* is discussed. It is concluded that the Australian species have been incorrectly included in *Heteromyia* and that so far the genus has not been recognized in this region. Three of the species hitherto assigned to this genus are placed in *Palpomyia* Meigen, and the fourth, with an additional new species, is placed in a new genus.

The first species to be described from Australia as a *Heteromyia* was *H. brevibarba* Kieffer, 1917, based on a single female from Brisbane, Queensland. Apparently Kieffer regarded the form of the greatly swollen and spinose fore femur and curved fore tibia as of paramount importance, as *brevibarba* disagrees with the generic diagnosis of *Heteromyia* in several respects. Lee (1948) published a translation of Kieffer's original description, and noted the differences in tarsal and ungual characters between *Heteromyia* Say and *H. brevibarba*. However, he suggested that *brevibarba* be retained in *Heteromyia* until specimens became available for study and its true generic position could be established. He also described a new species, *Heteromyia tasmanica,* which was similar to *brevibarba* in most characters but lacked the batonnets on the fifth tarsal segments which are a feature of the latter. Tokunaga (1966) added a further two species, *abdominalis* and *pallida,* which are very close to *H. tasmanica.* He noted that all the Australian Region species described had hind claws equally developed in both sexes, unlike *Heteromyia,* and suggested that the ungual diagnosis for the genus should be corrected to include species with equal claws on all legs, giving the characteristic of this genus as "the apical projection of the fore arcuated tibia beyond the articulation to the tarsus".

The ungual difference, however, is not the only distinction between the Nearctic-Neotropical species and Australian species which have been assigned to *Heteromyia* by the above authors. These differences are set out below.

Australian species previously assigned to Heteromyia	*Nearctic-Neotropical* Heteromyia *species*
(1) Claws of all legs equal in both sexes.	Female hind claws long and very unequal.
(2) Fourth tarsal segment cordate on all legs in both sexes.	Female hind fourth tarsal segment cylindrical, very long.
(3) Fifth tarsal segment of fore leg not inflated.	Fifth tarsal segment of fore leg inflated.
(4) Hind tarsi not exceptionally long, hind tarsal ratio 2·0 or more.	Hind legs, especially tarsi, much elongated, hind tarsal ratio about 1·0 or less.
(5) Fifth tarsal segments armed with batonnets (only in *brevibarba* Kieffer, 1917).	Fifth tarsal segments unarmed.

Apart from *brevibarba,* the Australian Region species differ from *Palpomyia* only in having an apical projection of variable size on the fore tibia. The degree of swelling and spinosity of the fore femur and the arcuation of the fore tibia are variable within *Palpomyia,* and the Australian species classed as *Heteromyia* represent an extreme development of these features. It is apparent therefore that the affinities of these species are with *Palpomyia* rather than *Heteromyia,* and, with the exception of *brevibarba,* they are not generically distinct from *Palpomyia.* They are therefore transferred as follows:

PALPOMYIA TASMANICA (Lee), comb. nov.

Heteromyia tasmanica Lee, 1948, *Proc. Linn. Soc. N.S.W.,* 73 (1–2): 62–63.

PALPOMYIA ABDOMINALIS (Tokunaga), comb. nov.

Heteromyia abdominalis Tokunaga, 1966, *Pac. Insects,* 8 (1): 106.

PALPOMYIA PALLIDA (Tokunaga), comb. nov.

Heteromyia pallida Tokunaga, 1966, *Pac. Insects,* 8 (1): 107–108.

Amongst previously unidentified material in the School of Public Health and Tropical Medicine collection two specimens were found which proved to be identifiable as Kieffer's *Heteromyia brevibarba.* With the additional information available from the examination of actual specimens it was found that *H. brevibarba* has most of the characters of *Palpomyia* but differs quite markedly in having several pairs of stout batonnets on the fifth tarsal segment of each leg. It also has only a single spermatheca. A further specimen has been examined which is close to *brevibarba* but differs at the specific level. All the above are placed in a new genus, *Mackerrasomyia.*

Genus MACKERRASOMYIA gen. nov.

Heteromyia Say, 1825 sensu Kieffer, 1917, p. 192 (Australian), nec sensu Kieffer, 1917 pp. 325–6 (American) = *Heteromyia* Say, 1825. *Type-species*: *Mackerrasomyia brevibarba* (Kieffer, 1917).

Diagnosis

Female: Eyes bare, widely separated. Antenna with distal five segments elongated, cylindrical. Maxillary palp long, slender, segment III without a large sensory pit, but with sensillae borne on surface. Scutum with a strong anterior tubercule. Fore femur greatly swollen, with numerous short, stout spines, hind femur weakly clubbed distally, mid and hind femora with one or two ventral preapical spines; fore tibia strongly arcuate, with a blunt apical projection, mid and hind tibiae normal; all fourth tarsal segments cordate, fifth tarsal segments armed with several pairs of stout batonnets, the distal pair being separated from the other pairs. Claws paired and equal on all legs, each with a large internal basal tooth. Wing narrow, with conspicuous microtrichia, without macrotrichia; costa extending to $\frac{3}{4}$ of wing length; two radial cells, the second about twice as long as the first; median fork broadly sessile; no intercalary fork; anal vein with a curving fold extending downwards from near its mid-point. Abdomen of female without gland rods; a single spermatheca.

Male: Unknown.

Mackerrasomyia differs from *Palpomyia* in having stout batonnets on the fifth tarsal segment of each leg, and in having only a single spermatheca. It differs from *Heteromyia* in having female claws equal on all legs, all fourth tarsal segments cordate, fifth tarsal segment of fore leg not inflated, hind legs not elongated, and fifth tarsal segments armed. The genus is named in honour of Dr. I. M. Mackerras, who has made many contributions to the knowledge of Australian Diptera over the past forty years.

Key to the species of Mackerrasomyia

1.—All tibiae dark brown .... *brevibarba* (Kieffer)
Fore tibia largely yellow, mid and hind tibiae dark brown on basal half, yellow on apical half .... *marginata* n. sp.

The following descriptions are based on specimens mounted in balsam on microscope slides. All measurements are given in millimetres. Wing length is measured from the basal arculus of the wing. Morphological terms used are largely adopted from Wirth, 1952. SPHTM = School of Public Health and Tropical Medicine, Sydney.

MACKERRASOMYIA BREVIBARBA (Kieffer)

Heteromyia brevibarba Kieffer, 1917, *Ann. Mus. Nat. Hung.*, 15: 192. (Type locality: Brisbane, Queensland.)

Kieffer's holotype specimen was deposited in the Magyar Nemzeti Muzeum. A letter from this museum (28/11/1963, on file in SPHTM) has provided the information that the Ceratopogonidae were among the collections of that museum consumed by fire in 1956. As the holotype is no longer in existence, the two specimens in the SPHTM collection are designated as neotype and neoparatype respectively.

Types: Neotype ♀ and one ♀ neoparatype, in SPHTM.

Type Locality: Brisbane, Queensland (11.xii.1922, I. M. Mackerras).

Female: Length 3·34 mm., wing 2·38 × 0·84 mm.

Head dark reddish-brown. Proboscis ½ the height of the head. Eyes bare, widely separated. Mandibular teeth 7 large, 2 small. Palp dark brown, segment III not swollen, with a few small, shallow sensory pits and long sensillae on the distal surface (Fig. 1). Palpal ratio 3·0.

Palpal segment ..	I	II	III	IV	V
Length	0·038	0·064	0·091	0·064	0·079

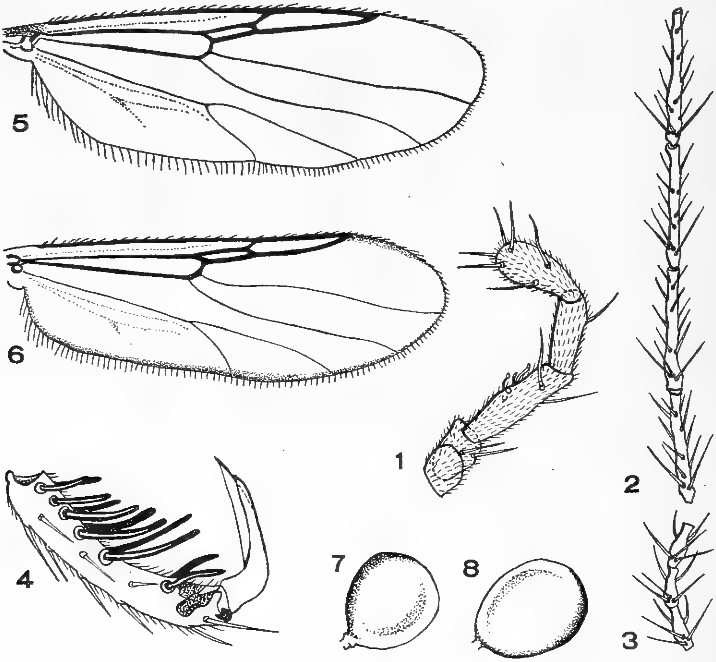
Antennal segment II dark brown, segment III yellowish with apical third dark brown, IV–VI dark brown, basal third yellow, VII–X dark brown, bases paler, XI–XIV dark brown with bases slightly paler, elongated, XV missing (Figs 2–3).

Antennal segment	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Length	0·121	0·064	0·064	0·068	0·072	0·072	0·072	0·076	0·186	0·193	0·197	0·228	?

Thorax entirely dark blackish-brown, with a strong, sharp anterior tubercule. All coxae, trochanters, femora and tibiae dark brown, the fore tibia slightly paler, tarsi yellowish, segments I–II with apices brown, III–V light brown except base of III yellow and V of mid and hind legs yellowish ventrally, fore femur with 22–26 ventral black spines, mid femur with 1–2 preapical ventral spines, mid tibia with 1 apical spine, hind femur club-shaped distally, with 2 preapical ventral spines. Hind tibial comb of 7–10 pale spines. Fore and mid fifth tarsal segment with five ventral pairs of batonnets, hind tarsus V with 5–6 pairs, in all cases the batonnets restricted to the basal half of the segment except for the distal pair, which are preapical, the pairs on the basal half becoming progressively longer distally, the apical pair shorter (Fig. 4).

Leg segment:		*Femur*	*Tibia*	*Tarsus* I	II	III	IV	V	*Tarsal Ratio*
Length:	*Fore*	1·035	0·795	0·285	0·178	0·098	0·079	0·197	1·59
	Mid	1·200	0·915	0·471	0·201	0·102	0·091	0·186	2·34
	Hind	1·380	1·080	0·653	0·292	0·110	0·083	0·216	2·23

Tarsal spines: mid I with 2 apical, II with 1–2 paler apical; hind I–II with 1 fine apical. All claws paired, equal, just over ½ the length of the fifth tarsal segment, each with a large internal basal tooth.



Figs 1–5, 7. *Mackerrasomyia brevibarba* (Kieffer). 1, ♀ maxillary palp, × 165; 2, ♀ antennal segments XI–XIV, × 80; 3, ♀ antennal segments VIII–X, × 80; 4, ♀ hind fifth tarsal segment and claws, × 165; 5, ♀ wing, × 25; 7, ♀ spermatheca, × 165.

Figs 6, 8. *Mackerrasomyia marginata* n. sp. 6, ♀ wing, × 25; 8, ♀ spermatheca, × 165.

Haltere brown, knob black. Wing with conspicuous microtrichia, macrotrichia absent. Costal and radial veins dark brown, rest light brown. Dark bristles on costa. Costal ratio 0·76. Lengths of first and second radial cells 0·307 and 0·525 mm. respectively (Fig. 5).

Abdomen brown, spiculate, with a large pale area anteriorly, pleural membranes blackish-brown. Cerci pale brown. Spermatheca single, oval, 0·083 × 0·068 mm., with a short chitinised neck (Fig. 7).

Male: Unknown.

Distribution: Known only from type locality.

MACKERRASOMYIA MARGINATA, n. sp.

This species can be readily distinguished from *brevibarba* by the yellow fore tibia and partially yellow mid and hind tibiae.

Type: Holotype ♀, in SPHTM.

Type Locality: Ingham, Queensland (7.iv.1961, light trap, K. L. Harley).

Female: Length 3·30 mm., wing 2·28 × 0·78 mm.

Head dark brown. Proboscis ⅖ the height of the head. Eyes bare, separated, but not as widely as in preceding species. Mandibular teeth 7. Palp light brown, segment III with several sensillae on distal surface. Palpal ratio 2·7.

Palpal segment ..	I	II	III	IV	V
Length	0·041	0·057	0·083	0·053	0·083

Antennal segment II dark brown, IV–X yellowish on basal half, brown on apical half, XI–XV dark brown, slightly paler basally, XV with a long apical bristle.

Antennal segment	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Length	?	0·064	0·068	0·068	0·072	0·068	0·072	0·079	0·186	0·182	0·190	0·224	0·239

Thorax and legs as in *brevibarba*, except: fore tibia yellow, slightly brownish basally and apically, mid and hind tibiae with basal half dark brown, apical half yellow, hind tibia with apex brown; tarsi more whitish than yellowish; hind femur with a preapical ventral spine, fore and mid fifth tarsal segments with 4–5 pairs of batonnets, hind with 5 pairs. Hind tibial comb of 6 spines.

Leg segment:		Femur	Tibia	*Tarsus*					Tarsal
				I	II	III	IV	V	*Ratio*
Length:	*Fore*	0·930	0·735	0·304	0·171	0·079	0·068	0·190	1·78
	Mid	1·050	0·780	0·494	0·171	0·083	0·072	0·159	2·89
	Hind	1·155	0·975	0·646	0·288	0·114	0·083	0·182	2·24

Tarsal spines: mid I with 1 ventral, 2 apical, II with 1 apical; hind I with 1 apical, II with 1 fine and 1 stronger apical. Claws as in *brevibarba*.

Haltere with stem dark brown, knob black. Wing as in *brevibarba*, but the wing margin shaded blackish (Fig. 6). Costal ratio 0·76. Lengths of first and second radial cells 0·255 and 0·517 mm. respectively.

Abdomen dark brown, without conspicuous anterior pale area. Cerci light brown. Spermatheca single, oval, 0·091 × 0·076 mm., with a short chitinised neck (Fig. 8).

Male: Unknown.

Acknowledgements

The assistance given in the preparation of this paper by Associate Professor D. J. Lee, of the School of Public Health and Tropical Medicine, is gratefully acknowledged, as are the comments provided by Dr. W. W. Wirth, Systematic Entomology Laboratory, U.S. Department of Agriculture, on the relationships of the Australian species formerly classed as *Heteromyia*.

References

DURET, J. P. and LANE, J., 1955.—Novas *Heteromyia* da Argentina (Diptera, Ceratopogonidae). *Dusenia*, 6 (1/2): 35–40.

JOHANNSEN, O. A., 1943.—A Generic Synopsis of the Ceratopogonidae (Heleidae) of the Americas, a Bibliography, and a List of North American Species. *Ann. Ent. Soc. Amer.*, 36: 763–791.

KIEFFER, J. J., 1906.—Chironomidae. Wytsman's Genera Insectorum, fasc. 42: 44–78.

————, 1917*a*.—Chironomides d'Australie. *Ann. Mus. Nat. Hung.*, 15: 177–199.

————, 1917*b*.—Chironomides d'Amerique. *Ann. Mus. Nat. Hung.*, 15: 292–364.

LEE, D. J., 1948.—Australasian Ceratopogonidae (Diptera, Nematocera). Part V. The *Palpomyia* Group of Genera. PROC. LINN. SOC. N.S.W., 73 (1–2): 57–70.

MACFIE, J. W. S., 1940.—The Genera of Ceratopogonidae. *Ann. Trop. Med. and Parasit.*, 34: 13–30.

SAY, T., 1825.—American Entomology, 2: 79.

TOKUNAGA, M., 1966.—Biting Midges of the Palpomyiinae from New Guinea (Diptera: Ceratopogonidae). *Pac. Insects*, 8 (1): 101–152.

WILLISTON, S. W., 1900.—In Godman, F. D., and Salvin, O., eds., Biologia Centrali—Americana, 43 (Diptera, Vol. I, Supplement, pp. 217–332).

WIRTH, W. W., 1952.—The Heleidae of California. Univ. Calif. Publ. Ent., 9: 95–266.

AUSTRALASIAN CERATOPOGONIDAE (DIPTERA, NEMATOCERA)

PART XIII: AUSTRALIAN AND NEW GUINEA SPECIES OF ECHINOHELEA MACFIE

MARGARET L. DEBENHAM
School of Public Health and Tropical Medicine, University of Sydney

(35 Text-figures)

[Read 30th July, 1969]

Synopsis

Until recently the biting midge genus *Echinohelea* Macfie was known only from the Nearctic and Neotropical regions, with four described species. A species from Africa was described in 1959, and in 1963 and 1966 Tokunaga described six species from New Guinea. In the present paper, the genus is recorded for the first time from Australia, with two new species, and three further New Guinea species are described. In addition, new records are provided for some of Tokunaga's species, and a key to the known Australian and New Guinea species is given.

Genus ECHINOHELEA Macfie

Echinohelea Macfie, 1940, *Proc. r. ent. Soc. London,* (B), 9 (11): 187 (Type species, *Echinohelea ornatipennis* Macfie, by original designation).

Diagnosis: Eyes bare. Antennal segments long and slender, distal five elongated in both sexes, male without antennal plume, sparse verticels present in both sexes, these longer in the male, some antennal segments bearing sensory pits surrounded by fine cilia, these always present on the basal flagellar segment, sometimes on other segments. Maxillary palp long and slender, 5-segmented, third segment with a preapical sensory pit. Thorax without anterior tubercle. Legs with stout, often long, black spines on all femora and most, or all, tibiae, these spines scattered rather irregularly, male sometimes with long, delicate hairs on legs; tarsal segment IV short, not distinctly cordate or bilobed, segment V long, unarmed, not inflated. Female claws equal or unequal, with an internal basal tooth, male claws equal, with or without a basal tooth. Wing without macrotrichia, with two radial cells, the second much longer than the first, costa extending to just over $\frac{3}{4}$ of wing length, not prolonged beyond junction with R_{4+5}, M_2 arising at or just before r-m. Abdomen of female with sternites VI–VIII fused into a more highly sclerotized, subtriangular genital plate bearing the gonopore in a cleft on its posterior margin; a single large spermatheca usually with hyaline punctures. Male genitalia large, bent under abdomen, the coxites bulbous, separating the reduced sternite and tergite completely, styles short and stout, only slightly curved, ninth sternite a subtriangular plate connected by a spiculate membrane to the base of the aedeagus, ninth tergite displaced distally, narrow and elongate, bearing a pair of apicolateral triangular lobes; aedeagus with a broad, rounded basal arch, distally produced into a pair of contiguous, or almost contiguous, slender lobes which sometimes bear subapical lateral points; parameres separate or fused along midportion, with a basal laterally produced process, stem slender, distal portion usually bent or recurved laterally, modified into various shapes.

Despite the sessile median fork, this genus is allied to *Stilobezzia* and related genera rather than the *Palpomyia* group of genera (Wirth, 1962).

METHOD OF DESCRIPTION

Unless otherwise stated, descriptions are based on specimens cleared in a mixture of 1 part absolute alcohol to 1 part creosote and mounted in balsam on microscope slides. When necessary, male genitalia were further cleared in KOH.

Table of measurements: Dimensions of newly described species are based on the holotype and, where available, the allotype. In these, wing length is measured from the basal arculus to the wing tip. Dimensions of species described previously by Tokunaga are taken directly from the published descriptions, except for the measurements of the mid femur and tibia of *Echinohelea zonata* Tokunaga which are taken directly from the holotype, as they were not given in the original description. Wing length in Tokunaga's species is measured from the incision between squama and alula, which gives a slightly greater value than the measurement used for new species. Dimensions of the newly described male of *Echinohelea flava* Tokunaga are based on a selected specimen which has been suitably labelled as such.

Morphological terms: These are based on Wirth (1952) with the following substitutions: in the female, cerci for lamellae; in the male, coxite and style for basistyle and dististyle. The length of the proboscis is measured from its junction with the clypeus to its tip; the height of the head is measured from the junction of the proboscis and clypeus to the upper margin of the eyes. The palpal ratio is the length of the third palpal segment divided by its maximum breadth. The tarsal ratio is the length of the first tarsal segment divided by the length of the second tarsal segment. The costal ratio is the length of the costa divided by the length of the wing.

Illustrations: These were done using a compound microscope, with the aid of a graticule and squared paper. All are based on type specimens unless otherwise stated.

Location of types: Types of newly described species are lodged in the collection of the School of Public Health and Tropical Medicine (SPHTM), Sydney, and the Australian National Insect Collection (A.N.I.C.), Canberra, A.C.T. Types of Tokunaga's species are in the B. P. Bishop Museum, Honolulu.

Key to Australian and New Guinea Species of ECHINOHELEA

1. Wing with two dark costal spots .... *pictipennis* Tokunaga
   Wing without spots, entirely hyaline or anterior portion enfuscated 2
2. Hind tibia entirely yellow, apex sometimes brownish 3
   Hind tibia largely brown 6
3. Scutum largely brown, or with conspicuous brown markings 4
   Scutum yellow, with only inconspicuous fuscous areas 5
4. Scutum reddish-brown with humeral areas yellow, all coxae yellow, proboscis long, ⅗ the height of the head .... *longirostris*, n. sp.
   Scutum yellow with brown markings on anterior margin and posterior half, mid and hind coxae brown on apical half, proboscis less than ½ the height of the head .... *moresbyensis*, n. sp.
5. Femora of all legs with 6 or more spines .... *flava* Tokunaga
   Mid and hind femora with 1 or 2 spines .... *papuensis* Tokunaga
6. Hind femur with apical fourth either entirely brown, or brown interrupted by a whitish median band 7
   Hind femur not marked as above 8
7. Small species, about 1·5 mm. long, hind femur with apex brown and a brown preapical band, and a single preapical spine .... *notipes*, n. sp.
   Large species, over 2 mm. long, hind femur broadly brown apically, with about 15 spines in ♂, 6–7 in ♀ .... *australiensis*, n. sp.
8. Hind femur with about 14 or more spines, fore tibia with 1–2 spines 9
   Hind femur with fewer than about 8 spines, fore tibia without spines 10

9. Large species, over 2 mm. long, abdomen yellow with extensive brown markings .... *zonata* Tokunaga
Small species, about 1·2 mm. long, abdomen almost entirely yellow .. *pallida*, n. sp.
10. Caudoscutal area without fuscous markings, ♀ with mid and hind claws unequal .... *hardyi* Tokunaga
Caudoscutal area with faint fuscous markings, ♀ claws all equal .. *laensis* Tokunaga

ECHINOHELEA PICTIPENNIS Tokunaga

Echinohelea pictipennis Tokunaga, 1963, *Pac. Insects,* 5 (1) : 231. (*Type locality*: Amok, 165 m., NE New Guinea. *Allotype* ♂ from Gurakor village, 950 m., Wampit Valley, nr. Wau, NE New Guinea; *paratype* ♂ from Waris, 450–500 m., S of Hollandia, NW New Guinea; *paratype* ♀ from Swart Valley, 1300–1350 m., W Fork, NW New Guinea.)

Specimens examined: 3 ♂ ♂, 1 ♀, Malaria Control Sect., Maprik, New Guinea[1] (iv.1958).

A large species, over 2 mm. long, thorax yellow with fuscous markings, legs yellow except the hind tibia which has apex and basal two-thirds dark brown, wing with brown spots over r-m cross vein and at end of R_{4+5}, haltere pale, abdomen yellow, tergites brown laterally and on posterior margins, parameres with long, sharply pointed apicolateral processes.

The specimens examined differ slightly from the type in having the head yellowish-brown, and the female with a basal spine on the first tarsal segment and a smaller spermatheca (0·072 × 0·070 mm.). Femoral spines of males: fore with 13–14 [10–13 in type series], mid with 13–14 [10–12], hind with 13–15 [15]; tibial spines of males: fore with 1 [1], mid with 2–3 [2–5], hind with 8–9 [8–11]. Femoral spines of female: fore with 9 [9–10], mid with 13 [12–13], hind with 13 [14–15]; tibial spines of female: fore with 1 [1], mid with 4 [4], hind with 8–9 [9–11].

This is the only spotted-winged species so far described from the area. Wirth (unpublished MS) records *pictipennis* from the Philippines, but this may be a new species, the hind tibia having only the basal half brown, the male hind tibia being more spinose (13 spines), and the apicolateral processes of the male parameres begin shorter and more rounded.

Distribution: Northern New Guinea; Philippines (?).

ECHINOHELEA LONGIROSTRIS, n. sp.

Type: Holotype ♀, in SPHTM.

Type locality: Malaria Control Sect., Maprik, New Guinea (1958).

This species is very similar to *flava* and *moresbyensis,* but is readily distinguished by the scutal coloration. Male unknown.

Female: Length 1·50 mm., wing 1·30 × 0·43 mm.

Head light brown, vertex and frons yellow. Proboscis long and narrow, $\frac{3}{5}$ the height of the head (Fig. 2). Eyes bare, just contiguous. Mandibular teeth eight. Palp pale yellowish, long and slender, segment III with a shallow preapical sensory pit, palpal ratio 3·2 (Fig. 1). Antennal segment II ochreous, flagellum missing.

Scutum reddish-brown except for humeral areas, which are yellow, scutellum and postscutellum brownish-ochreous, scutellum with 6 large setae, pleuron yellow. All coxae, trochanters, femora and tibiae yellow, fore femur with 8–9 spines, mid femur with 12–13, hind femur with 10, fore tibia with 0,

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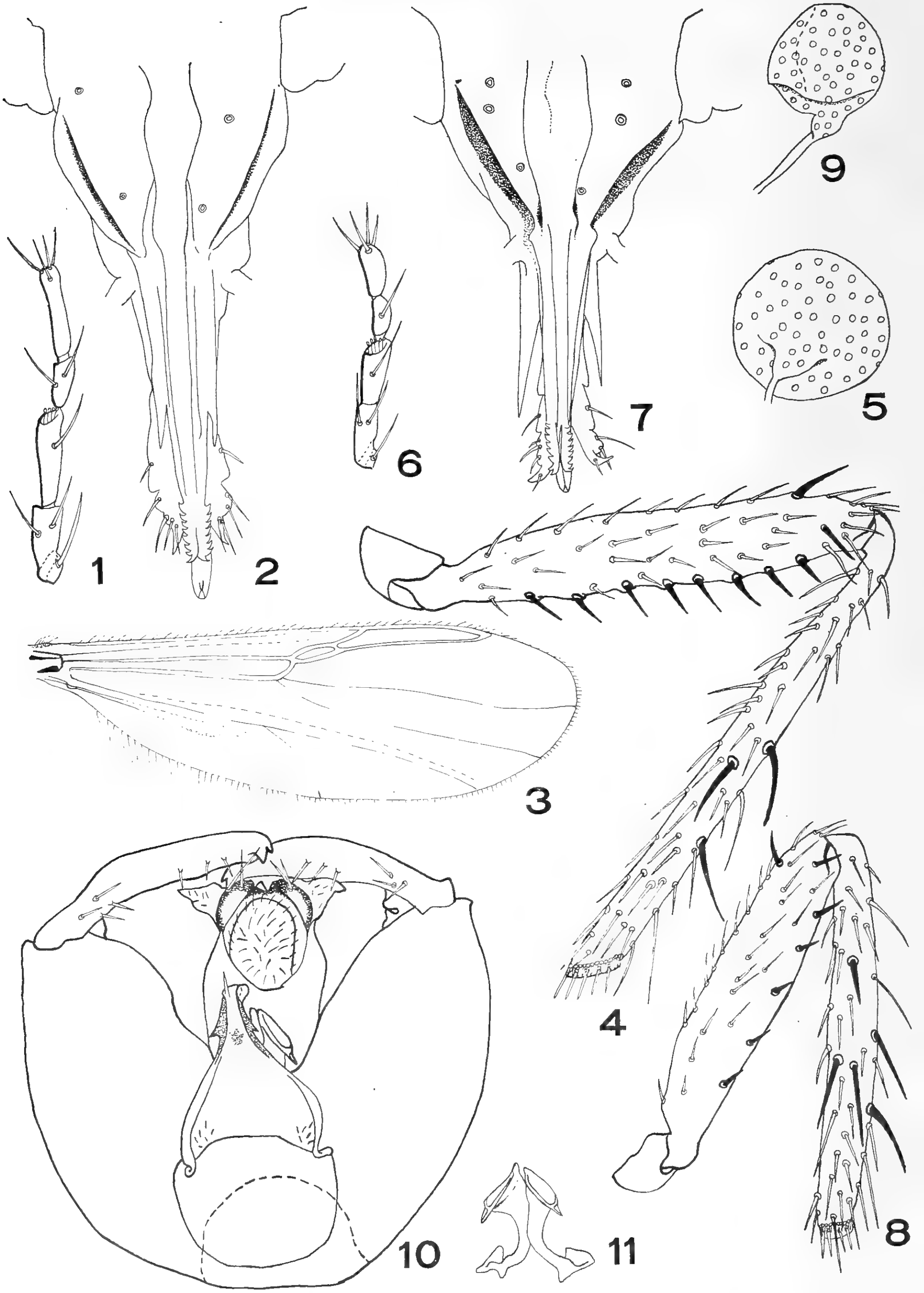
[1] Specimens with the data "Malaria Control Section, Maprik, New Guinea" are part of bulked light trap collections sent to SPHTM for study by Dr. W. Peters.



Figs. 1–5. *Echinohelea longirostris*, n. sp. 1, ♀ maxillary palp, × 200; 2, ♀ proboscis, × 200; 3, ♀ wing, × 55; 4, ♀ hind femur and tibia, × 100; 5, ♀ spermatheca, × 200. Figs. 6–11. *Echinohelea flava* Tokunaga. 6, ♀ maxillary palp, × 200; 7, ♀ proboscis, × 200; 8, ♀ hind femur and tibia, × 100; 9, ♀ spermatheca, × 200; 10, ♂ hypopygium (Maprik specimen), × 200; 11, ♂ parameres (Maprik specimen), × 200.

mid tibia with 2, hind tibia with 2–3, hind tibial comb of about 5 pale spines (Fig. 4); tarsi yellowish, the fifth segment fuscous, tarsal spines: fore I with 1 apical, 1 basal, II–III with 1 apical; mid I with 1 basal, 1 apical, II–III 1 apical; hind I with 1 basal, III 2 apical; tarsal ratios of fore, mid and hind legs 1·80, 1·89 and 2·53 respectively. Claws of all legs paired, equal, about ½ the length of the fifth tarsal segment, each claw with an internal basal tooth.

Wing (Fig. 3) with veins light brown; intercalary fork not distinct; costal ratio 0·84, lengths of first and second radial cells 0·098 mm. and 0·353 mm. respectively. Haltere pale fuscous yellow.

Abdomen yellow, more ochreous distally, posterior margins of segments dark brown; cerci brown. Spermatheca brown, oval, with hyaline punctures, 0·102 mm. × 0·098 mm., with a short chitinized neck (Fig. 5).

As well as the dark scutum, this species differs from *flava* Tokunaga in having a longer proboscis, longer, more slender palp, and more spinose mid and hind femora. It differs from *moresbyensis* n. sp. in the more extensively brown scutum, entirely yellow coxae, longer palp and longer proboscis, more spinose mid femur and less spinose hind femur and tibia.

Distribution: Known only from the type locality.

ECHINOHELEA MORESBYENSIS, n. sp.

Type: Holotype ♂, in SPHTM.

Type locality: Musgrave R., near Port Moresby, New Guinea (25.ii.1964, D. H. Colless).

This species is distinguished from other species with yellow legs by the scutal coloration and brown apices of mid and hind coxae. Female unknown.

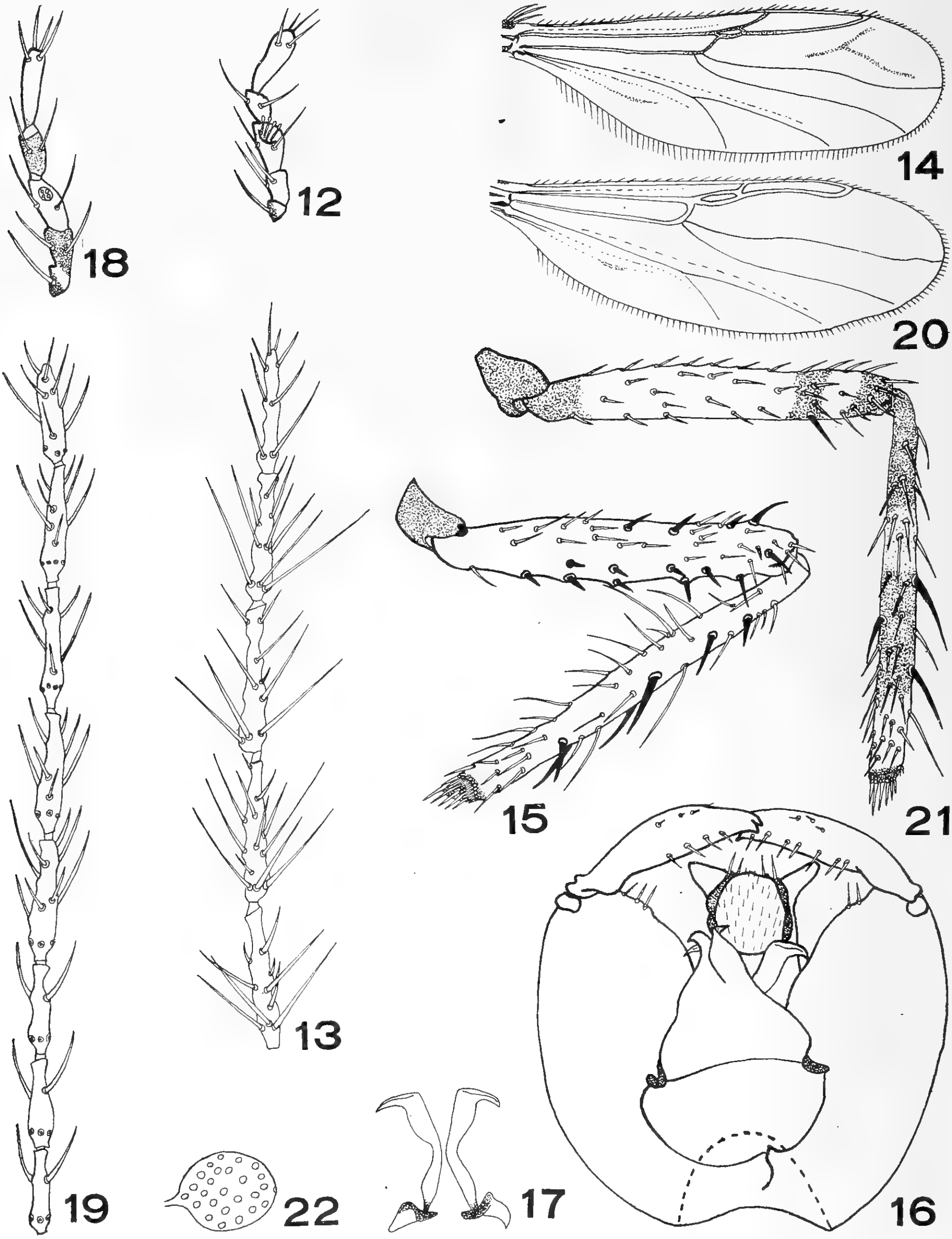
Male: Length 1·14 mm., wing 1·00 × 0·34 mm.

Head light brown. Proboscis just under ½ the height of the head. Eyes bare, broadly contiguous. Palp light brown, rather short, segment III with a large preapical sensory pit, palpal ratio 2·0 (Fig. 12). Antennal segment II ochreous, III–X light brown basally, darker brown apically, XI–XV brown (Fig. 13).

Scutum yellow with brown markings on anterior and anterolateral margins and posterior half, scutellum fuscous yellow, with six large setae, postscutellum brown on anterior half, yellow on posterior half, pleuron yellow with some brownish markings. Fore coxa pale yellowish-brown, mid and hind coxae yellow on basal half, brown on apical half, fore and mid trochanters yellow, hind brown; femora and tibiae yellow, knees slightly fuscous; hind femur with a very pale preapical fuscous cloud, hind tibia narrowly brown apically, fore and mid femora each with 9 spines, hind femur with 14, fore tibia with 1, mid tibia with 2, hind with 6, hind tibial comb of 5 spines (Fig. 15); tarsi whitish, the fifth segment fuscous, tarsal spines: fore I with 1 apical, II–III with 1 apical; mid I with 1 basal, 2 apical, II–III 2 apical; hind I with 1 basal, III with 1 apical; tarsal ratios of fore, mid and hind legs 1·94, 1·68 and 2·32 respectively. Claws of all legs paired, equal, about ½ the length of the fifth tarsal segment, each claw with an internal basal tooth.

Wing (Fig. 14) with veins light brown; intercalary fork distinct; costal ratio 0·82; lengths of first and second radial cells 0·068 and 0·266 mm. respectively. Haltere fuscous.

Anterior abdominal segments fuscous yellow with posterior borders light brown, posterior segments light brown, pleural membranes brown. Hypopygium (Figs 16–17) fuscous yellow, styles dark brown; aedeagus with a very



Figs. 12–17. *Echinohelea moresbyensis*, n. sp. 12, ♂ maxillary palp, × 200; 13, ♂ antennal segments XI–XV, × 200; 14, ♂ wing, × 55; 15, ♂ hind femur and tibia, × 100; 16, ♂ hypopygium, × 200; 17, ♂ parameres, × 200. Figs. 18–22. *Echinohelea notipes* n. sp. 18, ♀ maxillary palp, × 200; 19, ♀ antennal segments VIII–XV, × 200; 20, ♀ wing, × 55; 21, ♀ hind femur and tibia, × 100; 22, ♀ spermatheca, × 200.

low basal arch, divided apically into two lobes, each with a small, sharp, apicolateral point, parameres expanded on apical half, with short, tapering apicolateral processes.

This species is distinguished from *flava* Tokunaga by the brown markings on the thorax and coxae, and from *longirostris* n. sp. by the more yellowish scutum, brown apices on the coxae, less spinose mid femur and more spinose hind femur and tibia, shorter proboscis and palp, and more distinct intercalary fork in wing.

Distribution: Known only from the type locality.

ECHINOHELEA FLAVA Tokunaga

Echinohelea flava Tokunaga, 1963, *Pac. Insects,* 5 (1): 235 ♀ only. (*Type locality*: Lowlands Agr. Stat., Keravat, New Britain.)

A female and 2 males collected from Maprik, New Guinea, and a single male from Guadalcanal Island, Solomon Islands (in the USNM) of a different species to the Maprik specimens, all agree with Tokunaga's original description of *E. flava* in general details. The males of both differ in having more spinose legs, the Maprik males having 10 spines on the fore femur, 10 on the mid femur and 12–13 on the hind femur, 1 on the fore tibia, 2–3 on the mid tibia and 5–6 on the hind tibia, the Guadalcanal I. male having 10, 12 and 17 spines on the femora and 1, 3 and 7 spines on the tibiae. However, the leg spinosity of the female from Maprik is similar to that of the holotype of *flava,* and possibly the females of the Guadalcanal species are also less spinose than the males. Here, the Maprik specimens are tentatively assigned to *flava* on the basis of the number of large scutellar setae (6, as in the holotype of *flava,* compared to 8 in the Guadalcanal I. specimen) and the number of supra-alar setae (7–9 in Maprik specimens, 8–9 in holotype, 13 in Guadalcanal I. specimen). Confirmation of this assignation will depend on collection of both females and males identifiable as *E. flava* from the type locality.

Specimens examined: 1 ♂, 1 ♀, Malaria Control Sect., Maprik, New Guinea (iv.1958); 1 ♂, same locality (vii.1958). Holotype ♀ also examined (Figs 6–9).

Male (description based on specimen collected in April, 1958): Length 1·36 mm., wing 1·08 × 0·36 mm.

Generally similar to female, differing as follows:

Legs more spinose (see above); tarsal spines as in female (note: holotype has fore tarsus I with 1 basal and 1 apical spine, as do present specimens), tarsal ratios of fore, mid and hind legs, 1·90, 2·00 and 2·62 respectively. Claws as in female, each $\frac{1}{2}$ the length of the fifth tarsal segment.

Costal ratio of wing 0·76, lengths of first and second radial cells 0·076 mm. and 0·266 mm. respectively.

Hypopygium (Figs 10–11) yellow, styles brown; aedeagus with median distal portion divided into two pointed lobes, each bearing a small subapical lateral point, parameres short, thickened on apical half, the apices flattened and somewhat anvil-shaped.

This species is distinguished from *papuensis* Tokunaga by the more spinose legs. The genitalia of the Guadalcanal Island species differ in having the apex of the aedeagus without lateral subapical points, and the parameres more slender and with pointed subapical ventrolateral processes.

Distribution: New Britain, northeastern New Guinea.

ECHINOHELEA PAPUENSIS Tokunaga

Echinohelea papuensis Tokunaga, 1966, *Pac. Insects,* 8 (1): 112. (*Type locality*: Mendi, 1660 m., S Highlands, SE New Guinea. *Allotype* ♂ from Matoko, Main Finisterre Range, Saidor Subdistrict, NE New Guinea.)

A medium sized species, almost entirely yellow as in *flava,* but legs much less spinose, femoral spines (in both sexes): 5 on fore, 1 on mid, 2 on hind; tibial spines: 0 on fore, 2 on mid, 3–4 on hind. Wings hyaline. Aedeagus of male with subapical lateral points, parameres with apical parts flattened and triangular.

Distribution: Eastern New Guinea.

ECHINOHELEA NOTIPES, n. sp.

Type: Holotype ♀, in SPHTM.

Type locality: Crystal Cascades, Cairns, N. Qld. (19.iv.1967, D. H. Colless).

A medium-sized species with legs distinctively banded, and with few spines. Male unknown.

Female: Length 1·47 mm., wing 1·05 × 0·37 mm.

Head brown. Proboscis ½ the height of the head. Mandible with 8 teeth. Palp light brown except for segments III and V which are whitish, III with a shallow preapical sensory pit, palpal ratio 2·2 (Fig. 18). Antennal segment II ochreous, III brown, IV–X light brown with basal half to one-third whitish, XI–XII brown, bases paler, XIII–XV brown, all segments with a basal verticel (Fig. 19).

Scutum yellow, but with a brown median longitudinal band on anterior half, posterior half brown dorsally, and a narrow transverse brown band behind each humeral area not quite reaching the median band, scutellum yellow, brownish anteriorly and centrally, postscutellum brown, pleuron yellow with irregular brown areas. Fore coxa brown, mid and hind coxae yellow with dark brown apices, fore trochanter pale brown, mid and hind trochanters darker brown; legs pale whitish-yellow, fore femur with base pale brown and two pale brown bands, one just before centre and one past centre, mid femur with base light brown and a single pale brown preapical band, hind femur with base and apex brown and a brown preapical band, fore and mid tibiae with bases pale fuscous, apices brown, and a broad, very pale brown preapical band, hind tibia brown with a yellowish sub-basal and whitish preapical band (Fig. 21), spines on fore femur 5, on mid femur 2, on hind femur 1, on fore tibia 0, on mid tibia 1–2, on hind tibia 3, hind tibial comb of 6 spines; tarsi fuscous except basal half of hind segment I, which is brown, tarsal spines: fore I with 1 basal, 1 apical, II–III with 1 apical; mid I with 1 basal, 1–2 ventral, 2 apical, II–III 2 apical; hind I with 1 basal; tarsal ratios of fore, mid and hind legs 2·10, 2·15 and 2·27 respectively. Claws of all legs paired, equal about ½ the length of the fifth tarsal segment, each with an internal basal tooth.

Wing (Fig. 20) with veins light brown; intercalary fork not distinct; costal ratio 0·79, lengths of first and second radial cells 0·095 mm. and 0·220 mm. respectively. Haltere brown, apex of knob paler.

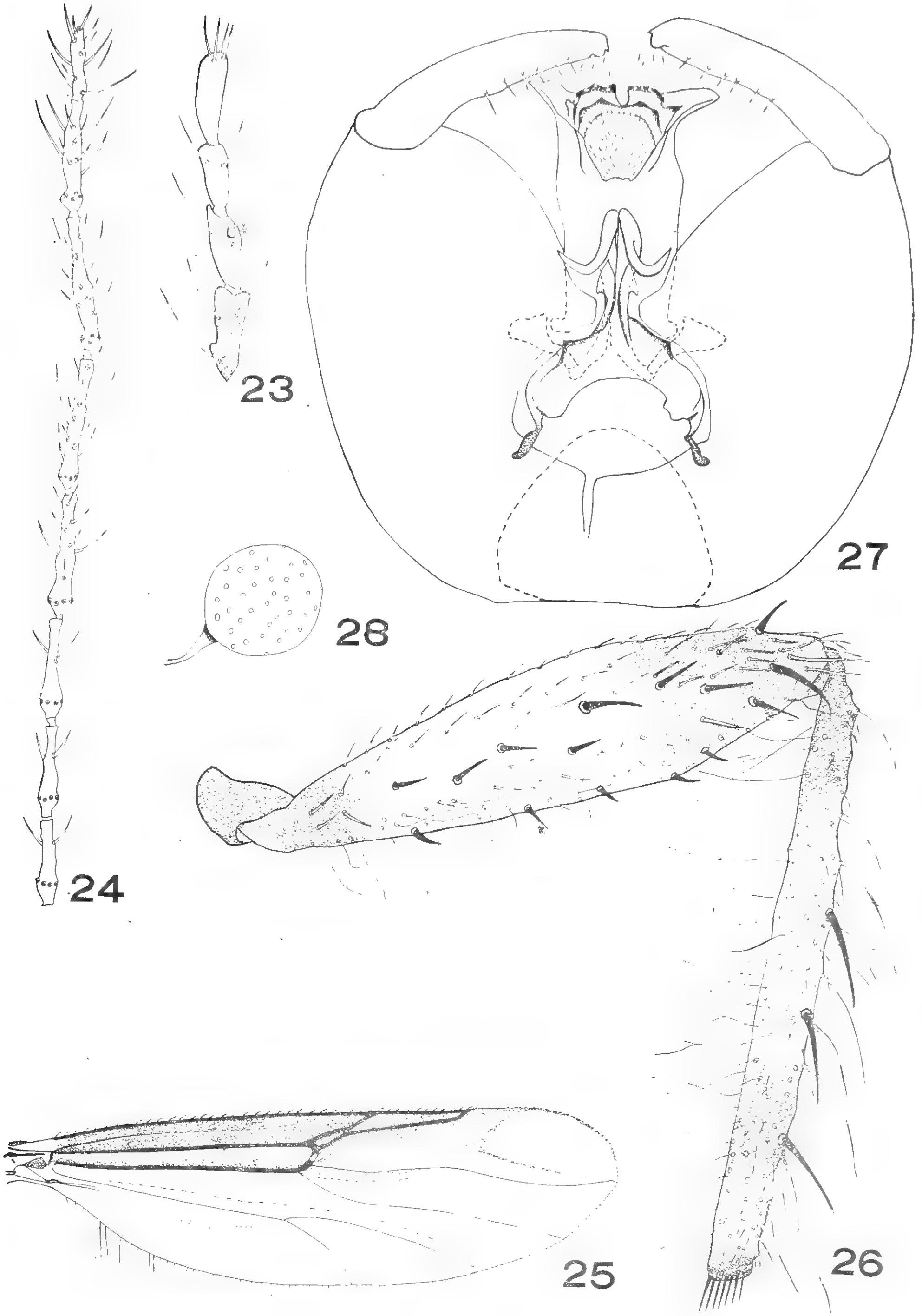
Abdomen brown, segments darker brown on posterior margins; cerci dark brown. Spermatheca brown, oval, with hyaline punctures, 0·060 × 0·049 mm., with a short chitinized neck (Fig. 22).

The markings on the thorax and legs of this species are similar to those of *australiensis* n. sp., but it is readily distinguished by its smaller size and less spinose legs.

Distribution: Known only from the type locality.

ECHINOHELEA AUSTRALIENSIS, n. sp.

Types: Holotype ♂, allotype ♀, in A.N.I.C., and one ♀ paratype (pinned), in SPHTM.



Figs. 23–28 *Echinohelea australiensis*, n. sp. 23, ♂ maxillary palp, × 160; 24, ♂ antennal segments VIII–XV, × 160; 25 ♂ wing, × 40; 26, ♂ hind femur and tibia, × 80; 27, ♂ hypopygium, × 160; 28, ♀ spermatheca, × 160.

Type locality: Uriara State Forest, A.C.T. (14.xii.1960, D. H. Colless). Paratype from Colo Vale, N.S.W. (swept from bog near stream, 17.i.1957, W. W. Wirth).

This species is distinguished by its large size and banded legs.

Male: Length 2·45 mm., wing 1·92 × 0·62 mm.

Head brown, frons and clypeus more reddish. Proboscis ½ the height of the head. Eyes bare, broadly contiguous. Palp pale yellowish-brown except segments I and II, which are brown, III not swollen, with a large shallow, preapical sensory pit bearing several sensillae, palpal ratio 2·5 (Fig. 23). Antennal segment II dark brown, III yellow with apex brown, IV–IX brown with base yellow, X–XV brown; all segments except XV with a basal verticel of very long hairs; IV–X narrow vasiform, XI–XV slender, not much elongated, XV being very short (Fig. 24).

Scutum yellow with a broad median longitudinal brown band which divides narrowly on the posterior half of the scutum, the two halves extending to the scutellum, a narrow transverse brown band just behind each humeral area not quite reaching the median band, and a diagonal band extending forward from each wing base to join the median band just behind its point of bifurcation, scutellum yellow, brown on lateral ends, postscutellum brown, pleuron yellow with irregular brown bands. Fore coxae and trochanters brown, mid and hind coxae yellow, apical third of coxae and mid and hind trochanters dark brown; femora yellow, bases brown, knee joints dark brown, mid femur with a light brown preapical band, hind femur with apex broadly dark brown, tibiae yellow, apices dark brown, fore and mid tibiae with a broad slightly brownish median band, and a broad pale yellow preapical band, hind tibia with base broadly dark brown, apex narrowly dark brown, and a broad subcentral dark brown band (Fig. 26), hind femora swollen, all femora, tibiae and tarsi with numerous long, delicate, wavy hairs, femora and tibiae with dark spines arranged as follows: on femora, fore with about 14, the ventral ones on large conical tubercles, mid with 11–12, hind with 15; on tibiae, fore and mid with 1 sub-basal, hind with 3–4; hind tibial comb of 7–8 dark spines; tarsi pale yellow except segment V, which is brown, tarsal spines: fore I with 1 basal, 1 apical, II–III 1 apical; mid I with 1 very long basal, 1 long and 1 shorter apical, II–III with 1 long and 1 short apical; hind I with 1 basal, III with 1 apical; tarsal ratios of fore, mid and hind legs 1·46, 2·02 and 2·11 respectively; claws of all legs paired, equal, with internal basal tooth, claws about ½ as long as fifth tarsal segment.

Wing (Fig. 25) with membrane fuscous anteriorly, becoming paler posteriorly, veins brown; microtrichia conspicuous; intercalary fork distinct; costal ratio 0·75, lengths of first and second radial cells 0·117 mm. and 0·383 mm. respectively. Haltere brown, flat part of knob whitish.

Abdomen dark brown, tergite II with a broad yellow transverse band, III–V with a pair of lateral yellowish spots, these becoming progressively smaller and less distinct. Hypopygium (Fig. 27) dark brown except coxites yellowish sub-basally, styles blackish-brown; aedeagus with broad, shallow basal arch, median distal portion divided into two lobes, each with a small lateral preapical point, parameres with long, tapering apicolateral processes.

Female: Length 2·27 mm., wing 1·86 × 0·59 mm.

Differs from male as follows: Eyes just contiguous. Mandible with 8 teeth, palpal ratio 2·9. Proportions of antennal segments similar to male, hairs of basal verticels shorter, verticel on all segments including terminal one.

Legs lacking long delicate hairs, but with numerous shorter, bristle-like hairs; fewer spines on legs, femora with 11–12 in fore, 8 in mid, 8 in hind, tibiae with 0 in fore, 4 in mid, 6–7 in hind; tarsal spines as in male except mid I also with 1–2 ventral; tarsal ratios—fore 1·71, mid 2·06, hind 2·21; claws as in male.

Radial cells of wing longer, 0·125 mm. and 0·406 mm. respectively.

Spermatheca single, oval, dark brown with small hyaline punctures, 0·182 × 0·171 mm., chitinized neck 0·038 mm. long (Fig. 28).

Details of the coloration of the scutum and abdomen are based on the pinned paratype, as they are not clear in the slide specimens. The paratype differs in having the frons, clypeus and upper eye margins yellow rather than reddish-brown.

Distribution: A.C.T., southern N.S.W.

ECHINOHELEA ZONATA Tokunaga

Echinohelea zonata Tokunaga, 1963, *Pac. Insects,* 5 (1): 234. ♂ only. (*Type locality*: Busu River, E of Lae, 100 m., NE New Guinea.)

Specimen examined: 1 ♂, Malaria Control Sect., Maprik, New Guinea (1958). Holotype ♂ also examined.

A large species, over 2 mm. long, mainly yellow, thorax with fuscous markings, basal half and apex of hind tibia brown (Fig. 34), abdominal tergite I with slender fuscous band on middle part, tergites II–VII with a brown band along posterior margin, this band broadened medially and ventrally. Wing hyaline. Aedeagus without subapical lateral points, parameres with sharply tapering apicolateral processes, similar to *pictipennis.*

The Maprik specimen has fewer spines on the legs than the type, as follows: fore femur with 13–14 [type with 14], mid with 13–14 [15], hind with 17–19 [23]; fore tibia with 1–2 [2], mid with 3 [4], hind with 7–9 [9].

The leg markings of this species are similar to those of *pallida,* n. sp, *hardyi* and *laensis,* but it can be distinguished by its larger size, from *pallida* by the form of the male genitalia, and from *hardyi* and *laensis,* the males of which are unknown, by its more spinose legs.

Distribution: Northern New Guinea.

ECHINOHELEA PALLIDA, n. sp.

Types: Holotype ♂, in SPHTM, and 1 ♂ paratype, in A.N.I.C.

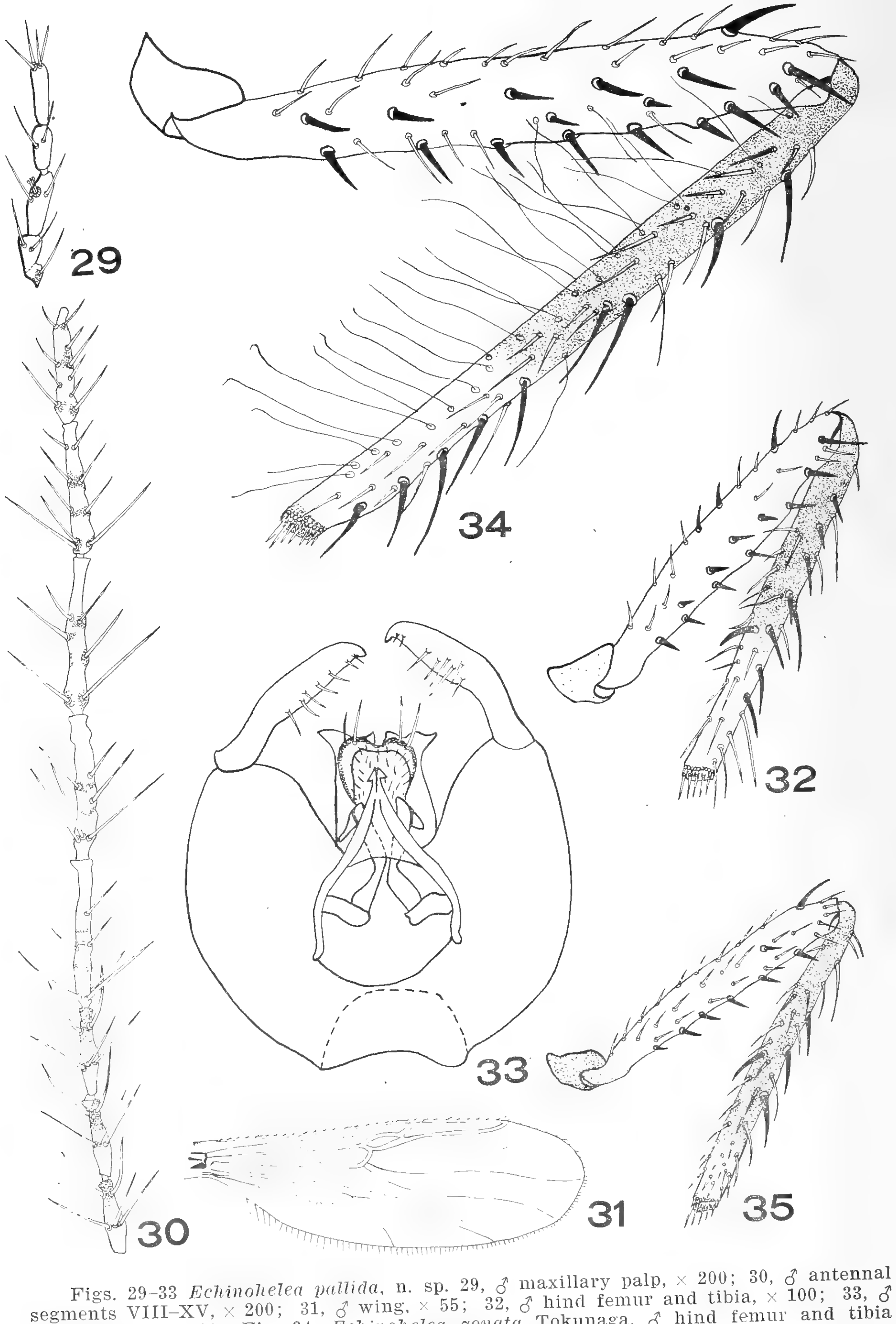
Type locality: Malaria Control Sect., Maprik, New Guinea (holotype 1958; paratype 22.iii.1964, D. H. Colless).

A small, pale species with the basal half of the hind tibia brown, similar to *zonata.* Female unknown.

Male: Length 1·18 mm., wing 0·97 × 0·33 mm.

Head yellow, clypeus and proboscis light brown, proboscis just under $\frac{1}{2}$ the height of the head. Eyes bare, broadly contiguous. Palp whitish, segment III with a shallow preapical sensory pit, palpal ratio 2·7 (Fig. 29). Antennal segment II yellow, III–VII whitish with apices pale brown, VIII–X with basal half whitish, apical half pale brown, XI–XV pale whitish-brown, light brown at bases of some hairs (Fig. 30).

Thorax yellow. Legs yellow except fore femur with central light brown spot dorsally, hind tibia with basal half and apex brown (Fig. 32), femoral spines 8 in fore, 13 in mid, 14–15 in hind, tibial spines 1 in fore, 5–6 in mid,



Figs. 29–33 *Echinohelea pallida*, n. sp. 29, ♂ maxillary palp, × 200; 30, ♂ antennal segments VIII–XV, × 200; 31, ♂ wing, × 55; 32, ♂ hind femur and tibia, × 100; 33, ♂ hypopygium, × 200. Fig. 34. *Echinohelea zonata* Tokunaga, ♂ hind femur and tibia (Maprik specimen), × 100. Fig. 35. *Echinohelea hardyi* Tokunaga, ♀ hind femur and tibia (Maprik specimen), × 100.

8–9 in hind, hind tibial comb of 5 spines; tarsi whitish except segment V, which is fuscous, tarsal spines: fore I with 1 basal, 1 apical, II–III 1 apical; mid I with 1 basal, 2 apical, II–III 2 apical, hind I with 1 basal; tarsal ratios of fore, mid and hind legs 1·84, 1·86 and 2·24 respectively. Claws of all legs paired, equal, about ½ the length of the fifth tarsal segment, each with an internal basal tooth.

Wing (Fig. 31) with veins very pale yellow; intercalary fork not distinct; costal ratio 0·80, lengths of first and second radial cells 0·079 mm. and 0·266 mm. respectively. Haltere pale yellow.

Abdomen pale yellow, the segments light brown laterally. Hypopygium (Fig. 33) deep yellow, styles brown; aedeagus deeply arched, divided medially at the apex, each lobe with a small, sharp lateral subapical point; parameres with short, thick, rounded apicolateral processes.

In the paratype the mid and hind legs have slightly fewer spines, the mid femur having 10, the tibia 4, the hind femur 11–12, the tibia 6–7. This species can be distinguished from *zonata* by its much smaller size, the pale bases of the antennal segments, the less spinose femora, the absence of long, delicate hairs on the legs, and the form of the male genitalia. It differs from *hardyi* and *laensis* in lacking a brown pattern on the scutum, in having the brown on the hind tibia less extensive, the legs more spinose, and the abdomen mainly yellow.

ECHINOHELEA HARDYI Tokunaga

Echinohelea hardyi Tokunaga, 1963, *Pac. Insects,* 5 (1): 235. ♀ only. (*Type locality*: Kampong Landbouw, 46 m., 30 km. NE of airstrip, Biak, NW New Guinea.)

Specimen examined: 1 ♀, Malaria Control Sect., Maprik, New Guinea (1958); 1 ♀, Doa Estate, 50 m. W of Port Moresby, New Guinea (8.viii.1962, R. Straatman). Holotype ♀ also examined.

A medium-sized, yellow and brown species, thorax yellow but scutum with fuscous clouds, legs mainly yellow, but spot at middle of fore femur, bases of mid and hind femora, and basal third of mid tibia faintly fuscous, hind tibia brown except for preapical yellow band (Fig. 35), female claws unequal on mid and hind legs. Wing hyaline, haltere brown. Abdomen brown.

Number of spines on femora and tibiae of the present specimen is: fore femur 8 [8–9 in type series], mid femur 7 [6–7], hind femur 8 [8], fore tibia 0 [0], mid tibia 2 [2–3], hind tibia 3–4 [2–3].

This species resembles *zonata, pallida,* n. sp. and *laensis*. It is distinguished from the first two by its less spinose legs, more extensively dark hind tibia, dark haltere and brown abdomen, and from *zonata* by its smaller size; it is distinguished from *laensis* by the absence of fuscous markings on the caudoscutal area, the presence of 2 apical spines on mid and hind fourth tarsal segments, the unequal claws on the mid and hind legs of the female, and the smaller spermatheca.

Distribution: New Guinea.

ECHINOHELEA LAENSIS Tokunaga

Echinohelea laensis Tokunaga, 1963, *Pac. Insects,* 5 (1): 236. ♀ only. (*Type locality*: Lae, 10 m., NE New Guinea.)

A medium-sized, yellow and brown species, differing from *hardyi* only in the following: scutum with faint fuscous markings on caudoscutal area,

TABLE 1

Measurements of Echinohelea *Species (mm.)*

	pictipennis		*longirostris*		*moresbyensis*		*flava*		*papuensis*		*notipes*		*australiensis*		*zonata*		*pallida*		*hardyi*		*laensis*	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Length ..	1·90	2·08	—	1·50	1·14	—	1·36	1·29	1·39	1·85	—	1·47	2·45	2·27	2·21	—	1·18	—	—	1·43–1·52	—	1·56
Wing length	1·70–1·87	1·87–2·04	—	1·30	1·00	—	1·08	1·17	1·37	1·65	—	1·05	1·92	1·86	1·96	—	0·97	—	—	1·17–1·26	—	1·37
Wing breadth	0·49–0·55	0·53–0·65	—	0·43	0·34	—	0·36	0·39	0·43	0·55	—	0·37	0·62	0·59	0·53	—	0·33	—	—	0·39–0·42	—	0·50
Palpal segment I	0·015	0·021	—	0·019	0·015	—	0·011	0·010	0·015	0·015	—	0·015	0·026	0·026	0·015	—	0·019	—	—	0·015	—	0·018
II	0·033	0·045	—	0·045	0·026	—	0·028	0·030	0·030	0·030	—	0·030	0·053	0·049	0·039	—	0·034	—	—	0·033	—	0·036
III	0·048	0·075	—	0·060	0·034	—	0·049	0·042	0·042	0·054	—	0·041	0·072	0·079	0·063	—	0·041	—	—	0·043	—	0·063
IV	0·024	0·042	—	0·030	0·020	—	0·022	0·020	0·033	0·033	—	0·030	0·057	0·045	0·045	—	0·026	—	—	0·027	—	0·030
V	0·042	0·060	—	0·060	0·041	—	0·041	0·036	0·036	0·051	—	0·045	0·079	0·083	0·057	—	0·045	—	—	0·042	—	0·052
Antennal segment III	0·111	0·111	—	—	0·068	—	0·082	0·075	—	0·087	—	0·079	0·102	0·110	0·120	—	0·087	—	—	0·075	—	—
IV	0·069	0·069	—	—	0·038	—	0·041	0·045	—	0·045	—	0·038	0·068	0·060	0·072	—	0·049	—	—	0·039	—	—
V	0·075	0·072	—	—	0·045	—	0·049	0·045	—	0·051	—	0·038	0·064	0·060	0·084	—	0·045	—	—	0·042	—	—
VI	0·076	0·072	—	—	0·041	—	0·049	0·048	—	0·054	—	0·041	0·068	0·064	0·084	—	0·045	—	—	0·042	—	—
VII	0·078	0·072	—	—	0·041	—	0·049	0·051	—	0·057	—	0·049	0·072	0·072	0·084	—	0·045	—	—	0·042	—	—
VIII	0·076	0·085	—	—	0·041	—	0·049	0·051	—	0·058	—	0·053	0·072	0·079	0·087	—	0·045	—	—	0·048	—	—
IX	0·078	0·090	—	—	0·049	—	0·060	0·054	—	0·060	—	0·060	0·083	0·083	0·093	—	0·049	—	—	0·051	—	—
X	0·079	0·093	—	—	0·049	—	0·057	0·057	—	0·063	—	0·057	0·091	0·112	0·090	—	0·057	—	—	0·057	—	—
XI	0·126	0·129	—	—	0·079	—	0·076	0·078	—	0·093	—	0·076	0·110	0·117	0·126	—	0·098	—	—	0·087	—	—
XII	0·112	0·123	—	—	0·087	—	0·060	0·081	—	0·093	—	0·076	0·114	0·114	0·120	—	0·095	—	—	0·087	—	—
XIII	0·115	0·120	—	—	0·087	—	0·091	0·075	—	0·090	—	0·072	0·118	0·114	0·120	—	0·112	—	—	0·093	—	—
XIV	0·094	0·111	—	—	0·076	—	0·091	0·070	—	0·087	—	0·068	0·102	0·098	0·111	—	0·087	—	—	0·084	—	—
XV	0·094	0·105	—	—	0·076	—	0·082	0·069	—	0·088	—	0·060	0·068	0·083	0·126	—	0·068	—	—	0·087	—	—
Fore leg :																						
Femur ..	0·585	0·676	—	0·540	0·375	—	0·450	0·429	0·442	0·516	—	0·375	0·825	0·675	0·780	—	0·390	—	—	0·422	—	0·507
Tibia ..	0·533	0·624	—	0·495	0·330	—	0·420	0·390	0·403	0·474	—	0·330	0·795	0·660	0·702	—	0·345	—	—	0·390	—	0·468
Tarsus I	0·195	0·221	—	0·171	0·133	—	0·144	0·143	0·208	0·244	—	0·159	0·288	0·239	0·253	—	0·133	—	—	0·152	—	0·169
II	0·104	0·114	—	0·095	0·068	—	0·076	0·065	0·091	0·104	—	0·076	0·155	0·144	0·126	—	0·072	—	—	0·082	—	0·091
III	0·078	0·078	—	0·076	0·053	—	0·060	0·052	0·071	0·078	—	0·060	0·114	0·110	0·091	—	0·053	—	—	0·065	—	0·065
IV	0·052	0·052	—	0·045	0·034	—	0·038	0·039	0·041	0·045	—	0·038	0·068	0·068	0·065	—	0·038	—	—	0·039	—	0·039
V	0·123	0·143	—	0·117	0·076	—	0·106	0·097	0·088	0·091	—	0·076	0·171	0·163	0·156	—	0·076	—	—	0·101	—	0·109
Mid leg :																						
Femur ..	0·663	0·741	—	0·570	0·420	—	0·495	0·481	0·507	0·611	—	0·405	0·930	0·750	0·840	—	0·450	—	—	0·487	—	0·546
Tibia ..	0·559	0·637	—	0·450	0·315	—	0·405	0·390	0·442	0·500	—	0·345	0·825	0·690	0·720	—	0·360	—	—	0·403	—	0·468
Tarsus I	0·299	0·338	—	0·266	0·197	—	0·212	0·218	0·301	0·322	—	0·212	0·406	0·376	—	—	0·197	—	—	0·234	—	0·266
II	0·143	0·175	—	0·140	0·117	—	0·106	0·104	0·143	0·149	—	0·098	0·201	0·182	—	—	0·106	—	—	0·110	—	0·123
III	0·104	0·107	—	0·083	0·068	—	0·072	0·074	—	0·091	—	0·064	0·114	0·106	—	—	0·068	—	—	0·068	—	0·078
IV	0·052	0·052	—	0·038	0·030	—	0·038	0·035	—	0·039	—	0·034	0·072	0·060	—	—	0·034	—	—	0·040	—	0·039
V	0·091	0·117	—	0·095	0·072	—	0·098	0·078	—	0·091	—	0·068	0·148	0·133	—	—	0·064	—	—	0·088	—	0·078
Hind leg :																						
Femur ..	0·715	0·806	—	0·600	0·435	—	0·510	0·500	0·539	0·650	—	0·450	1·005	0·870	0·975	—	0·465	—	—	0·517	—	0·585
Tibia ..	0·819	0·897	—	0·690	0·495	—	0·570	0·533	0·624	0·702	—	0·480	1·065	0·930	1·092	—	0·510	—	—	0·563	—	0·650
Tarsus I	0·390	0·455	—	0·345	0·273	—	0·258	0·286	0·364	0·390	—	0·258	0·456	0·444	0·513	—	0·247	—	—	0·303	—	0·325
II	0·156	0·169	—	0·136	0·117	—	0·098	0·104	0·136	0·156	—	0·114	0·216	0·201	0·195	—	0·110	—	—	0·117	—	0·130
III	0·110	0·117	—	0·083	0·076	—	0·072	0·071	—	—	—	0·068	0·136	0·129	0·143	—	0·072	—	—	0·075	—	0·090
IV	0·058	0·052	—	0·049	0·038	—	0·045	0·039	—	—	—	0·041	0·091	0·076	0·078	—	0·034	—	—	0·044	—	0·049
V	0·123	0·130	—	0·121	0·072	—	0·106	0·088	—	—	—	0·072	0·192	0·167	0·156	—	0·083	—	—	0·100	—	0·109
																				0·064 ×		0·105 ×

fuscous spot on midportion of fore femur absent, no strong apical spines on mid and hind fourth tarsal segments, all female claws equal, spermatheca larger.

Distribution: Known only from the type locality.

CHECKLIST OF DESCRIBED SPECIES OF *Echinohelea* MACFIE

australiensis Debenham, n. sp. (A.C.T. and N.S.W., Australia).
flava Tokunaga, 1963, *Pac. Insects,* 5 (1) : 235 (New Britain).
harbelensis de Meillon, 1960, *J. ent. Soc. S. Africa,* 23 (2) : 409 (Liberia).
hardyi Tokunaga, 1963, *Pac. Insects,* 5 (1) : 235 (New Guinea).
laensis Tokunaga, 1963, *Pac. Insects,* 5 (1) : 236 (New Guinea).
lanei Wirth, 1951, *Proc. ent. Soc. Washington,* 53 (6) : 319 (Virginia, U.S.A.)
longirostris Debenham, n. sp. (New Guinea).
macfiei Lane, 1948, *Arq. Fac. Hig. S. Pub. Univ. Sao Paulo,* 1: 228 (Brazil).
moresbyensis Debenham, n. sp. (New Guinea).
notipes Debenham, n. sp. (Queensland, Australia).
ornatipennis Macfie, 1940, *Proc. r. ent. Soc. Lond.,* (B), 9 (11) : 188 (Guyana).
pallida Debenham, n. sp. (New Guinea).
papuensis Tokunaga, 1966, *Pac. Insects,* 8 (1) : 112 (New Guinea).
pictipennis Tokunaga, 1963, *Pac. Insects,* 5 (1) : 231 (New Guinea).
richardsi Macfie, 1940, *Proc. r. ent. Soc. Lond.,* (B), 9 (11) : 189 (Guyana).
smarti Macfie, 1940, *Proc. r. ent. Soc. Lond.,* (B), 9 (11) : 190 (Guyana).
voltana de Meillon, 1959, *Novos Taxa Entomologicos,* 13: 15 (Lower Volta).
zonata Tokunaga, 1963, *Pac. Insects,* 5 (1) : 234 (New Guinea).

Acknowledgements

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References

WIRTH, W. W., 1952.—The Heleidae of California. Univ. Calif. Publ. Ent., 9: 95–266.

————, 1962.—A reclassification of the *Palpomyia-Bezzia-Macropeza* Groups, and a revision of the North American Sphaeromiini (Diptera, Ceratopogonidae). *Ann. ent. Soc. Amer.,* 55 (3): 272–287.

AUSTRALASIAN CERATOPOGONIDAE (DIPTERA, NEMATOCERA)

PART XIV: THE GENUS SERROMYIA MEIGEN

MARGARET L. DEBENHAM
School of Public Health and Tropical Medicine, University of Sydney

(15 Text-figures)

[Read 30th July, 1969]

Synopsis

The genus *Serromyia* Meigen has not previously been recorded from the Australia-New Guinea area. In this paper a new species of the genus is described from Australia.

Genus SERROMYIA Meigen

Serromyia (Megerle, MS, in) Meigen, 1818, Syst. Beschr. Eur. Zweifl. Ins., 1: 83. (Genotype: *Ceratopogon femoratus* Meigen, monobasic.) *Prionomyia* Stephens, 1829, Cat. Brit. Ins., 2: 237. *Ceratolophus* (part) Kieffer, 1899 (*nec* Barboza de Bocage, 1873), *Bull. Soc. ent. France,* p. 69. *Johannseniella* Williston, 1907, *J. N.Y. ent. Soc.,* 15: 1 (*nom. nov.* for *Ceratolophus* K., *nec* Barboza de Bocage).

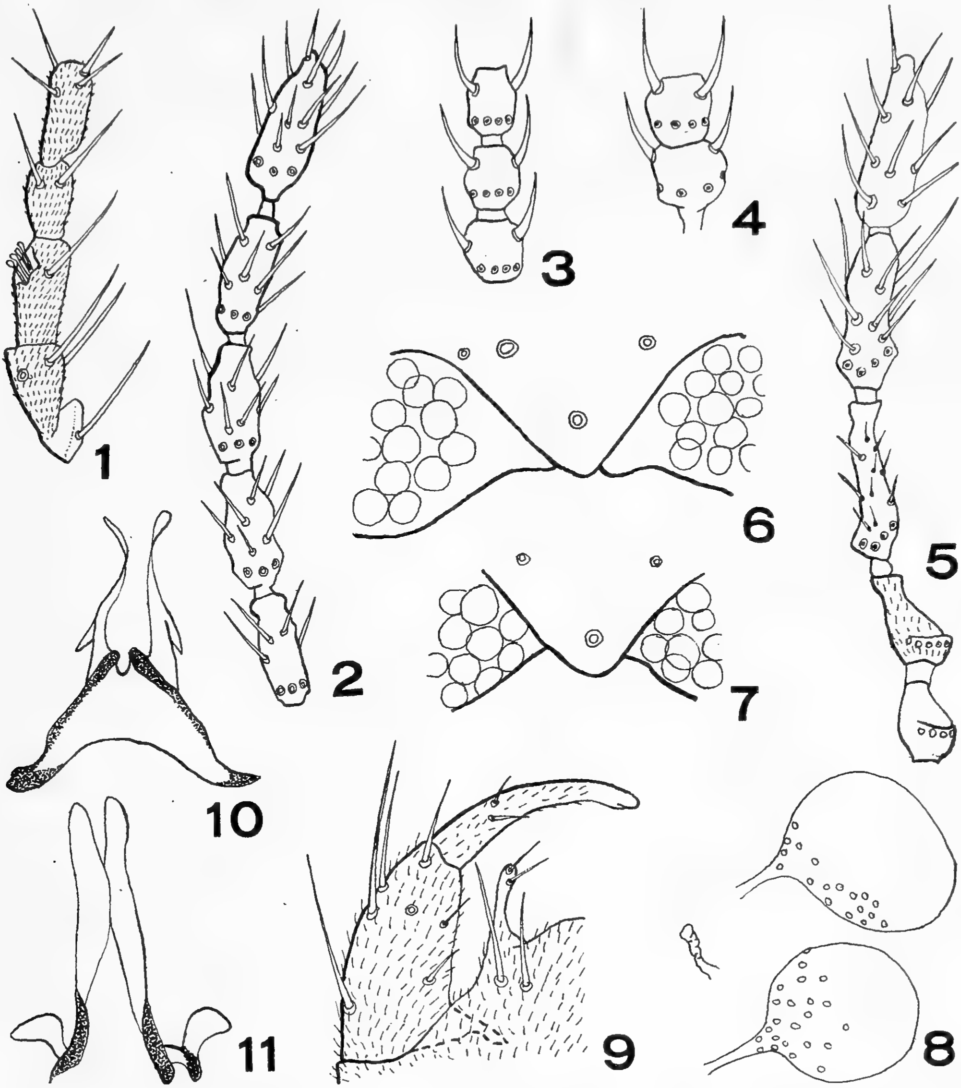
Diagnosis (modified from Wirth, 1952): Body slender, rather bare. Eyes bare. Female antennae with distal five segments elongate, male antennae with distal three segments elongate, with a distinct antennal plume. Scutum without anterior tubercle, with fine bristles arranged mostly in dorsocentral and acrostichal series; humeral pits not developed. Fore and mid legs slender, unarmed [or fore and mid femora with 3–6 spines (e.g. ♂ *S. europaea,* Clastrier, 1963, ♂ *S. atra* (Meigen), 1818, ♂ *S. nitens* Goetghebuer, 1920); fore femur with 1–5 spines (e.g. *S. albitarsis* Kieffer, 1919), *S. spinosipes* Kieffer, 1919, and sometimes *S. micronyx* Kieffer, 1919); fore femur and tibia with 2 or more spines (e.g. ♂ *S. nocticolor* Kieffer, 1914); *S. bispinosa* Goetghebuer, 1936); fore femur and fore and mid tibia with several spines (♂ *S. femorata* (Meigen), 1804); mid tibia with 1 spine (*S. reyei* n. sp.)], hind femur swollen, with numerous ventral spines, hind tibia slender, curved basally; fore and mid fourth tarsal segments cordate [but nearly cylindrical in *S. reyei* n. sp.], hind fourth tarsal segment cylindrical. Claws of female paired and equal on fore and mid legs, hind claw usually single, very long, occasionally paired and equal, claws of male all paired and equal; empodium absent. Wing with fine microtrichia, occasionally a few macrotrichia at apex; costa to two-thirds of wing length; two anterior radial cells, second not much longer than first; crossvein r-m nearly vertical; intercalary fork not evident, median fork sessile or with short stalk [but with a long stalk in *S. esakii* Tokunaga, 1940 and *S. reyei,* n. sp.], M_2 not interrupted at base [or broadly interrupted at base in *S. aethiopiae* Clastrier and Wirth, 1961, *S. esakii* Tokunaga and *S. reyei* n. sp.]; anal vein bent just beyond middle, an indistinct fold arising from bend; alula bare. Male genitalia with ninth sternite transverse; tergite conical, with anal lobes prominent; coxites stout, styles long and slender; aedeagus with basal arms widespread, apex slender; parameres bent in middle, with rather blunt apices.

This genus belongs in the *Stilobezzia* group of Lee (1948) = the tribe Stilobezziini of Wirth (1952).

SERROMYIA REYEI, n. sp.

A medium-sized, mainly brown species. (All measurements are in millimetres.)

Female: Length 1·90 mm., wing 0·97 × 0·39 mm.



Figs. 1–11. *Serromyia reyei* n. sp. 1, ♀ maxillary palp, × 230; 2, ♀ antennal segments XI–XV, × 230; 3, ♀ antennal segments VIII–X, × 230; 4, ♀ antennal segments III–IV, × 230; 5 ♂ antennal segments XI–XV, × 230; 6, ♀ vertex, × 230; 7, ♂ vertex, × 230; 8, ♀ spermathecae, × 230; 9, ♂ coxite, style and part of ninth tergite; × 230; 10, ♂ aedeagus, × 230; 11, ♂ parameres, × 230.

Head dark brown, paler at vertex, frons yellowish, clypeus and proboscis brown, proboscis half the height of the head. Eyes bare, broadly separated (Fig. 6). Mandibular teeth 7–8. Palp (Fig. 1) light yellowish brown, segment III slightly swollen, with a large preapical sensory pit bearing several long sensillae, palpal ratio 2·0.

Palpal segment ..	I	II	III	IV	V
Length	0·022	0·041	0·045	0·030	0·049

Antennal segment II dark brown, flagellar segments light brown, segment III not much larger than succeeding segment, segments IV–X short, stout, barrel-shaped, segments XI–XV not very elongate, all segments with a basal verticel, segment XV with a stiff apical bristle (Figs 2–4).

Antennal segment	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Length	0·034	0·022	0·024	0·024	0·026	0·026	0·026	0·028	0·045	0·045	0·049	0·049	0·060

Scutum dark brown dorsally but narrowly yellow posteriorly, slightly lighter brown laterally except for humeral areas and a median dorsoventral band, which are dark brown, scutellum slightly fuscous centrally, yellow laterally, with 4 large and 6 small setae, postscutellum dark brown, pleuron lighter brown. Coxae, trochanters, femora and tibiae brown, the hind pair darker, fore femur with an indistinct yellowish-brown area extending dorsally from the centre to near the apex, mid femur slightly yellowish in the same area, fore and mid tibiae paler than femora, especially on apical half, hind tibia slightly paler at apex, mid tibia with a short, strong apical spine, hind femur (Fig. 13) swollen, with about 20 strong ventral spines, hind tibia slightly curved basally, hind tibial comb of six spines; tarsi whitish, but segment V slightly fuscous, tarsal spines: for I with 1 basal, 1 apical, II–III with 1 apical; mid I with 1 basal, 2 ventral, 2 apical, II–III with 2 apical; hind I with 1 basal, 1 apical, II–III with 1 apical.

Leg Segment:	*Femur*	*Tibia*	*Tarsus*					*Tarsal*
			I	II	III	IV	V	*Ratio*
Length: Fore ..	0·390	0·375	0·159	0·091	0·038	0·041	0·049	1·75
Mid ..	0·465	0·427	0·235	0·121	0·072	0·045	0·072	1·94
Hind ..	0·555	0·427	0·209	0·106	0·079	0·064	0·087	1·96

Claws of fore and mid legs small, paired, equal, each with a small basal tooth, the claws 0·7 and 0·4 as long as the respective fifth tarsal segments, claw of hind leg single, 1·4 times the length of the fifth tarsal segment, with a fine basal tooth about $\frac{1}{4}$ the length of the claw.

Wing membrane very pale, microtrichia inconspicuous, macrotrichia absent; veins whitish, difficult to distinguish; dark bristles on costa, radius and R_{4+5}. Venation (Fig. 12): costa short, ending at level of end of M_{3+4}, costal ratio 0·69; first radial cell narrow, linear, second broader, lengths of first and second radial cells 0·121 and 0·167 mm. respectively; base of M_2 indistinct, but M_{1+2} apparently quite long, slightly longer than r-m; $FmCu_1$ level with r-m. Haltere white.

Abdomen very pale brown, with a darker brown pattern (Fig. 14); cerci brown. Spermathecae (Fig. 8) three, two large, oval, with long chitinized necks and hyaline punctures on the surface, 0·070 × 0·057 mm. with neck 0·022 mm. and 0·060 × 0·054 mm. with neck 0·026 mm., and one vestigial, tubular, 0·022 × 0·005 mm.

Male: Length 1·54 mm., wing 1·00 × 0·33 mm.

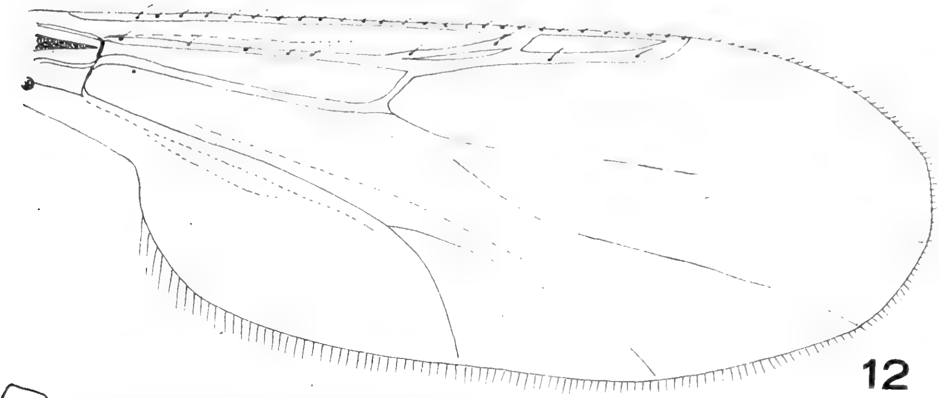
Generally similar to female in appearance, with the following differences:

Eyes more broadly separated (Fig. 7). Relative lengths of palpal segments differ slightly.

Palpal segment	I	II	III	IV	V
Length	0·019	0·045	0·045	0·028	0·041

Antennal segments XIII–XV slightly elongated, segments XIII–XIV with a basal verticel, antennal plume brown (Fig. 5.)

Antennal segment	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Length	0·087	0·034	0·034	0·034	0·030	0·030	0·030	0·034	0·038	0·045	0·064	0·064	0·068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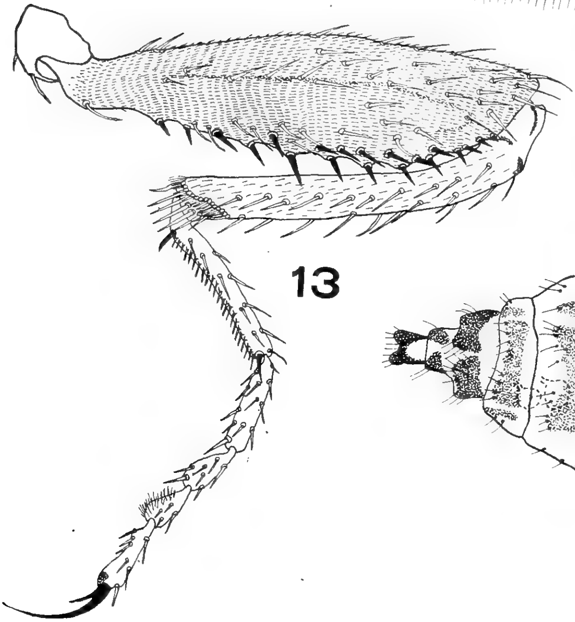
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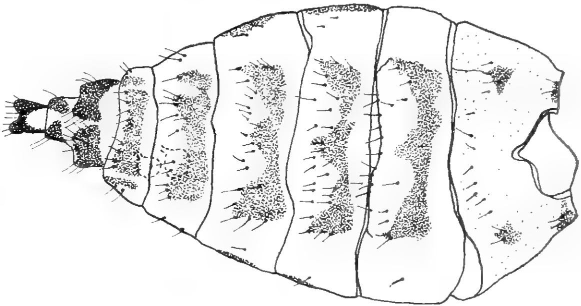
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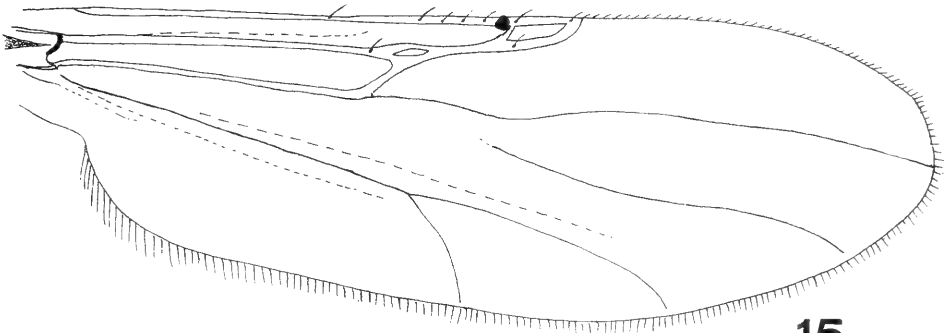
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Figs. 12–15. *Serromyia reyei* n. sp. 12, ♀ wing, 115; 13, ♀ hind leg, × 115; 14, ♀ abdomen, × 55; 15, ♂ wing, × 115.

Thorax and legs as in female, except hind femur with fewer (15–16) ventral spines, all fourth tarsal segments nearly cylindrical, tarsal ratios of fore, mid and hind legs 1·80, 1·97 and 1·79 respectively, claws of all legs equal, simple, in fore and mid legs just under $\frac{1}{2}$, and in hind legs just under $\frac{1}{3}$, the length of the fifth tarsal segment.

Wing (Fig. 15) relatively longer and narrower than in female. Venation: costa very short, ending halfway between the ends of M_{3+4} and Cu_1, costal ratio 0·60; first radial cell very small, almost completely closed, second radial cell broader, very short, the two radial cells separated for some distance by the fusion of the veins between them, lengths of first and second radial cells 0·045 mm. and 0·076 mm. respectively; base of M_2 indistinct, but M_{1+2} apparently very long; $fMCu_1$ below r-m.

Proximal half of abdomen light brown, distal half darker brown, anterior and posterior edges of segments whitish, tergites without a distinct pattern. Hypopygium (Figs 9–11) brown, styles paler brown, slightly longer than coxites, aedeagus mainly membranous, parameres rodlike, chitinized.

The degree of closure of the first radial cell and the extent of fusion of the veins between the first and second radial cells in the male wing is variable, in some specimens little or no fusion occurring.

Types: Holotype ♀, allotype ♂ and 41 ♂ ♂ and 15 ♀ ♀ paratypes.

Type locality: Darwin, Northern Territory (*holotype* and 2 ♀ ♀ *paratypes* from R.A.A.F. Marine Sect., 25–26. xi.1957, N.J. light trap, E. J. Reye; *allotype*, with 37 ♂ ♂ and 1 ♀ *paratypes*, from Sadgroves Cr., Jindiji Road, over gravel, 30.x.1957, 1600 hrs., net, E. J. Reye; 3 ♂ ♂ and 10 ♀ ♀ *paratypes* from Quarantine Stn., 26–27, 30–31.x.1957, 1–2, 2–3, 22–23. xi.1957, N.J. light trap, E. J. Reye; 1 ♀ *paratype*, 18.xi.1952, E. J. Reye; 1 ♂ *paratype*, from *Avicennia*, 6.xi.1957, 1715 hrs., E. J. Reye; 1 ♀ *paratype*, from crab hole, Gravelly Pt., 9–10. vi.1958, E. J. Reye).

The holotype and allotype are lodged in the School of Public Health and Tropical Medicine, University of Sydney. Paratypes are in S.P.H.&T.M.; United States National Museum, Washington; British Museum (Natural History); Australian National Insect Collection, Canberra, A.C.T.; B. P. Bishop Museum, Honolulu.

Discussion

Although this genus is at present known to occur in all zoogeographic regions except the Neotropical, by far the greatest number of described species are European, with a much smaller number of African and North American species. It is very poorly represented in Asia and the Pacific, and I have only been able to locate two previously described species from this area, *Serromyia pendleburyi* Macfie from Malaya and *S. esakii* Tokunaga from the Caroline and Marshall Islands. This distribution would suggest that *Serromyia* was originally a northern hemisphere genus, but is gradually extending its range southward.

Differentiation of Species

Serromyia reyei is distinguished from the only known geographically close species as follows:[1]

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[1] Whether or not the distribution of Ceratopogonidae conforms to the accepted subregional divisions of the Pacific area is a question which would best be left until current revisions of the Australian and Malayan fauna are completed.

1. *S. pendleburyi* Macfie, 1934 (Malaya—described from male only). Much larger, wing 2·6 mm. long. Coloration darker, head almost black, palp dark brown, scutum entirely black, abdomen dark brown. Mid tibia lacking apical spine. Costal ratio nearly 0·75, petiole of media shorter, equal to cross-vein. Ninth tergite very long, longer than coxite, with larger apical processes. Aedeagus with a much deeper basal arch, distal process of aedeagus single, very short and broad, tapering to a point, parameres similar in form to those of *reyei*, but completely separate.

2. *S. esakii* Tokunaga, 1940 (Caroline and Marshall Islands). Paler in colour, head and thorax yellowish, abdomen completely, or almost completely, white. Legs entirely brown. Ninth tergite longer than coxite, narrow. Aedeagus without basal arch, median lobe thinly chitinized, accessory processes short, swollen preapically, parameres separate, with recurved, pointed apices.

Acknowledgement

The assistance given in the preparation of this paper by Associate Professor D. J. Lee, of the School of Public Health and Tropical Medicine, is gratefully acknowledged.

References

CLASTRIER, J., 1960.—Notes sur les Cératopogonidés. X. Cératopogonidés de la République du Congo (2). *Arch. Inst. Pasteur d'Algérie*, 38 (2): 258–298.

————, 1963.—Notes sur les Cératopogonidés. XVIII. Espèces du genre *Stilobezzia* Kieffer ou apparentées de la région paléarctique. *Ibid.*, 40 (1–2): 41–68.

————, and WIRTH, W. W., 1961.—Notes sur les Cératopogonidés. XIII. Cératopogonidés de la région éthiopienne. *Ibid.*, 39 (2): 190–240.

EDWARDS, F. W., 1926.—On the British biting midges (Diptera, Ceratopogonidae). *Trans. r. ent. Soc. London*, 74: 389–426.

GOETGHEBUER, M., 1920.—Ceratopogoninae de Belgique. *Mém. Mus. royal d'histoire nat. Belgique*, 8 (fasc. 3): 1–116.

————, 1936.—Nouvelle contribution à la connaissance des Cératopogonidés et Chironomides de Belgique. *Bull. et Ann. Soc. ent. Belgique*, 76: 319–326.

KIEFFER, J. J., 1914.—South African Chironomidae (Diptera). *Ann. S. Afric. Mus.*, 10: 259–270.

————, 1919.—Chironomides d'Europe conservés au Musée National Hongrois de Budapest. *Ann. Mus. Nat. Hung.*, 17: 1–160.

MACFIE, J. W. S., 1934.—Report on a collection of Ceratopogonidae from Malaya. *Ann. trop. Med. Parasit.*, 28 (3): 279–293.

MEIGEN, J. W., 1804.—Klass. beschr. eur. zweifl. ins. *Braunschweig*, 1: 28–152; 6–314.

LEE, D. J., 1948.—Australasian Ceratopogonidae (Diptera, Nematocera). Part I. PROC. LINN. SOC. N.S.W., 72 (5–6): 313–331.

MALLOCH, J. R., 1914.—Notes on North American Diptera. *Bull. Ill. State Lab. nat. Hist.*, 10: 213–243.

TOKUNAGA, M., 1940.—Ceratopogonidae and Chironomidae from the Micronesian Islands. *Philippine J. Sci.*, 71 (2): 205–226.

TOKUNAGA, M., and MURACHI, E. K., 1959.—Diptera: Ceratopogonidae. *Ins. Micronesia*, 12 (3): 103–434.

WIRTH, W. W., 1952.—The Heleidae of California. Univ. Calif. Publ. Ent., 9 (2): 95–266.

GENERIC BOUNDARIES IN THE PODOCARPACEAE

C. J. QUINN
School of Botany, University of New South Wales

[Read 25th June, 1969]

Synopsis

Generic boundaries in the Podocarpaceae are critically reviewed in the light of recent data on gametophyte development, embryogeny, cytology and vegetative anatomy. While there is general support for the smaller genera, both *Dacrydium* and *Podocarpus* appear to be artificial assemblages. It is concluded that *Dacrydium* should be divided into at least five genera, and that each of the eight sections of *Podocarpus* should be raised to generic rank.

INTRODUCTION

The Podocarpaceae is a family of conifers of mainly southern distribution, and includes seven genera. Five of these, viz. *Phyllocladus* L.C. and A. Rich., *Acmopyle* Pilger, *Microstrobos* Gard. and Johns. (*Pherosphaera*), *Microcachrys* Hook. f., and *Saxegothaea* Lindl., either comprise a small number of obviously closely related species, or are monotypic (Table 1). Both *Podocarpus* L'Herit. ex Pers. and *Dacrydium* Soland. ex G. Forst., however, include a much larger number of species which have been variously arranged into subgenera and sections.

The taxonomy of *Dacrydium* is in a very unsatisfactory state. Florin (1931) arranged the species into three sections, A, B, and C, on the basis of their leaf epidermal structures. Florin himself stressed the provisional nature of these groupings, and pointed out that Section C, in particular, was clearly artificial. Subsequent studies by Quinn (1965, 1966*a*, 1966*b*) and Tengner (1965) indicate that the actual situation is far more complex.

Podocarpus, on the other hand, presents a much more clearly defined picture, as a result of the intensive studies of leaf anatomy made by Buchholz and Gray (1948). In this revision the genus was divided into eight sections, of which three, viz. *Eupodocarpus, Stachycarpus* and *Nageia,* were further subdivided into subsections.

While there has been a general acceptance of the smaller genera, there has developed a tendency to question the validity of these two large genera, *Podocarpus* and *Dacrydium* (e.g. Hair, 1963). The aim of this paper is to examine the validity of these genera as founded on presently accepted criteria, and to suggest a possible alternative treatment more in line with recent evidence.

CRITERIA OF PRESENT GENERIC BOUNDARIES

Present generic boundaries within the family are largely based on the structure of the female cone (see Table 1). There is convincing evidence that during the evolution of the Podocarpaceae the female cone has undergone increasing reduction in the number of fertile bracts (Florin, 1951: p. 363). Thus a cone containing only one or two fertile bracts, such as is found in some members of *Podocarpus* and *Dacrydium,* and in *Acmopyle,* is a specialized feature. Those genera which retain a recognizable cone with many fertile bracts, viz. *Saxegothaea* and *Microcachrys,* are primitive in this respect.

Table 1

Morphology of the female cone and karyotypes in the Podocarpaceae

	Number of species	Number of fertile scales/cone	Position of cones	Orientation of ovules	Ovuliferous scale fused to	Karyotype*	
						n	Number of arms
PODOCARPUS							
Afrocarpus	6	1–2	axillary	inverted	integument	12	20
Dacrycarpus	10	1–2	terminal	inverted	bract and integument	10	20
Eupodocarpus	74	1–3	axillary	inverted	integument	17–20	19, 20
Microcarpus	1	1–2	terminal	inverted	integument	18	20
Nageia	7	1–2	axillary	inverted	integument	10, 13	20
Polypodiopsis	5	1–2	axillary†	inverted	integument	10	20
Stachycarpus	10	1–8	axillary	inverted	integument	18, 19	20
Sundacarpus	1	1–2	axillary	inverted	integument	19	20
DACRYDIUM							
Section A	3	1–2	terminal	semi-erect	(free)	10	20
Section B	13	1–5	terminal	semi-erect	(free)	10	20
Section C							
D. bidwillii group ..	3	1–3	terminal	inverted	(free)	9, 11, 12	16
D. laxifolium group ..	2	1–2	terminal	erect	(free)	15	20
D. colensoi group.. ..	3	2–5	terminal	semi-erect	(free)	10, 15	20
ACMOPYLE	3	1–2	axillary†	semi-erect	integument	10	20
SAXEGOTHAEA	1	4–12	axillary	inverted	(free)	12	20
MICROCACHRYS	1	20–28	terminal	inverted	(free)	15	20
MICROSTROBOS	2	4–5	terminal	erect	(absent)	13	20
PHYLLOCLADUS	7	2–20	axillary	erect	(absent)	9	18

* Hair (1963) and Hair (pers. com.).

† sometimes terminal (de Laubenfels, pers. com.).

An epimatium or ovuliferous scale (or more correctly, the sterile part of the seed-scale complex—Florin, 1951: p. 364) is present in all the genera except *Phyllocladus* and *Microstrobos.* Both these genera have few species, and *Phyllocladus* is highly specialized in both karyotype (Table 1) and vegetative morphology. The presence of an ovuliferous scale in all but a few species, some of which were highly specialized in other respects, is consistent with the view that the ovuliferous scale is a primitive feature in the family, and that its absence in *Phyllocladus* and *Microstrobos* is due to reduction. Such an interpretation is also in line with Florin's theory of the origin of the coniferous cone, in which the ovuliferous scale is regarded as a primitive feature in the conifers as a whole (Florin, 1951).

Fusion between the ovuliferous scale and the integument is found throughout all sections of *Podocarpus* and in the genus *Acmopyle.* While this occurrence could equally well fit either a primitive or derived feature, the fusion of two adjacent structures is more easily visualized than their separation from a single structure. Again, the fossil evidence indicates that such fusion is a derived feature for the conifers generally (Florin, 1951). It seems highly probable, therefore, that fusion of the ovuliferous scale with the integument is a specialization within this family.

Florin (1951) regards the erect ovule as primitive in the conifers as a whole, though the inverted condition was developed at a very early stage in the evolution of some lines. In the Podocarpaceae there is a complete range in ovule orientation from the erect type seen in *Microstrobos* and *Dacrydium laxifolium,* through intermediate types where the ovule is partly reflexed as in *D. cupressinum,* to the completely inverted ovule of *Podocarpus* and *Dacrydium bidwillii.* The fact that in *D. colensoi* the ovule becomes more erect during its development has been interpreted as an indication that some species have developed the erect condition secondarily (Sinnott, 1913). Inverted ovules characterise the Pinaceae (s. str.) and Araucariaceae, and are found along with erect ovules in the Taxodiaceae and Podocarpaceae. Thus a change in the orientation of the ovule has occurred several times in the evolution of the Coniferales. It is possible, therefore, that changes in either direction may have occurred more than once in the Podocarpaceae. Clearly, ovule orientation is a character to be used with caution in assessing affinities.

The terminal position of the female cones seen in *Dacrydium, Microcachrys, Microstrobos* and Sections *Dacrycarpus* and *Microcarpus* of *Podocarpus* is considered primitive, the axillary fertile shoots found elsewhere in the family having been derived from it.

The genus *Dacrydium* is at present constituted by species with relatively few fertile bracts in the female cone (1–6), the cones terminal on vegetative branches, and the ovuliferous scale present and free from the integument. Of these features, only the reduced cone is considered derived, and this is a specialization that has found very general expression in the family. The other features of cone morphology that serve to unite the genus, viz., the free ovuliferous scale and the terminal position of the cones, are both primitive conditions, and so do not indicate any close relationship between the species concerned. In other aspects of cone morphology there is considerable diversity. This is particularly evident in the orientation of the ovule, the size of the cone, and the development of the ovuliferous scale. There seems little support, then, for the retention of this genus on the basis of cone morphology alone.

All sections of *Podocarpus* show an inverted ovule with fusion between the ovuliferous scale and the integument, and a relatively reduced female cone (1–2 fertile bracts in all except *Stachycarpus*). It is the fusion between the ovuliferous scale and the integument of the ovule that alone distinguishes all members of the genus from all those of *Dacrydium*. While such fusion is most probably a specialization, a development of this kind could easily have occurred more than once. In fact, it appears to have occurred at least twice in the family, being found in a somewhat different form in *Acmopyle,* where it is associated with an erect ovule. Thus the retention of a genus defined by this character alone is hard to justify without strong supporting evidence.

It seems essential, therefore, that the present taxonomic boundaries of *Podocarpus* and *Dacrydium* should be critically evaluated in the light of more recent data drawn from the fields of cytology, embryology and anatomy.

Cytology

The karyotype of representatives of every genus and section in the family is now known (Hair, 1963). There is a range in chromosome number from $n = 9$ to $n = 20$ (Hair, pers. com.). Hair and Beuzenberg (1958) have established, however, that the number of major chromosome arms in the haploid complement is constant at 20 for all members of the family, with the notable exceptions of *Phyllocladus* (18), the *Dacrydium bidwillii* group of *Dacrydium* (16), and Subsections B and F of *Podocarpus* Section *Eupodocarpus* (19) (see Table 1). Many sections of *Podocarpus* show a high degree of uniformity in both the number and morphology of their chromosomes, which lends support to the groupings of these species made by Buchholz and Gray (1948). In *Dacrydium,* the karyotype has been established as $n = 10$, with 20 major arms, for all members of Sections A and B so far examined. There is wide variation in Section C, however, both in the number of chromosomes and major arms. This underlines the need for a revision of this section mentioned above.

While karyotype can be used to characterize several sections of *Podocarpus* and *Dacrydium* (see Hair, 1963), there are no features that set all members of either genus apart from the rest of the family. Indeed, the cytological differences between sections of the one genus are generally at least as great as those that separate the smaller genera of the family from one another.

Gametophytes and Embryogeny

Detailed accounts of gametophyte development and embryogeny are now available for representatives of every genus in the family except *Acmopyle,* and for five of the eight sections of *Podocarpus,* as well as four of the species groups in *Dacrydium* (see Table 2). In most cases these details are available for only a single species. In some instances, however, observations have been made on two or more species. In the large and rather diverse *Eupodocarpus* records are available for at least some stages in *Podocarpus macrophyllus, P. coriaceus, P. glomeratus, P. latifolius, P. purdeanus, P. urbanii* and *P. totara,* which are drawn from three different subsections (B, C and D). These observations have been critically reviewed by Doyle in his thorough account of *P. nivalis* (Boyle and Doyle, 1953, 1954; Doyle, 1954). Also limited observations have been made on the male and female gametophytes and embryos of *P. ferrugineus* and *P. spicatus* (*Stachycarpus*; Sinnott, 1913), the female gametophyte of *P. imbricatus* (*Dacrycarpus;* Gibbs, 1912), the embryo of *P. usumbarensis* (*Afrocarpus;* Buchholz, 1941), the male and female gametophytes of *Dacrydium biforme* (*D. bidwillii* group; Sahni and Mitra, 1927), and the female gametophyte and embryo of *Phyllocladus glaucus* (Holloway, 1937). In each instance a high degree of uniformity is apparent within the genus, section or species group.

TABLE 2

Summary of specialization in the life histories of members of the Podocarpaceae

P denotes primitiveness, *A* an advanced condition, and *I* an intermediate level of specialization in each character

PRIMITIVE CONDITION	PODOCARPUS Stachycarpus (*P. andinus*)	Afrocarpus (*P. falcatus*)	Nageia (*P. nagi*)	Dacrycarpus (*P. dacrydioides*)	Eupodocarpus (*P. nivalis*)	DACRYDIUM Section B (*D. cupressinum*)	Section C (*D. laxifolium*)	Section C (*D. colensoi*)	Section C (*D. bidwillii*)	SAXEGOTHAEA	PHYLLOCLADUS (*P. alpinus*)	MICROSTROBOS	MICROCACHRYS
Life cycle of two years	P	A	A	A	A	P	P	A	P	P	A	A	A
Prothallial nuclei many	P	I ?	I ?	P	I	I	P	I	I	I	A	A	A
Male gamete cells equal	I	A	?	A	A	?	I	I	I	P	A	A	I
Gynospore membrane thickened	P	P ?	?	A	P	P	P	A	P	P	P	A	P
Archegonia few (1–3)	P	A	A	I	A	P	P	P	P	P	P	I	I
Archegonia embedded	P	A	?	A	A	?	P	P	P	A	I ?	P	I
Archegonia long and narrow	P	A	?	I	A	I	P	P	I	P	I	A	A
Archegonia separate	P	A	P	I	P	P	P	P	P	P	P	I	A
Gametes grossly unequal	P	A	?	A	A	?	P	P	P	A	A	A	A
Embryogeny with five free mitoses	P	P	P	A	A	A	P	A	A	A	A	A	A
E cells many	P	I	P	I	A	I	P	P	P	P	P	I	I ?
E cells storied	P	A	A	A	A	I	P	P	P	P	P	I	I
Cap cells present	P	A	A	A	A	A	P	P	A	P	A	A	A
Cleavage absent	P	P	A	A	A	A	P	P	A	P	P	A	A

All species so far examined are characterized by a three-tiered proembryo with binucleate embryo initials. Furthermore, these initials always pass through a distinctive "embryo-tetrad" stage, as was first fully described by Looby and Doyle (1944). This pattern of embryogeny is unique to the Podocarpaceae, and its presence in all members investigated strongly supports the naturalness (phylogenetic unity) of the family.

Analysis of the data has led to the recognition of a primitive condition for the family in a number of features of the life cycle (Quinn, 1966*b*). The occurrence of these primitive conditions throughout the family was summarized in tabular form in the paper cited, and is reproduced here, with corrections and some modification, as Table 2. The point to be made is that each section of *Podocarpus* and *Dacrydium*, as well as each of the other four genera, appears to be characterized by a unique set of both primitive and advanced features, as would be expected if each represented the end of an independent line that has evolved from an ancestral stock common to the entire family. The variation that occurs in the number of embryo initials in the proembryo serves to illustrate the general pattern of evolution. It seems most probable that the primitive embryo possessed a large number of initials, and that there has been a tendency for reduction in their number. This tendency has been expressed to varying degrees in *Microstrobos, Microcachrys, Dacrydium* Section B and *Podocarpus* Sections *Dacrycarpus* and *Afrocarpus*, reaching its fullest expression in Section *Eupodocarpus*, where the number of initials is generally only one to three. In some cases this reduction in embryo initials has been accompanied by a reduction in the number of cells in the proembryo as a whole (e.g. *Eupodocarpus*) while in other cases it has not (e.g. *Afrocarpus*). Thus, there has been a tendency for the primitive condition to become modified in certain ways, and those modifications have occurred independently, and to varying degrees, during the evolution of several different groups. A similar situation exists in the cytological evolution of the family (Hair and Beuzenberg, 1958).

The five sections of *Podocarpus* which have been studied do not have a single derived feature in common (see Table 2). The same is true for *Dacrydium*, with the possible exception of the differentiation of the two male gamete nuclei. There is, therefore, no evidence to support the grouping of these species into *Podocarpus* and *Dacrydium* as currently defined. The level of difference in gametophyte and embryological characters between the various sections of each of these genera is no less significant than the differences that separate the remaining genera in the family. In fact, *Podocarpus* includes a greater range of variation in these features than is found in all the rest of the family (cf. *Stachycarpus* and *Eupodocarpus*). The evidence of gametophyte and embryological studies therefore suggests that each section of *Podocarpus* and each of the species groups in *Dacrydium* is sufficiently distinct from all the rest of the family to be treated as a separate genus.

Vegetative Anatomy

Buchholz and Gray (1948) in the introduction to their revision of *Podocarpus*, stated that there was no evidence of a closer relationship between any of the eight sections of the genus that would justify their grouping into subgenera. It was their opinion that the genus consisted of eight equivalent groups which might be either subgenera or sections. A most comprehensive survey of the vegetative anatomy of the entire family has recently been undertaken by Tengner (1965, 1967). His studies of both leaf and wood anatomy have already demonstrated the heterogeneous nature of both *Podocarpus* and *Dacrydium*.

CONCLUSIONS

On the evidence presented above it is clear that both *Podocarpus* and *Dacrydium* represent artificial assemblages. It seems desirable that all the sections of *Podocarpus* should be raised to generic rank in order to reflect accurately their affinities within the family. Tengner (1965) has already demonstrated the need to divide *Dacrydium* into at least two separate genera, one containing Sections A and B as defined by Florin (1931), and the other Section C. On the basis of cytology, cone morphology and embryology, however, a further division of this last group into at least three genera seems essential. The first of these genera would comprise *Dacrydium laxifolium* and *Dacrydium intermedium*. The second would comprise *D. bidwillii, D. biforme* and *D. kirkii*. Each of these proposed genera shows a remarkable degree of cytological and morphological uniformity.

The three remaining species, *D. colensoi, D. franklinii* and *D. fonkii* show some similarity in cone morphology. However, Tengner (1965) has shown that they differ in several aspects of vegetative anatomy. Thus, a conclusion as to whether these three species form a closely related group and so constitute a single genus must await the results of more detailed studies.

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References

BOYLE, P., and DOYLE, J., 1953.—Development in *Podocarpus nivalis* in relation to other podocarps. I Gametophytes and fertilization. *Scient. Proc. r. Dublin Soc.*, 26: 179–205

————, ————, 1954.—Development in *Podocarpus nivalis* in relation to other podocarps. II Embryogeny in *Eupodocarpus*. *Scient. Proc. r. Dublin Soc.*, 26: 289–312.

BUCHHOLZ, J. T., 1941.—Embryogeny in the Podocarpaceae. *Bot. Gaz.*, 103: 1–37.

————, and GRAY, NETTA E., 1948.—A taxonomic revision of *Podocarpus*. I. The sections of the genus and their subdivisions, with special reference to leaf anatomy. *J. Arnold Arboretum*, 29: 49–63.

DOYLE, J., 1954.—Development in *Podocarpus nivalis* in relation to other podocarps. III General conclusions. *Scient. Proc. r. Dublin Soc.*, 26: 347–377.

FLORIN, R., 1931.—Untersuchungen zur Stammesgeschichte der Coniferales und Cordaitales. I. Morphologie und Epidermisstruktur der Assimilationsorgane bei den rezenten Koniferen. *Svenska Vetensk-Akad.*, 10: 256–259.

————, 1951.—Evolution in Cordaites and Conifers. *Acta Horti Bergiana*, 15: 285–388.

GIBBS, L., 1912.—On the development of the female strobilus in *Podocarpus*. *Ann. Bot. (Lond.)*, 26: 515–572.

HAIR, J. B., 1963.—Cytogeographical relationships of the southern podocarps. "Pacific Basin Biogeography—Antarctica," pp. 401–414. Bishop Museum Press, Hawaii.

————, and BEUZENBERG, E. J., 1958.—Chromosomal evolution in the Podocarpaceae. *Nature*, 161: 1584–1586.

HOLLOWAY, J. T., 1937.—Ovule anatomy and development in *Phyllocladus alpinus* Hook. and in *P. glaucus* Carr. *Trans. roy. Soc. N.Z.*, 67: 149–165.

LOOBY, W. J., and DOYLE, J., 1944.—Fertilization and early embryogeny in *Podocarpus andinus*. *Scient. Proc. r. Dublin Soc.*, 23: 257–270.

QUINN, C. J., 1965.—Gametophyte development and embryogeny in the Podocarpaceae. II *Dacrydium laxifolium*. *Phytomorphology*, 15: 37–45.

————, 1966*a*.—Gametophyte development and embryogeny in the Podocarpaceae. III *Dacrydium bidwillii*. *Phytomorphology*, 16: 81–91.

————, 1966*b*.—Gametophyte development and embryogeny in the Podocarpaceae. IV *Dacrydium colensoi*: General conclusions. *Phytomorphology*, 16: 191–211.

SAHNI, B., and MITRA, A. K., 1927.—Notes on the taxonomy of some New Zealand species of *Dacrydium*. *Ann. Bot. (Lond.)*, 41: 75–89.

SINNOTT, E. W., 1913.—The morphology of the reproductive structures in the Podocarpineae. *Ann. Bot. (Lond.)*, 27: 39–82.

TENGNER, J., 1965.—*Dacrydium*—Anatomy and taxonomy. *Bot. Notiser*, 118: 450–452.

————, 1967.—Anatomy and taxonomy in the Podocarpaceae. *Bot. Notiser*, 120: 504–506.

THE FAMILY ANEURACEAE IN AUSTRALIA AND NEW GUINEA: I. THE GENUS *ANEURA*

H. J. Hewson
*School of Biological Sciences, University of Sydney**

(Plates XI–XII and 3 Text-figures)

[Read 30th July, 1969]

Synopsis

Seven new species and two new varieties of an eighth species are described. The separation of the genus *Aneura* Dum. from the genus *Riccardia* Gray *sens. lat.* is analysed. Some of the distinguishing features have been modified. An attempt is made to classify the eight species into the two subgenera *Aneura* Dum. and *Lobatiriccardia* Miz. et Hatt. Several of the diagnostic characters are shown to be ineffective. Keys are provided to the species studied which are found in Australia and in New Guinea.

Introduction

It is generally recognized in the Hepaticae that the basic haploid chromosome number in any given family is stable. The previous records for Aneuraceae indicate a stable basic haploid number of ten. However, a species from the family Aneuraceae, found near Sydney, was discovered to have a basic haploid number of eight. This seemed to provide an interesting problem. However, it rapidly became evident that the taxonomy of the family was very critical in Australia and New Guinea and required sorting out before the cytology could be interpreted.

The first species of the Aneuraceae to be described from Australia was *Riccardia crassa* (sub *Jungermannia*) by Schwägrichen in 1814. Linnaeus (1753) provided the first legitimate names of members of the family, namely the European *Jungermannia pinguis* L., and *J. multifida* L. However, since they are clearly not *Jungermanniae,* S. F. Gray (1821) provided the first available generic name for members of this family. He described the genus *Riccardius* with *R. multifidus, R. pinguis,* and *R. dichotomus.*

In 1869, Carrington proposed that *Riccardius* was an orthographic error but he did not publish the correct spelling. However, in 1874 Trevisan changed the spelling to *Riccardia. R. multifida* is accepted as the lectotype.

In 1961 in the International Code of Nomenclature, *Riccardia* Gray corr. Trevisan was conserved. Thus it would seem that there is no basis for *Riccardia* Gray corr. Trevisan being called a Nomen Rejiciendum in the Index Hepaticarum (Bonner, 1962).

In 1822, Dumortier described the genus *Aneura* with the species *A. multifida, A. pinguis, A. sinuata,* and *A. palmata.* Despite the fact that *Riccardia* has priority over *Aneura* the latter name has been used extensively for the combined genera. Stephani in his Species Hepaticarum used it and was responsible for the bulk of species descriptions for Australia and New Guinea.

In the following decades there were several other illegitimate taxonomic synonyms created (see Generic Description). There also were several attempts to subdivide the genus *Riccardia sens. lat.* (then commonly known as "*Aneura*").

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* Present address: Botany Dept., School of General Studies, A.N.U., Canberra, A.C.T

In 1831, Dumortier divided his genus *Aneura* (including *Riccardia*) into two sections:

1. *Phymatia* Dum. (*A. multifida* (L.) Dum. and *A. palmata* (Hedw.) Dum. *A. multifida* is herewith accepted as the lectotype of *Phymatia*).

2. *Aneurotypus* Dum. (*A. pinguis* (L.) Dum. which is herewith accepted as the lectotype species of *Aneura*).

In 1867, Gottsche divided the genus *Aneura* Dum. (including *Riccardia*) into two genera:

1. *Aneura* Dum. (*A. pinguis* (L.) Dum. and *A. palmata* (Hedw.) Dum.).

2. *Pseudoneura* Gottsche. (*P. multifida* (L.) Gottsche, *P. humilis* Gottsche and *P. pöeppigiana* Gottsche. *P. multifida* (L.) Gottsche is herewith accepted as the lectotype of *Pseudoneura*). But *Pseudoneura* is therefore a later taxonomic synonym of *Riccardia* Gray.

Schiffner in Engler and Prantl (1893) divided the genus *Riccardia* Gray *sens. lat.* into three sections:

1. *Spinella* Schiffner et Gottsche (*R. spinulifera* Mass. = *S. magellanica* Schiffner et Gottsche—holotype).

2. *Aneura* Dum. (*Phymatia* Dum. and *Aneurotypus* Dum.).

3. *Acrostolia* Dum. (*Pseudoneura* Gottsche. *Acrostolia* is superflous since *Pseudoneura* was given as a synonym in the original publication).

The holotype of section *Spinella* is *Riccardia magellanica* (Schiffner et Gottsche) which is characterized by unique epidermal projections. This section is not known to be represented in Australia and New Guinea and consequently is not considered in this treatment.

In 1933, Malmborg segregated the genus *Cryptothallus* from *Riccardia* Gray *sens. lat.* This is a characteristic subterranean plant and the genus is accepted. However it has not been found in Australia.

In 1957, Mizutani and Hattori divided the genus *Riccardia* Gray *sens. lat.* into three subgenera:

1. *Trichostylium* (Corda) Miz. et Hatt. (*R. pinguis* (L.) Gray—holotype).

2. *Lobatiriccardia* Miz. et Hatt. (*R. lobata* Schiffner—holotype).

3. *Riccardia* Gray (*R. multifida* (L.) Gray—holotype).

In 1958, Schuster combined the two subgenera *Trichostylium* and *Lobatiriccardia* to form a new genus *Trichostylium.* The type species of *Trichostylium* is also that of *Aneura* and it is therefore a taxonomic synonym of *Aneura* (Grolle, 1960).

In 1963, Schuster divided the genus *Riccardia sens. str.* into two subgenera:

1. *Riccardia* Gray (*R. multifida* (L.) Gray).

2. *Phycaneura* Schust. (*R. reducta* Schust.—holotype).

In 1964, Schuster described a third subgenus:

3. *Anomaneura* Schust. (*R. cochleata* (Hook.f. et Tayl.) Kuntze—holotype). The two new subgenera are based on Australian species. He also recognized the two subgenera of *Aneura* described by Mizutani and Hattori:

1. *Aneura* Dum. (*A. pinguis* (L.) Dum. = *Riccardia* Gray subgenus *Trichostylium* (Corda) Miz. et Hatt.).

2. *Lobatiriccardia* Miz. et Hatt. (*A. lobata* (Schiffn.) Steph. = *Riccardia* Gray subgenus *Lobatiriccardia* Miz. et Hatt.).

Meanwhile these taxa were included in the family Jungermanniaceae until 1910. In 1838, Nees ab Esenbeck attempted classification within the

Order Jungermanniales *sens. lat.* and circumscribed a Grade Aneurae with *Aneura pinguis, A. pinnatifida, A. multifida, A. palmata* and *Trichostylium affine.* It is questionable that he intended this to circumscribe the "natural order" or Family. It was not until 1910, when Cavers described it, that the family Aneuraceae, as we know it, was effectively named and circumscribed.

Since 1814 fifty species have been recorded as occurring in Australia and New Guinea. The initial problem was to decide whether these species included both *Riccardia sens. str.* and *Aneura,* and if so, whether the distinguishing characters supported or otherwise the decision to elevate *Aneura* to generic status.

In summary see Table 1 for the distinguishing characters.

TABLE 1

Characters of Riccardia *and* Aneura

Character	*Riccardia*		*Aneura*	
	Schuster	This Treatment	Schuster	This Treatment
1. Width of thallus ..	—	(0·05) 0·5–2 (4) mm.	—	(1·5) 2–6 (12) mm.
2. Branching	1–3 pinnate	(1) 2–4 pinnate	—	1–2 pinnate
3. Gemmae	Endogenous	Endogenous	Unknown	Unknown (? exog.)
4. Oil body number ..	0–1 few/cell	0–15 per cell	(3–5) 6–40+	1–40+/cell
5. Oil body size ..	Large	2 × 3–12 × 150μ	Small	1·5 × 2–15 × 20μ
6. ♀ branches ..	On lat. branch	Lat. vent.-lat.	Ventral	Rarely lat.
7. Seta	12–16+ 4 cells	4 cells diam.	Massive	8–16 cells diam.
8. Capsule wall anatomy	—	*Riccardia*-type	—	*Trichostylium* or *Lobatiriccardia*-type

Aneura has a thallus which is more massive but less freely branched than *Riccardia.* It probably does not produce endogenous gemmae and usually carries smaller oil bodies than *Riccardia.* It has a massive seta (Fig. 2) and a capsule wall anatomy different from that of *Riccardia.*

Thus, there are two discrete definable sporophyte characters (7 and 8) separating the taxa and a number of correlated (though not so clearly discrete) vegetative characters (1–6) which support these two sporophyte characters. Since the discrete characters are structural differences and will probably be supported by the rather negative character of production versus non-production of gemmae, I have accepted them and it seems reasonable to distinguish the two genera as separate.

THE SUBGENERIC CLASSIFICATION OF *Aneura*

The subgeneric classification of the genus *Aneura* Dum. into the two subgenera, *Aneura* and *Lobatiriccardia* is based on thallus size, oil bodies, seta size, capsule wall anatomy and spore size.

In this work I have treated eight species, seven of which are new. There are two new varieties for the eighth species which also occurs in New Zealand. Using these species an attempt has been made to classify them into the subgenera as circumscribed by Mizutani and Hattori (1957) (see Table 2).

The result is that some of the distinctions appear inadequate. The Australian and New Guinea species include intermediates which overlap the classes. Hence, thallus size, seta diameter and spore size are ineffective diagnostic characters. On the other hand the classes for oil body size and

Table 2

Subgeneric Classification after Mizutani and Hattori (1957)

Subgenera and Species	Thallus Size			Oil Bodies		Seta	Capsule Wall Anatomy		Spores	
	Length cm.	Width mm.	Thickness Cells	Number per Cell	Size μ	Diameter Cells	Outer	Inner	Diameter μ	Ornamentation
Aneura										
Trichostylium (A)	—	5–10	10–15	10–40+	1·5×2·5–3×5	8–12	ad and abaxial	ad and abaxial often both	20–25	—
Lobatiriccardia (L)	—	3–6 (7)	+/− thinner	(3–5) 6–12	5–6×7·5 to 8–15×10–20	12+	adaxial	both (ad) and abaxial (i)	12–19	—
A. eachamensis ..	1–3	(1·5) 2–3 (5) L	(7) 9–10 (12) L	?	?	8 A	ad and abaxial A	ad and abaxial A	14–22 between	minutely sculptured-pilate
A. cerebrata ..	1–2 (3)	(1·5) 2–5 (10) between	15–20 (30) A	20–30 A	2×3–5×8 A	10 A	ad and abaxial A	ad and abaxial A	10–17 L	projections-papillate
A. alterniloba var. *gigantea*	(2) 3–6 (8)	(2) 4–6 (8) L	(5) 7–10 (12) L	(1) 2–5 (8) L	5×8–15×20 L	12–15 L	adaxial L	ad and (abaxial) (iii) L	14–19 L	minutely sculptured-scabrate
A. alterniloba var. *robusta*	(2) 3–5 (6)	(2) 3–6 (10) between	(6) 8–12 (15) between	1–3 L	3×3–8×15 L	11–14 between	adaxial L	ad and (abaxial) (iii) L	17–21 between	minutely sculptured-scabrate
A. athertonensis ..	2–3 (5)	2–4 L	(7) 8–10 (12) L	1–4 L	8×15–10×18 L	11–12 A	adaxial L	ad and (abaxial) (iii) L	10–15 L	minutely sculptured-scabrate
A. rodwayi ..	(1) 2–3 (4)	(2) 3–5 (10) between	10–20 (25) A	?	?	13–15 L	?	?	?	?
A. novaguineensis	(1) 2–4 (5)	(1·5) 3–5 (12) between	(7) 10–15 (20) A	?	?	16 L	?	?	?	?
A. giangena ..	2–3	2–6 L	8–12 between	?	?	?	?	?	?	?
A. kaguaensis ..	1–3	3–4 L	7–10 L	?	?	?	?	?	?	?

number, and capsule wall anatomy are discrete. If one accepts these characters as being adequate to retain the subgeneric classification, then *A. cachamensis* and *A. cerebrata* are in the subgenus *Aneura,* and *A. alterniloba* and *A. athertonensis* are in the subgenus *Lobatiriccardia*. The last four species, *A. rodwayi, A. novaguineensis, A. giangena,* and *A. kaguaensis,* cannot be classified for want of study of their oil bodies and capsule wall anatomy.

If, however, one does not accept these characters as adequate to retain subgeneric classification, further attempts to erect subgeneric taxa should wait until a complete generic monograph is available.

General Analysis and Definitions of Terms used in Classification and Description

Thallus: The external morphology of the gametophyte of *Aneura* was found to be very variable within and between localities, and within and between seasons. The range of variation within and the degree of overlap between species is sufficient to render the gametophyte of very little taxonomic value.

(i) Texture and Colour: All species have a waxy texture. The colour, however, is variable in intensity of green and this seems to be correlated with habitat, substrate and age.

(ii) Size: The thalli of all species are massive and fleshy and the classes for width and thickness as circumscribed by Mizutani and Hattori are overlapped by several species (Table 2).

(iii) Transverse Section Shape: All species are plano-convex to concavo-convex with recurved margins. However, *A. cerebrata* and *A. rodwayi* are usually very deeply concave so that the margins have a vertical orientation (Fig. 1).

(iv) Margin: The margins may be obtuse, acute or winged (see Part II). They may also be uniform or dentate. Dentition is the tendency for the margin to produce scalelike or toothlike projections. This is not found in all species, but where it is found is much more pronounced in female thalli.

(v) Apex, Mucilage papillae and Rhizoids: The apices are usually deeply dissected as a result of rapid lateral growth immediately behind the apex. *A. kaguaensis,* however, does not have a markedly dissected apex because growth is almost uniform behind and lateral to the apex.

All have ventral, non-persistent mucilage papillae, and all have ventral rhizoids. No dorsal rhizoids were observed in this genus.

(vi) Branching: All species have at least two types of branching. The first type is simply an irregular pinnate branching arising from an apparent dichotomy of the apical cell; this does not result in limited growth. The second type is usually the formation of regular alternate lobes of limited growth (i.e. bipinnate).

The most distinctive phenomenon observed in branching is that shown in *A. kaguaensis.* In this species, the second type (lobing) does not always remain limited in growth. Some of these produce upright cylindrical branches which are gemmiferous. The possibility that these are a result of etiolation is discounted since some of these branches revert to the prostrate broad growth form. There was no evidence of change in habitat which would induce this growth.

Gemmae: Asexual reproduction by means of gemmae occurs within the family Aneuraceae. However, the ability to produce gemmae seemed to be restricted to the genus *Riccardia.* These gemmae are two-celled elements produced endogenously in the epidermal cells of the thallus, usually in the region of the apex. The apparent absence of gemma production in the genus

Aneura has led workers to suggest that this character may be important taxonomically (Schuster, 1964). But since the production of gemmae has a limited duration in most species, it would seem that its importance as a taxonomic character is limited to classification on a negative basis. It can only be positive in identification when present.

However, gemma production has been observed in *A. kaguaensis*. These gemmae are not like the characteristic *Riccardia* gemmae, being multicellular exogenous elements, produced on stalks in the growing region of the narrow upright cylindrical branches peculiar to this species (Plate XI). The initial development is by transverse divisions followed by longitudinal divisions resulting in a club shaped element on a stalk cell. Each element is composed of 7–10 cells (Fig. 1).

Consequently, this observation lends support to the view that organs of asexual reproduction may be important taxonomically. More light may be thrown on the subject if gemma production could be induced experimentally in other species of the genus *Aneura*.

Oil Bodies: The use of oil bodies as an aid to identification and classification is being recommended by recent workers dealing with the family Aneuraceae (Mizutani and Hattori, 1957; Schuster, 1958, 1963, 1964). It is regrettable that it should be necessary to go to such extremes to find a positive character because the oil bodies can only be studied in fresh material. However, since the gametophyte provides such variable characters a thorough description of the oil bodies in a complete generic monograph may be valuable, especially in identification.

The oil bodies of only three species have been studied here (Fig. 1). Although these observations broaden the class value for the subgenus *Lobatiriccardia*, the two classes remain discrete. Hence, *A. cerebrata* fits the subgenus *Aneura*, and *A. alterniloba* var. *gigantea* and *A. athertonensis* fit the subgenus *Lobatiriccardia*.

Mycorrhizae: by extending the definition of the word mycorrhiza to include endothrophic associations with absorbing organs other than roots, we can say the the association observed in some members of the Family Aneuraceae is a mycorrhiza. Accepting this, then the classical example of a mycorrhiza in the Family is provided by *Cryptothallus*. Even so a mycorrhiza was described by Denis (1919) in chlorophyll-free saprophytic varities of *A. pinguis* some fourteen years prior to the description of *Cryptothallus mirabilis* by Malmborg (1933).

Mycorrhizae have been observed in six of the eight species studied. These mycorrhizae are of the orchid type as are those previously described for the Family. They are septate, form complex hyphal coils in the cells and are ultimately digested. They appear to enter through the rhizoids and infect the ventral internal cells leaving the epidermal cells uninfected. The hyphae pass through the cell walls and constrict when they do so (Plate XI). The extent of infection is usually limited to a region immediately dorsal to the region bearing rhizoids (Fig. 1).

The range in size of the hyphae is from the extremely fine 1–2μ in *A. rodwayi* to the more massive 4–5μ in *A. alterniloba*.

It is interesting to note that at least two species appear to be evolving towards the chlorophyll-free saprophytic condition of the subterranean *Cryptothallus*. They are *A. rodwayi* from Tasmania and *A. cerebrata* from New Guinea. Both are pale green, though still with chlorophyll, and both tend to be very deeply concave and sunken in their substrate. It is obvious that there is a tendency towards saprophytism and it would seem probable that more subterranean species will be discovered.

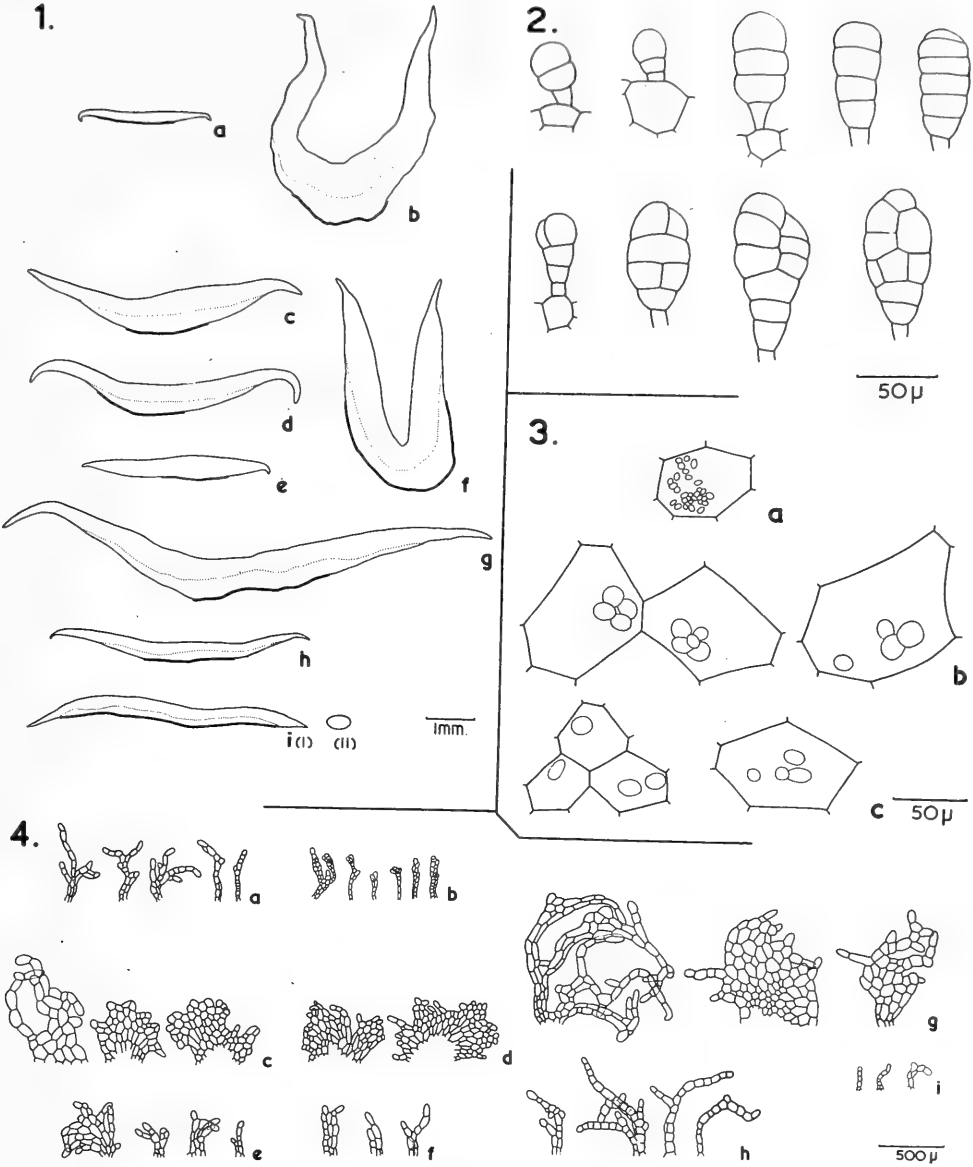

Fig. 1. 1. Transverse sections of the thallus. Mycorrhizae ventral beneath the dotted line and rhizoids in the region of the thick line. a. *Aneura eachamensis;* b. *Aneura cerebrata;* c. *Aneura alterniloba* var *gigantea*; d. *Aneura alterniloba* var *robusta;* e. *Aneura athertonesis;* f. *Aneura rodwayi;* g. *Aneura novaguineensis;* h. *Aneura giangena;* i. *Aneura kaguaensis*, (I) transverse section of prostrate thallus, (ii) transverse section or upright thallus branches.

2. Stages of development of multicellular exogenous gemmae of *Aneura kaguaensis.*

3. Oil bodies. a. *Aneura cerebrata,* in surface view; b. *Aneura alterniloba* var *gigantea,* insurface view (left), in transverse section (right); c. *Aneura athertonensis,* in surface view.

4. Pharaphyese. a. *Aneura eachamensis;* b. *Aneura cerebrata;* c. *Aneura alterniloba* var *gigantea;* d. *Aneura alterniloba* var *robusta;* e. *Aneura athertonensis;* f. *Aneura rodwayi;* g. *Aneura novaguineensis;* h. *Aneura giagena;* i. *Aneura kaguaensis.*

Sexual Reproduction: (i) Oecy—distribution of gametangia: All species examined are dioecious.

(ii) Male branches: When compared with *Riccardia*, the *Aneura* male branches are very irregular. There seems to be a tendency towards degeneration of the organization of this branch. Firstly, *A. alterniloba* and *A. athertonensis* are the only two species retaining the regular two row orientation of the antheridia. The remainder of the species bear their antheridia in irregular groups. Secondly, in *A. kaguaensis* the branch is so reduced that it appears to be lost. The antheridia are borne on the margin of the thallus or at the base of the upright cylindrical branches. Thirdly, in *A. novaguineensis* the antheridia are scarcely sunken in an antheridial chamber, but appear to be borne almost superficially. This is a result of very limited upward growth of the vegetative tissue of the branch between the antheridia.

(iii) Female branches: The female fertile regions of the thalli are lateral beneath the notch of the lobe branches. The archegonia are protected by (*a*) overtopping of the vegetative tissue of the branch, (*b*) lateral extension of the margin of the thallus and (*c*) a variety of multicellular hairs and scales. These I am calling paraphyses because some of them actually occur between the archegonia as well as around them.

The paraphyses are essentially highly modified scales (Fig. 1). They can be divided into two groups. (*a*) Hairlike scales being 1–3 cells broad at the base. (*b*) True scales being more than 3 cells broad at the base. The hairlike scales may be (1) simple with little or no branching, (2) fimbriate, (3) flat and scalelike without fimbriation, or (4) club-shaped terminally. The true scales may be (1) dentate, or (2) fimbriate.

Calyptra: (i) Size and thickness of calyptra: The *Aneura* calyptra is usually massive when compared with the *Riccardia* calyptra. It is rarely less than 3 mm. long at maturity. However the calyptra wall is not always a massive fleshy structure. The thickness in terms of number of cells seems to be a positive character for each species. Hence the calyptra wall of *A. eachamensis* (3–4 cells) is quite delicate.

(ii) Calyptra armation: In their treatment of the Japanese *Riccardiae*, Mizutani and Hattori (1957) classify the calyptra armation into two types, the *Trichostylium*-type, and the *Riccardia*-type. The genus *Aneura* has the *Trichostylium*-type, having rhizoid-like cilia and tubercles (scaly outgrowths). However these are absent in some species. *A. eachamensis* has a smooth calyptra; *A. alterniloba* var. *robusta* has a range of variation which includes some smooth calyptrae; and *A. rodwayi* has a smooth calyptra, however in the latter species only one capsule from an herbarium specimen was examined. Hence this observation needs to be checked in the field.

Sporophyte: (i) Seta: Mizutani and Hattori (1957) use seta diameter as one of the characters separating the two subgenera. The observations here show that the distinction is not clear-cut. Accepting 12 cells in diameter as the point of difference between the two subgenera, then clearly *A. athertonensis* falls across the two classes (Fig. 2.) Putting the level down to eleven cells in diameter would be equally unsatisfactory because *A. pellioides,* which is clearly in the subgenus *Aneura* on oil body and capsule wall characters, now would be in the subgenus *Lobatiriccardia*. An attempt to solve this has been made by noting the number of cells in the circumference. Hence the classes would be subgenus *Aneura* (35–55 cells) and *Lobatiriccardia* ((50) 55–60 cells). But *A. athertonensis,* which is clearly in the subgenus

Lobatiriccardia on oil body and capsule wall characters, would have to be classified in subgenus *Aneura* on this basis. Consequently it would seem that seta size is unsatisfactory in the delimitation of the subgenera as circumscribed by Mizutani and Hattori.

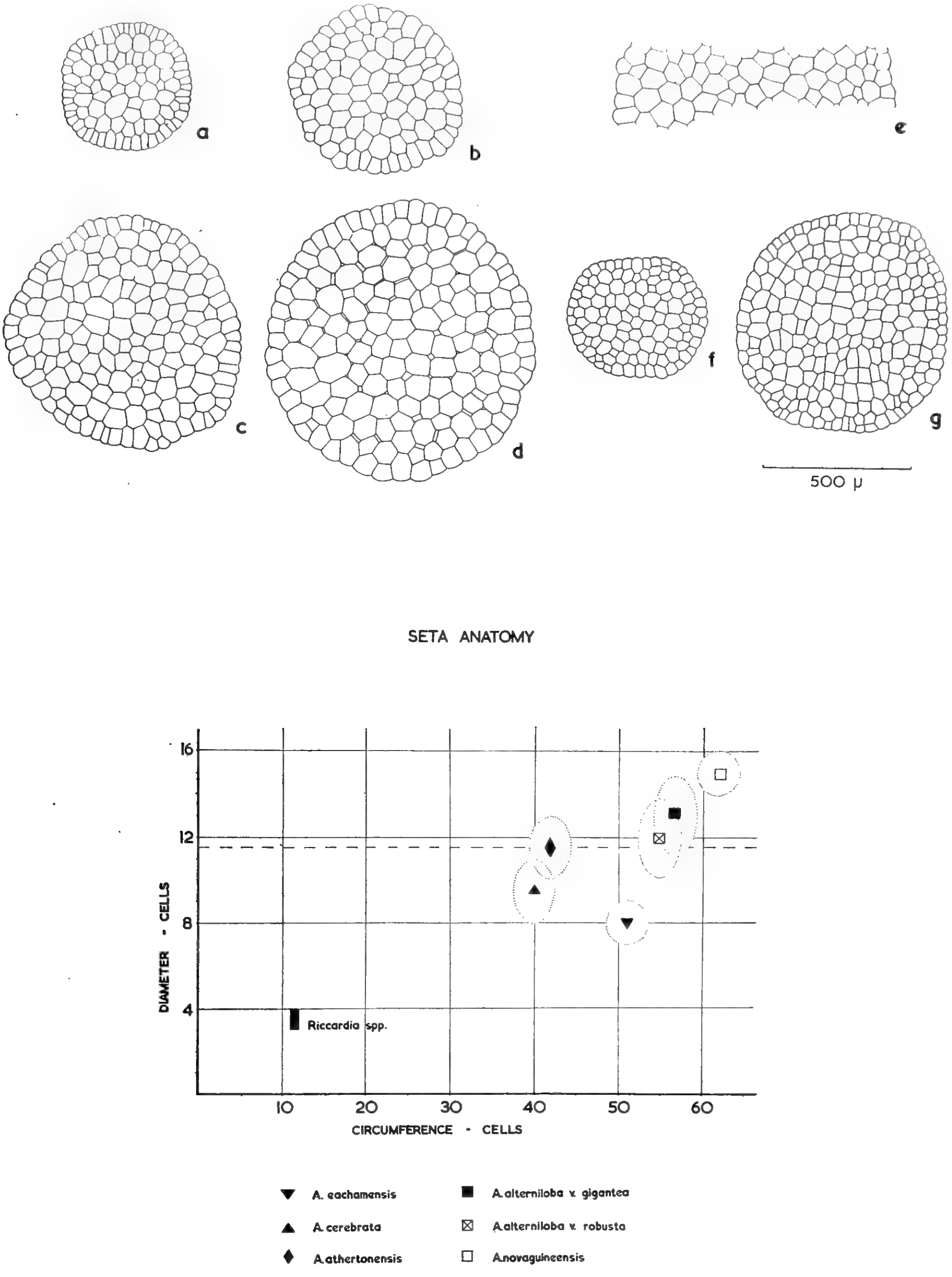

Fig. 2. Transverse sections of Setae of: a. *A. eachamensis*, b. *A. cerebrata*, c. *A. alterniloba* var *gigantea*, d. *A. alterniloba* var *robusta*, e. *A. rodwayi*, f. *A. athertonensis*, g. *A. novaguineensis;* and an analysis of Seta Anatomy for interpretation of subgenera.

(ii) Capsule wall anatomy: Evans (1937) studied the distribution of thickenings in the walls of the capsule wall cells of six species. He found two types. Mizutani and Hattori (1957) applied this study to the Japanese *Riccardiae sens. lat.* Evans' first type, which is found in the genus *Riccardia sens. str.*, they called *Riccardia*-type. Evans' second type, which is found in the genus *Aneura*, they called *Trichostylium*-type (Fig. 3). This has bands of thickenings on both adaxial and abaxial radial walls of the outer cell layer, and on the inner tangential and adaxial and abaxial radial walls (U-shaped) of the inner cell layer. This type is found in the subgenus *Aneura* (Plate XII).

They found a third type which is also found in the genus *Aneura*. This they called the *Lobatiriccardia*-type. Schuster (1964) described a variation of this and a third variation is described here.

(*a*) "Mizutani". This has bands of thickenings on the adaxial radial walls of the outer cell layer, and on the inner tangential and abaxial radial walls (L-shaped) and often on the adaxial radial walls (U-shaped) of the inner cell layer.

(*b*) "Schuster". This has the bands of the inner cell layer on the inner tangential and both the adaxial and abaxial radial walls (U-shaped).

(*c*) "Australia". This has the bands of the inner cell layer on the inner tangential and adaxial radial walls (L-shaped), and often on the abaxial radial walls (U-shaped).

These three variations are found in the subgenus *Lobatiriccardia* (Plate XII).

(iii) Spores: (*a*) Ornamentation: Spore wall ornamentation in the Bryophyta is now being described using palynological terminology (Erdtman, 1957). *Cryptothallus* spores have an areolate sexine pattern on the spore wall. This term was first used by Jackson (Kremp, 1965) and means divided into areas (areolae) separated by small grooves. However, the sexine pattern of the *Aneura* and *Riccardia* spore wall has been described as papillose or asperulate by Schuster (1964). The term asperulate does not appear to be in use in palynology. However, my interpretation of the term papillose is a pattern with projections or elevations which are small and narrow.

If we follow Harris's definition of papillate (see Kremp, 1965), then the "papilla" must not be less than 1μ in height. Moveover it is a projection and irrespective of height (above 1μ), must be less than twice as long as wide as seen in surface view. A papillate projection is a narrow one. Elevations have a length more than twice the width as seen in surface view.

On these definitions I have observed only one species which has projections. This is *A. cerebrata* (Plate XI). It has a pattern which ranges up to 1·5μ in height and is narrow. Hence it is papillate (= baculate). Occasionally some of these papillae appear to fuse to form elevations. The other species have "projections" which are less than 1μ in height. This is minutely sculptured (Harris, see Kremp, 1965) and they are scabrate, the pattern being flecked with minute "projections". However, in *A. eachamensis* these "projections" are slightly larger and pilate. They have a terminal thickening.

(*b*) Size: Mizutani and Hattori (1957) use spore diameter as one of the characters separating the two subgenera. The subgenus *Trichostylium* has spores 20–25μ in diameter, while the subgenus *Lobatiriccardia* has spores 12–16μ in diameter. Schuster (1964) supports this but extends the range for the subgenus *Lobatiriccardia* to 12–19μ in diameter. But some of the

Australian species form intermediates between the two classes and hence this character is inadequate as a basis for subgeneric classification as circumscribed by Mizutani and Hattori.

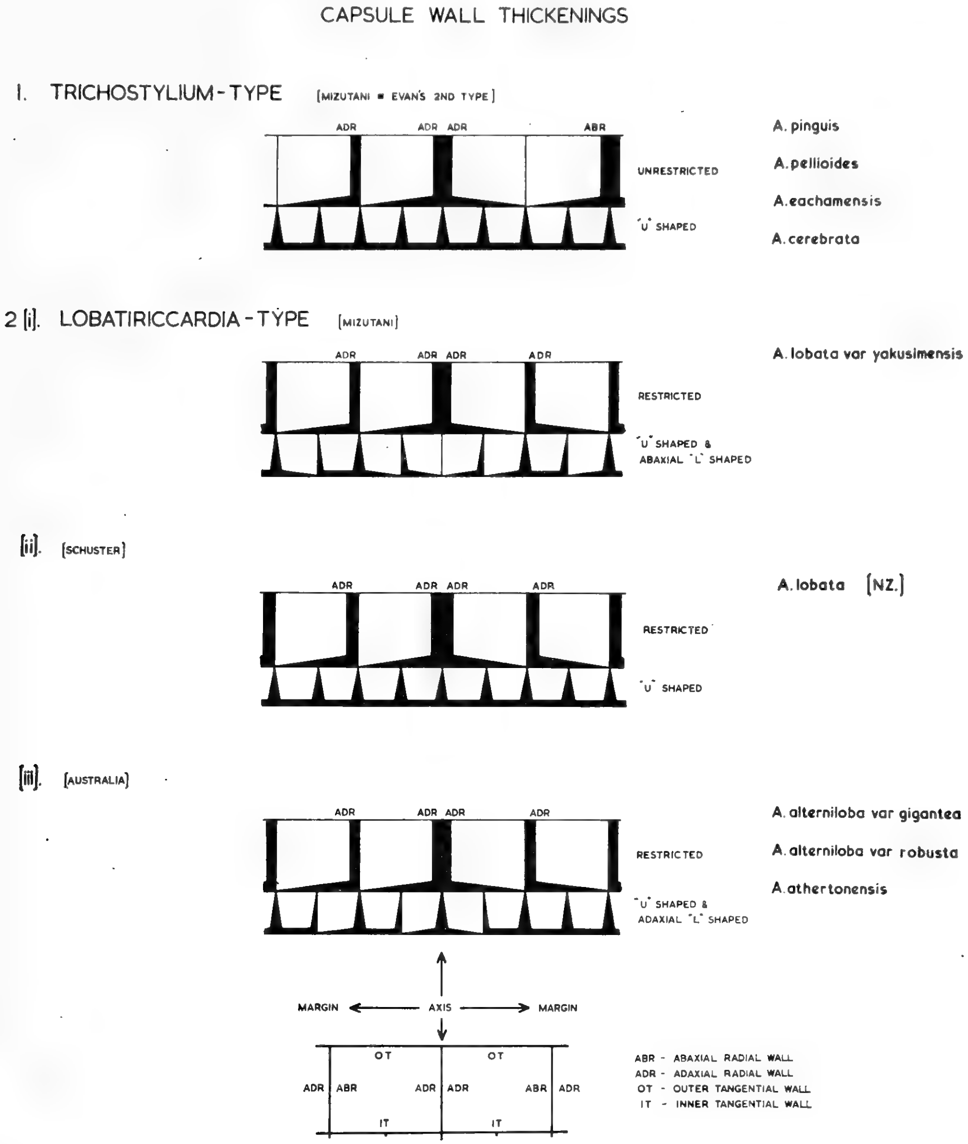

Fig. 3. Capsule wall thickenings.

Chromosomes: Counts have been made on four species. Ten was found to be the haploid number of *A. eachamensis, A. cerebrata* and *A. novaguineensis.* However *A. alterniloba* var. *gigantea* was found to have eight. There was no evidence of polyploidy in this genus. The cytology is to be dealt with in Part III of this treatment.

Distribution: The distribution is to be discussed in Part III of this treatment.

Generic Description

Aneura Dumortier, Commentationes Botanicae, 115, (1822).

Nomenclatural synonym: *Trichostylium* Corda, in Sturm, Deutschlands Flora, 2.5.6: 116, 119 (1835).

Taxonomic synonym: *Jungermannia* Linnaeus, Sp. Pl., 2: 1136 (1753) pp., excl. lectotype.

Dioecious. Plants prostrate in damp to wet habitat on rock, soil, or wood. *Thalli* waxy, yellowish to dark green, 1–8 cm. long, (1·5) 2–6 (10) mm. wide, with (rarely obtuse) acute to winged margins, ± dentate, plano- to concavo-convex (with recurved margins) to deeply concave in transverse section, (5) 7–20 (30) cells thick; branching pinnate with bipinnate lobes (rarely tripinnate lobes); apices deeply dissected; mucilage papillae ventral, non-persistent; rhizoids ventral; cuticle smooth. *Gemmae* multicellular exogenous, known in one species only. *Mycorrhizae* usually present in ventral internal cells. *Oil bodies* (fine) granular botryoidal, (1) 3–40 (70) per cell, 1·5 × 2·5–15 × 20μ. *Male plants* with lateral male branches; antheridia arranged regularly in two rows or irregularly, up to 15 antheridia per row; dorso-lateral wing up to 6 cells wide. *Female plants* with latero-ventral female branches, produced beneath lobes with thallus margin often dentate and overtopping; paraphyses hairlike to scalelike, arranged around or both around and between the archegonia. *Calyptra* massive, (2) 3–5 (10) mm. long at maturity, (3) 5–12 (15) cells thick; pachydermal ornamentation smooth or tuberculate, and/or ciliate (up to 500μ long). *Seta* 8–17 cells in diameter. *Capsule wall thickenings* of the *Trichostylium*-type, or the *Lobatiriccardia*-type. *Spores* 10–25μ in diameter, minutely sculptured with scabrate or pilate "projections", or papillate projections. *Haploid chromosome number* ten, except for *A. alterniloba* var. *gigantea* which has eight.

Typification: *Aneura* Dumortier—Lectotype—*Aneura pinguis* (L.) Dumortier (*Jungermannia pinguis* Linnaeus).

Species Descriptions

1. *Aneura eachamensis* Hewson, sp. nov.

Dioica. Thallus magnus, 1–3 cm. longus, (1·5) 2–3 (5) mm. latus, plano-convexus, (7) 9–10 (12) cellulis crassitie, margine acuto, plus minusve alato dentatoque; ramificatio irregularis, lobata. *Rami plantarum masculinarum* laterales, antheridiis in seriebus 2–4 irregularibus ordinatis, alis 1–2 (3) cellulis latitudine. *Plantae femineae* squamis pilisque multicellularibus archegonia cingentibus. *Calyptra* (2) 3 (5) mm. longis, laevis, 3–4 cellulis crassitie. *Seta* 8 cellulis diametro. *Paries capsulae* eo *Trichostylii* similis. *Sporae* 14–22μ crassae. *Chromosomata gametophytica* 10.

Dioecious. Plants prostrate on basalt rock in rain-forest. *Thalli* 1–3 cm. long, (1·5) 2–3 (5) mm. wide, with an acute ± winged margin, dentate especially in female plants, plano-convex usually with recurved margins in transverse section, (7) 9-10 (12) cells thick; branching of two types, pinnate with bipinnate lobes; apex deeply dissected and protected by ventral, non-persistent mucilage papillae; rhizoids ventral; cuticle smooth. *Gemmae* not observed. *Mycorrhizal association* not observed. *Oil bodies* unknown. *Male plants* bearing lateral antheridial branches, (1) 2–3 (5) together; antheridia in 2–4 irregular rows, up to 12 per row; dorso-lateral wing 1–2 (3) cells wide, irregular. *Female plants* bearing archegonia laterally beneath lobes; lateral margin of the thallus dentate and usually overtopping the archegonia; archegonia surrounded by multi-cellular, fimbriate, scalelike paraphyses. *Calyptra* (2) 3 (5) mm. long at maturity; smooth (in Hewson 401 a few capsules had slightly raised epidermal cells near the apex); not massive, 3–4 cells thick. *Seta* 8 cells in diameter. *Capsule wall anatomy* of *Trichostylium*-type. *Spores* 14–22μ in diameter, minutely sculptured, pilate. *Chromosome number*: n = 10.

Typification: *Aneura eachamensis* — Holotype — Vision Falls, Lake Eacham, Atherton Tableland, on basalt rock in rain-forest, Queensland, Hewson, 398, 8.1964, (NSW): Isotype (BRI).

Specimens examined: Vision Falls, Lake Eacham, Queensland, Hewson, 396, 401, 8.1964, (SYD.BRI).

Distribution: This species has a North Queensland distribution. It was not found on Mt. Spec, the Eungella Mtns., or the Bunya Mtns. It is possible that it extends further up the Cape York Peninsula and even as far as New Guinea.

Discussion: On the basis of capsule wall anatomy this species would be placed in the subgenus *Aneura,* as circumscribed by Mizutani and Hattori. It is the only species recorded for Australia found to be in this subgenus, and has no very close affinities with the other species.

2. *Aneura cerebrata* Hewson, sp. nov.

Dioica. *Thallus* magnus, 1–2 (3) cm. longus, (1·5) 2–5 (10) mm. latus, crispus, fragilis, valde concavus 15–20 (30) cellulis crassitie, margine acuto; ramificatio irregularis, lobata. *Corpora oleosa* 20–30 in quaque cellula, 2 × 3–5 × 8μ. *Rami plantarum masculinarum* laterales, antheridiis in seriebus 3–4 irregularibus ordinatis, alis 1–2 cellulis latitudine. *Plantae femineae* pilis multicellularibus, claviformibus circum interque archegonia. *Calyptra* 5 mm. longis, tuberculata, 9–10 cellulis crassitie. *Seta* 10 cellulis diametro. *Paries capsulae* eo *Trichostylii* similis. *Sporae* 10–17μ crassae. *Chromosomata gametophytica* 10.

Dioecious. *Plants* on damp soil in dense crisp patches often appearing like a pale green brain coral. Thalli 1–2 (3) cm. long, (1·5) 2–5 (10) mm. wide, with a sub-acute to acute margin (not winged or dentate), very deeply concave, with the margins presented dorsally and closely appressed to neighbouring thalli, 15–20 (30) cells thick; branching of two types, pinnate with bipinnate lobes; apex deeply dissected and protected by ventral, non-persistent mucilage papillae; rhizoids ventral; cuticle smooth. *Gemmae* not observed. *Mycorrhizae* in ventral internal cells, hyphae 2–3μ wide. *Oil bodies* 20–30 per cell, 2 × 3–5 × 8μ in diameter. *Chloroplasts* tend to be densely concentrated in upper region of thallus, and especially in the more exposed epidermal cells. *Male plants* bearing lateral antheridial branches, 1–3 together; antheridia in 3–4 irregular rows, up to 10 per row; dorso-lateral wing 0–2 cells wide. *Female plants* bearing archegonia laterally beneath the lobes, but presented dorsally as a result of the extreme concavity of the thallus; multicellular, club-shaped, hairlike paraphyses around and between the archegonia. *Calyptra* up to 5 mm. long at maturity, 9–10 cells thick, tuberculate at the apex. *Seta* 10 cells in diameter. *Capsule wall anatomy* of the *Trichostylium*-type. *Spores* 10–17μ in diameter, papillate. *Chromosome number*: n = 10.

Typification: Aneura cerebrata—Holotype—Chimbu River, Gembogl, 2,100 m., on granite soil on river bank, Chimbu District, New Guinea, Hewson, 577, 8.1965, (NSW): Isotype (LAE.L).

Specimens examined: New Guinea: Murigl River, Omkali, 1,370 m., Chimbu District, Hewson, 564, 7.1965, (NSW.LAE.L); Pengage Creek, Mt. Wilhelm, 2,590 m., Chimbu District, Hewson, 581, 8.1965, (NSW.LAE.L);

Lake Pinde, Mt. Wilhelm, 3,650 m., Chimbu District, Hewson, 612, 618, 8.1965, (NSW.LAE.L); Lake Aunde, Mt. Wilhelm, 3,500 m., Chimbu District, Hewson, 627, 8.1965, (NSW.LAE.L); near Brass Tarn, Mt. Wilhelm, 3,650 m., Chimbu District, Hewson, 646, 8.1965, (NSW.LAE.L).

Distribution: New Guinea.

Discussion: On the basis of capsule wall anatomy and oil body characters this species would be placed in the subgenus *Aneura* as circumscribed by Mizutani and Hattori. It has no close affinities with other species of *Aneura* described for New Guinea.

3. *Aneura alterniloba* (Hook.f. et Tayl.) Tayl., in Gottsche, Lindenberg, and Nees, Syn. Hep., 496 (1846); J. D. Hooker, Handbook of the New Zealand Flora, 543 (1867); Stephani, Sp. Hep., 1: 270 (1899); Rodway in Pap. & Proc. Roy. Soc. of Tas., 1916: 62 (1917); Schuster in J. Hatt. Bot. Lab., 26: 295 (1963).

Nomenclatural synonyms: *Jungermannia alterniloba* Hook.f. et Tayl., in Lond. J. Bot., 3: 572 (1844).

Sarcomitrium alternilobum (Hook.f. et Tayl.) Mitt., in J. D. Hooker, The Botany of the Antarctic Voyage, Flora Novae Zelandiae, 2, 2: 167 (1855), et loc. cit., Flora Tasmaniae, 3, 2: 239 (1860); Bastow in Pap. & Proc. Roy Soc. of Tas., 1887: 275 (1888).

Riccardia alterniloba (Hook.f. et Tayl.) Trevis., in R. Ist. Lomb. Sci. Lett. Rend., 431 (1877).

Taxonomic synonym: *Aneura epibrya* Col., in Trans. Proc. N.Z. Inst., 18: 253 (1886); Stephani in J. Linn. Soc. Lond., 29: 273 (1892); synonymy proposed by Stephani in Sp. Hep., 1: 270 (1899).

Misapplied name: *Aneura pinguis* (non (L.) Dum.) ∝ *lobulata, major* Gottsche, in Beitrage zur Pflanzenkunde, 28: 560 (1856).

Dioecious. *Plants* grow prostrate on rock, or soil in damp to wet conditions, often in spray of water-falls, or in running water. *Thalli* (2) 3–6 (8) cm. long, (2) 3–6 (10) mm. wide, with acute ± dentate margin, usually dentate in female plants, plano- to concavo-convex with slightly to very recurved margins in transverse section, (5) 7–12 (15) cells thick; branching of two types, pinnate with bipinnate lobes which tend to be opposite; apex deeply dissected and protected by ventral, non-persistent mucilage papillae; rhizoids ventral; cuticle smooth. *Gemmae* not observed. *Mycorrhizae* in ventral internal cells, hyphae 4–5μ in diameter. *Oil bodies* (1) 2–5 (8) per cell, 3×3–$15 \times 20\mu$. *Male plants* bearing lateral antheridial branches, 1–3 (4) together; antheridia in 2 regular, or 2–3 irregular rows, up to 12 per row; dorso-lateral wing 2–3 cells wide. *Female plants* bearing archegonia laterally beneath lobes; lateral margin of the thallus dentate, and overtopping the archegonia; archegonia surrounded by multicellular, fimbriate, scalelike paraphyses. *Calyptra* massive, (3) 5–8 (10) mm. long, 5–12 cells thick, smooth to tuberculate or tuberculate and ciliate. *Seta* 11–15 cells in diameter. *Capsule wall anatomy* of the *Lobatiriccardia*-type (2. (iii).). *Spores* 14–21μ in diameter, minutely sculptured, scabrate. *Chromosome number*: $n = 8$ in the New South Wales representatives.

Distribution: New Zealand, New South Wales, Victoria, and Tasmania.

Discussion: On the basis of capsule wall anatomy and oil body characters this species would be placed in the subgenus *Lobatiriccardia* as circumscribed by Mizutani and Hattori.

Aneura alterniloba (Hook.f. et Tayl.) Tayl. var. *alterniloba* (Hook.f. et Tayl.) comb. nov. occurs in New Zealand.

Aneura alterniloba (Hook.f. et Tayl.) Tayl. var. *gigantea* (Stephani), comb. nov.

Nomenclatural synonym: *Aneura gigantea* Stephani, in J. Proc. Roy. Soc. NSW, 48: 95 (1914).

Misapplied name: *Aneura dentata* (non Steph.), Rodway in Pap. & Proc. Roy. Soc. of Tas., 1916: 63 (1917).

Thalli (2) 3–6 (8) cm. long, (2) 4–6 (8) mm. wide, (5) 7–10 (12) cells thick. *Oil bodies* (1) 2–5 (8) per cell, 5 × 8–15 × 20μ. *Male branches* with antheridia in 2–3 irregular rows. *Calyptra* (5) 8–12 cells thick, tuberculate at the apex, ± cilia, 200–300 (500)μ long (these may be present or absent from capsules even at the same locality, not to be confused with rhizoids which are often on the ventral surface of the calyptra, up to 1000μ long). *Seta* 12–15 cells in diameter. *Spores* 14–19μ in diameter. *Chromosome number*: n = 8.

Typification: *Aneura gigantea* Steph.—Holotype—Cambewarra Mtn., under cliff, Watts, 920, 10.1907, (G 11042): Isotype (920 NSW).

Specimens examined: Tasmania: Adventure Bay, Tas., sine leg., 3, 5, 3.1921, (HO); West Coast, sine leg., 4, 11.1923, (HO); New South Wales: Somersby Falls, Hewson, 847, 7.1966, (SYD); Warrah, Pearl Beach, Hewson, 145, 146, 7.1963, 158, 8.1963, (SYD); Mermaid's Glen, Blackheath, Hewson, 847, 7.1966, (1966); Neate's Glen, Blackheath, Hewson, 3, 2.1963, 76, 5.1963, 172, 8.1963, (SYD); Wentworth Falls, Hewson, 99, 5.1963, (SYD); Bilpin, Hewson, 301, 4.1964, (SYD); Oxford Falls, Sydney, Hewson, 62, 5.1963, 155, 7.1963, (SYD); East Lindfield, Hewson, 153, 7.1963, (SYD); North Shore, Whitelegge, 24, 61, 8.1884, (MEL); Flat Rock Creek, North Shore, sine leg., 22, (NSW); Waterfall, Royal National Park, Hewson, 17, 3.1963, (SYD); Oakdale, Hewson, 37, 45, 4.1963, (SYD); Fitzroy Falls, Hewson, 194, 195, 8.1963, (SYD); Charlotte's Pass, Mt. Kosciusko, Hewson, 287, 1.1964, (SYD).

Distribution: New South Wales, and Tasmania.

Aneura alterniloba (Hook.f. et Tayl.) Tayl. var. *robusta* (Rodway), comb. nov.

Nomenclatural synonym: *Aneura alterniloba* (Hook.f. et Tayl.) Tayl. f. *robusta* Rodway in Pap. & Proc. Roy. Soc. of Tas., 1916: 62 (1917).

Thalli (2) 3–5 (6) cm. long, (2) 3–6 (10) mm. wide, (6) 8–12 (15) cells thick. *Oil bodies* 1–3 per cell, 3 × 3–8 × 15μ. *Male branches* with antheridia in two regular rows. *Calyptra* 5–10 cells thick; no pachydermal armation, though some specimens tend to be tuberculate near the apex. *Seta* 11–14 cells in diameter. *Spores* 17–21μ in diameter. *Chromosomes* unknown.

Typification: *Aneura alterniloba* (Hook.f. et Tayl.) Tayl. f. *robusta* Rodway—Holotype—Russell Falls, Mt. Field National Park, Tas., in wet places, Rodway, sine No., 11.1914, (HO ex Herb. Rodway).

Specimens examined: Tasmania: St. Patrick's River, sine leg., 1769 (NY ex Herb. W. Mitten); Russell Falls, Mt. Field National Park, Townrow, 150, 151, 7.1963, Hewson, 254, 9.1963, (SYD); Arve Bridge, Mt. Hartz National Park, Hewson, 225, 9.1963, (SYD); Reid's Track, Mt. Wellington, Hewson, 264, 9.1963, (SYD); Victoria: Sealer's Cove, Gottsche (MEL); Sealer's Cove, Wilson's Promontory, F. Mueller, 5.1853, (MEL); Loutit Bay, Lorne, Otways, Luehmann, (MEL); Ryson's Creek, Nth. of Labertouche, Willis, 56W, (MEL); Calder River, Sth. Otway Ranges, Wakefield, 44W, (MEL); Nayook Reserve, nr. Neerim Junction, Warragul Field Naturalists, 77W, (MEL).

Distribution: Victoria and Tasmania.

Discussion: In view of the absence of cilia on the calyptra in this taxon it is possible that it should be recognized as a new species. But the range of variation in *A. alterniloba* var. *gigantea* includes some capsules without cilia. However, there are positive variations in other characters, and if the haploid chromosome number of var. *robusta* is found to be ten, it should probably be accepted as a separate species.

4. *Aneura athertonesis* Hewson, sp. nov.

Dioica. Thallus magnus, 2–3 (5) cm. longus, 2–4 mm. latus, plano-convexus (7) 8–10 (12) cellulis crassitie, margine acuto, alato ramificatio irregularis, lobata. *Corpora oleosa* 1–3 (4) in quaque cellula 8 × 15–10 × 18μ. *Rami plantarum masculinarum* laterales, antheridiis in seriebus duabus regularibus ordinatis, alis 1–2 cellulis latitudine. *Plantae femineae* squamis pilisque multicellularibus archegonia cingentibus. *Calyptra* 4–6 mm. longis, ciliata, 4–6 cellulis crassitie. *Seta* 11–12 cellulis diametro. *Paries capsulae* eo *Lobatiriccardiae* similis. *Sporae* 10–15μ crassae.

Dioecious. Plants on basalt rock with other bryophytes on creek banks in disturbed rainforest. *Thalli* 2–3 (5) cm. long, 2–4 mm. wide, with an acute ± dentate margin, plano-convex usually with recurved margins in transverse section, (7) 8–10 (12) cells thick; two types of branching, pinnate with bipinnate lobes; apex deeply dissected and protected by ventral, non-persistent mucilage papillae; rhizoids ventral. *Cuticle* smooth. *Gemmae* not observed. *Mycorrhizal association* not observed. *Oil bodies* 1–3 (4) per cell, 8 × 15–10 × 18μ in diameter. *Male plants* bearing lateral antheridial branches, 1–3 together; antheridia in two regular rows, up to 5 per row; dorso-lateral wing 1–2 cells wide. *Female plants* bearing archegonia laterally beneath lobes; margin of thallus usually overtops the branch; archegonia surrounded by multicellular, fimbriate, scalelike paraphyses. *Calyptra* 4–6 mm. long at maturity, 4–6 cells thick, ciliate with pachydermal cilia up to 400μ long. *Seta* 11–12 cells in diameter. *Capsule wall anatomy* of the *Lobatiriccardia*-type. *Spores* 10–15μ in diameter, minutely sculptured, scabrate. *Chromosomes* unknown.

Typification: *Aneura athertonensis*—Holotype—Charmillan Creek, Tully Falls Road, Atherton Tableland, on basalt rock on creek bank in disturbed rain-forest, Qld., Hewson, 422, 8.1964, (NSW): Isotype (BRI).

Specimens examined: Charmillan Creek, Atherton Tableland, Qld., Hewson, 425, 8.1964 (SYD.BRI).

Distribution: North Queensland.

Discussion: On the basis of capsule wall anatomy and oil body characters this species would be placed in the subgenus *Lobatiriccardia* as circumscribed by Mizutani and Hattori. It is close to *A. alterniloba* but differs in having smaller seta, smaller spores, less massive calyptra, smaller paraphyses, and no mycorrhizal association.

5. *Aneura rodwayi* Hewson, sp. nov.

Misapplied names: *Sarcomitrium pinguis* (non (L.) Mitten), Bastow in Pap. & Proc. Roy. Soc. of Tas., 1887: 276 (1888).

Aneura pinguis (non (L.) Dum.), Rodway in Pap. & Proc. Roy. Soc. of Tas., 1916: 62 (1917).

Dioica. Thallus magnus, (1) 2–3 (4) cm. longus, (2) 3–5 (10) mm. latus, concavus, 10–20 (25) cellulis crassitie, margine acuto; ramificatio irregularis, lobata. *Rami plantarum masculinarum* laterales, antheridiis in seriebus irregularibus ordinatis, alis 2–3 cellulis latitudine. *Plantae femineae* squamis pilisque multicellularibus archegonia cingentibus. *Calyptra* laevis, 10–15 cellulis crassitie. *Seta* 13–15 cellulis diametro.

Dioecious. Plants pale green, usually in dense patches on clay soil. *Thallus* (1) 2–3 (4) cm. long, (2) 3–5 (10) mm. wide, with an acute to winged, ± dentate margin, concave- to deeply concave-convex with margins appressed, giving appearance of a brain coral which is buried almost to the level of the substrate, 10–20 (25) cells thick; branching of two types, pinnate with bipinnate lobes; apex deeply dissected and protected by ventral, non-persistent mucilage papillae; rhizoids ventral; cuticle smooth. *Gemmae* not observed. *Mycorrhizal association* in the ventral internal cells, hyphae 1–2μ in diameter. *Oil bodies* unknown. *Male plants* bearing lateral antheridial branches; up to 10 antheridia arranged irregularly; dorso-lateral wing 2–3 cells wide. *Female plants* bearing archegonia laterally in lobe with margin of thallus extended laterally around it; archegonia surrounded by multicellular, fimbriate, scalelike paraphyses. *Calyptra* 4+ mm. long 10–15 cells thick, without pachydermal armation, but Rodway (1917), described tubercles. *Seta* 13–15 cells in diameter. Material too immature to describe *capsule wall* and *spore* anatomy. *Chromosomes* unknown.

Typification: *Aneura rodwayi*—Holotype—Hartz River, Mt. Hartz National Park, on clay soil near river bank, Tas., Hewson, 215, 9.1963, (NSW).

Specimens examined: Tasmania Rd. to Esperance Lake, Mt. Hartz National Park, Hewson, 233, 9.1963, (SYD); Lake Dobson, Mt. Mawson, Hewson, 236, 9.1963, (SYD); Mt. Wellington, 1,330 m., Rodway, 15, 1913, (HO).

Distribution: Tasmania.

Discussion: Similar in external morphology to *A. cerebrata,* but paraphyses scalelike and surrounding the archegonia, and seta 13–15 cells in diameter. Without capsule wall anatomy and oil bodies it is difficult to classify this species. However, seta diameter indicates that it might belong to the subgenus *Lobatiriccardia,* but this character has been shown to be an inadequate basis for this classification and hence we are not justified in placing it.

6. *Aneura novaguineensis* Hewson, sp. nov.

Dioica. Thallus magnus, (1) 2–4 (5) cm. longus, (1·5) 3–5 (12) mm. latus, plano-concavus, (7) 1–15 (20) cellulis crassitie, margine acuto, plus minusve alato, plus minusve dentatoque; ramificatio irregularis, lobata. *Rami plantarum masculinarum* laterales, antheridiis superficialis, in seriebus 2–4 irregularibus ordinatis, alis 3–6 cellulis latitudine. *Plantae femineae* squamis pilisque multicellularibus archegonia cingentibus. *Calyptra* tubercularis, 12–15 cellulis crassitie. *Seta* 16 cellulis diametro. *Chromosomata gametophytica* 10.

Dioecious. Plants on damp soil with other Bryophytes in rainforest and marginal rainforest. *Thalli* (1) 2–4 (5) cm. long, (1·5) 3–5 (12) mm. wide, with an acute ± winged, ± dentate margin, plano- to concavo-convex with a tendency to recurved margins in transverse section, (7) 10–15 (20) cells thick; branching of two types, pinnate with tripinnate lobes (rarely bipinnate with tripinnate lobes); apex deeply dissected and protected by ventral, non-persistent mucilage papillae; rhizoids ventral; cuticle smooth. *Gemmae* not observed. *Mycorrhizal association* in the ventral internal cells, hyphae 3–4μ in diameter. *Oil bodies* unknown. *Male plants* bearing lateral antheridial branches, 1–4 together; antheridia superficial, in 2–4 irregular rows, up to 15 per row; dorso-lateral wing irregular, wavy, dentate, 3 to 6 cells wide. *Female plants* bearing archegonia laterally beneath lobes; margin of thallus usually continued lateral to archegonia, rarely overtopping; archegonia surrounded by multicellular, fimbriate, scalelike paraphyses. *Calyptra* 2+ mm.

long, 12–15 cells thick, with terminal tubercles. *Seta* 16 cells in diameter. *Capsule walls* and *spores* too immature for study. *Chromosome number*: n = 10.

Typification: *Aneura novaguineensis*—Holotype—track to Bulldog Road from Edie Creek, 2,130 m., on soil in rainforest, Morobe District, New Guinea, Hewson, 838, 9.1965, (NSW): Isotypes (LAE.L).

Specimens examined: New Guinea: Chimbu River, Gembogl, Chimbu District, 2,130 m., Hewson, 573, 8.1965, (NSW.LAE); Pengage Creek, Mt. Wilhelm, Chimbu District, 2,780 m., Hewson, 673, 675, 8.1965, (NSW.LAE.L); Wakaru Range, Kagua, SHD, 1,820 m., Hewson, 695, 701, 706, 9.1965, (NSW.LAE.L); near Mungeri Village, Kagua, SHD., 1,670 m., Hewson, 725, 9.1965, (NSW.LAE.L); near Edie Creek, 2,130 m., Morobe District, Hewson, 840, 9.1965, (NSW.LAE.L).

Distribution: New Guinea.

Discussion: This species has closest affinities with *A. giangena* but differs from it in sex branch characters.

7. *Aneura giangena* Hewson, sp. nov.

Dioica. Thallus magnus, 2–3 cm. longus, 2–6 mm. latus, planus vel concavo-convexus, 8–12 cellulis crassitie, margine acuto, alato, dentato; ramificatio irregularis, lobata. *Rami plantarum masculinarum* laterales, antheridiis in seriebus duabus regularibus ordinatis, alis 2–4 cellulis latitudine. *Rami feminei* pilis multicellularibus circum interque archegonia.

Dioecious. Plants on damp soil loosely with other bryophytes in marginal rainforest. *Thalli* 2–3 cm. long, 2–6 mm. wide, with an acute, winged, dentate margin, plano- to concavo-convex with a tendency to recurved margins in transverse section, 8–12 cells thick; branching of two types, pinnate with bipinnate lobes; apex deeply dissected and protected by ventral, non-persistent mucilage papillae; rhizoids ventral; cuticle smooth. *Gemmae* not observed. *Mycorrhizal association* in ventral internal cells, hyphae 3–4μ wide. *Oil bodies* unknown. *Male plants* bearing lateral antheridial branches, 2–4 together; antheridia in 2 ± irregular rows, up to 8 per row; dorso-lateral wing 2–4 cells wide, irregular, dentate. *Female plants* bearing archegonia laterally in lobes, overtopped by thallus margin; archegonia protected by multicellular, hairlike paraphyses, around and between the archegonia. *Sporophytes* and *chromosomes* unknown.

Typification: *Aneura giangena*—Holotype—in Pengage Valley above Komamamambuno Mt. Wilhelm, 2,730 m., with other bryophytes on creek bank, in marginal rainforest, Chimbu District, New Guinea, Hewson, 668, 8.1965, (NSW): Isotypes (LAE.L).

Distribution: New Guinea.

Discussion: It is unfortunate that sporophyte material was unavailable with this collection. The unique female branches made it worthy of description, although it shows some affinities with *A. maxima* (Schffn.) Steph. The name chosen is derived from the Chimbu word "giangen". "Giangen" is the name given to all Lichens and Bryophytes.

8. *Aneura kaguaensis* Hewson, sp. nov.

Dioica. Thallus magnus, 1–3 cm. longus, (0·5) 2–4 mm. latus, planus, 7–10 cellulis crassitie, margine acuto; ramificatio irregularis, lobata; pinnulae erectae, angustae, usque ad 1 cm. longae, 0·3–0·7 mm. latae, elliptico-circulares. *Gemmae* exogenae, multicellulares, in apicibus pinnularum dispositae. *Rami plantarum masculinarum* irregulares marginales vel in basibus pinnularum. *Plantae femineae* circum interque archegoniis, pilis multicellularibus instructis.

Dioecious. Plants prostrate on logs in disturbed rainforest. *Main thalli* 1–3 cm. long, 2–4 mm. wide, with acute margins in transverse section, 7–10 cells thick; apex not deeply dissected, protected by ventral, non-persistent mucilage papillae; rhizoids ventral; cuticle smooth. *Pinnules* up to 1 cm. long, (0·3) 0·5 (0·7) mm. wide with obtuse margins, elliptical to cylindrical in transverse section, 7–10 cells thick. *Gemmae* terminal on pinnules, multicellular, exogenous. *Mycorrhizal association* in ventral internal cells, hyphae 2–3μ in diameter. *Oil bodies* unknown. *Male branches* bearing up to 6 antheridia marginal on thallus and basal on pinnules. *Female plants* bearing archegonia laterally beneath lobes; lateral margin not overtopping branch; archegonia protected by multicellular, hairlike paraphyses, around and between archegonia. *Sporophytes* and *chromosomes* unknown.

Typification: *Aneura kaguaensis*—Holotype—track between Kagua Mungeri Village, 1,540 m., on log in disturbed rainforest, SHD, New Guinea, Hewson, 720, 8.1965, (NSW): Isotypes (LAE.L).

Distribution: New Guinea.

Discussion: This species has three types of branching, pinnate with bipinnate lobes or bipinnate upright cylindrical pinnules. The lobing is typical of *Aneura* and the pinnules appear as though the plant has suffered etiolation. There was no apparent cause of etiolation in the field, but it was noted that some of the narrow branches reverted to normal broad thalli which in turn produced more cylindrical branches. Consequently it is inferred that this habit is usual rather than abnormal.

It is unfortunate that sporophyte material was unavailable with this collection. However the unique method of asexual reproduction appears to distinguish it clearly from all other species, and may ultimately lead to the establishment of a new genus.

Key to the Australian Species of Aneura

1. Calyptra delicate, 3–4 cells thick; seta less than 10 cells diameter; capsule wall with bands of thickenings on either ad. or abaxial walls in the outer row of cells, and on the inner tangential and both ad. and abaxial walls on the inner row of cells; mature spores with minutely sculptured sexine pattern, pilate; oil bodies 5–70/cell, less than 5μ in diameter. .... *A. eachamensis*

1+. Calyptra massive, more than 4 cells thick; seta more than 10 cells diameter; capsule wall with bands of thickenings on the adaxial walls in the outer row of cells, and on the inner tangential, the adaxial and often the abaxial walls in the inner row of cells; mature spores with minutely sculptured sexine pattern, scabrate; oil bodies 1–12/cell, 5–20μ in diameter. 2

  2. Calyptra 4–6 cells thick; seta 11–12 cells in diameter, 39–45 cells in circumference. (N. Qld.). .... *A. athertonensis*

  2+. Calyptra (5) 8–10 (12) cells thick; seta 11–15 cells in diameter, 50–60 cells in circumference 3

    3. Thallus 10–20 (25) cells thick, usually very deeply concave; mycorrhizal hyphae 1–2μ in diameter; archegonial paraphyses hairlike, flat to simple to slightly fimbriate, less than 0·5 mm. long .... *A. rodwayi*

    3+. Thallus (5) 7–12 (15) cells thick, plano- to slightly concavo-convex with recurved margins; mycorrhizal hyphae 4–5μ in diameter; archegonial paraphyses true scales, dentate to fimbriate, (0·4) 0·5–1·0 mm. long 4

      4. Calyptra 8–12 cells thick, tuberculate and usually ciliate, cilia 200–300 (500)μ long; spores 14–19μ in diameter; oil bodies (1) 3–6 (8)/cell, 6 × 8–15 × 20μ .... *A. alterniloba* var. *gigantea*

      4+. Calyptra 5–10 cells thick, smooth to slightly tuberculate; spores 17–22μ in diameter; oil bodies 1–3/cell, 3 × 3–8 × 15μ .... *A. alterniloba* var. *robusta*

Key to Aneura *Material Lacking Sporophytes for New Guinea*

1. Thallus 7–10 cells thick, usually with two forms of growth-habit, flat prostrate and cylindrical upright; multicellular exogenous gemmae in the apical region of the upright branches; male branches reduced to lateral region on thallus or at base of upright branches; archegonial paraphyses hairlike, simple, 0·1–0·4 mm. long .... *A. kaguaensis*

1+. Thallus (7) 8–20 (30) cells thick, one form of growth-habit; without multicellular exogenous gemmae; male branches distinct lateral branch; archegonial paraphyses if hairlike are greater than 0·4 mm. long, or are club shaped 2

  2. Thallus 15–20 (30) cells thick, usually very deeply concave-convex and closely appressed to resemble brain coral; mycorrhizal hyphae 2–3μ in diameter; dorso-lateral wing of male branch 1–2 cells wide; archegonial paraphyses, hairlike, club shaped, 0·2–0·5 mm. long .... *A. cerebrata*

  2+. Thallus (7) 8–15 (20) cells thick plano- to slightly concavo-convex with recurved margins; mycorrhizal hyphae 3–4μ in diameter; dorso-lateral wing of male branch 2–4 cells wide; archegonial paraphyses greater than 0·5 mm. long 3

    3. Male branches with 2–4 irregular rows of antheridia up to 15 per branch, superficial, dorso-lateral wing 3–6 cells wide; archegonial paraphyses true scales, slightly to very fimbriate, 0·8–2·0 mm. long, around archegonia .... *A. novaguineensis*

    3+. Male branches 2 more or less irregular rows of antheridia up to 8 per branch, sunken, dorso-lateral wing 2–4 cells wide; archegonial paraphyses hairlike, simple to fimbriate, 0·5–1·0 mm. long, around and between the archegonia .... *A. giangena*

References

Bastow, R. A., 1888.—Tasmanian Hepaticae. *Pap. & Proc. roy. Soc. Tasmania*, 1887: 209–289.

Bonner, C. E. B., 1962.—"Index Hepaticarum". Vol. 2. (Weinheim.)

Carrington, B., 1869.—Dr. Gray's arrangement of the Hepaticae. *Trans. & Proc. Bot. Soc. Edinburgh*, 10: 305–309.

Cavers, F., 1910–11.—*The Inter-relationships of the Bryophyta.* New Phytologist reprint, No. 4. Cambridge. (*New Phytologist*, 9: 81–112, 196–234, 231–253, 269–304; 10: 1–46, 84–86 (1910–11).)

Corda, A. K. J., 1835.—Deutschlands Jungermannien, in J. Sturm, "Deutschlands Flora." 2 (5/6): 116–121.

Denis, M. M., 1919.—Sur quelques thalles d'*Aneura* depourvus de chlorophylle. *C. R. Acad. Sci. Paris*, 168: 64–66.

Dumortier, B. C., 1822.—*Commentationes Botanicae.* Tournay.

————, 1831.—*Sylloge Jungermannidearum Europae indigenarum.* Tournay.

Erdtman, G., 1957.—"Pollen and Spore Morphology/Plant Taxonomy. II." (Uppsala.)

Evans, A. W., 1938.—The structure of the capsule wall in certain species of *Riccardia. Ann. Bryol.*, 10 (1937): 20–35.

Gottsche, K. M., 1856.—Plantae Müllerianae: Hepaticae Australasiae a Dr. F. V. Müller. Linnaea. *Beitr. zur Pflanz.*, 28: 547.

————, 1867.—De Mexikanske Levermooser. *Dansk. Vid. Selsk. Skrift.*, 5, 6: 97–381.

————, Lindenberg, J. B. W., and Nees ab Esenbeck, C. G., 1844–47.—"Synopsis Hepaticarum." (Hamburg.)

Gray, S. F., 1821.—"A natural arrangement of British plants. V. 1." (London.)

Grolle, R., 1960.—Bryological Notes: Zur Nomenklatur von *Riccardia pinguis. Trans. Brit. bryol. Soc.*, 3 (5): 746–747.

Harley, J. L., 1959.—"The biology of mycorrhizae." (London.)

Hooker, J. D., 1867.—"Handbook of the New Zealand Flora, 2, Hepaticae." (London.)

————, and Taylor, T., 1844.—Hepaticae Antarcticae. *Lond. J. Bot.*, 3: 366–400.

Kremp, G. O. W., 1965.—"Morphologic Encyclopedia of Palynology." (Tuscon.)

Linnaeus, C., 1753.—"Species Plantarum." V. 2. (Holmiae.)

Mitten, W., 1855.—In J. D. Hooker, "Botany of the Antarctic Voyage. Flora Novae Zelandiae." V. 2. Pt. 2. (London.)

————, 1860.—In J. D. Hooker, "Botany of the Antarctic Voyage. Flora Tasmaniae." V. 3. Pt. 2. (London.)

Mizutani, M., and Hattori, S., 1957.—An etude on the systematics of Japanese *Riccardias. J. Hatt. Bot. Lab.*, 18: 27–64.

Nees ab Esenbeck, C. G., 1838.—"Naturgeschichte der Europäischen Lebermoose." 3: 1–594.

Rayner, M. C., 1927.—Mycorrhiza. *New Phytologist*, 26 (1): 22–45.

Rodway, L., 1917.—"Tasmanian Bryophyta." V. 2. (Hobart.) Reprinted from *Pap. & Proc. roy. Soc. Tasmania*, 1916: 1–92.

Schiffner, V., 1893.—Hepaticae, in Engler, E., and Prantl, K., "Die Natürlichen Pflanzenfamilien." 1 (3): 1–141. (Leipzig.)

Schuster, R. M., 1958.—Keys to the Orders, Families and Genera of Hepaticae of America and North of Mexico. *The Bryologist*, 61: 1–66.

————, 1963.—Studies on Antipodal Hepaticae, 1. Annotated keys to the genera of Antipodal Hepaticae with species reference to New Zealand and Tasmania. *J. Hatt. Bot. Lab.*, 26: 185–309.

————, 1964.—Studies on Antipodal Hepaticae, 4. Metzgeriales. *J. Hatt. Bot. Lab.*, 27: 183–216.

Schwägrichen, C. F., 1814.—"Historiae Muscorum Hepaticarum. Prodromus." (Leipzig.)

Stephani, F., 1892.—A revision of Colenso's Hepaticae with descriptions of new Species collected by him. *J. Linn. Soc. London*, 29: 263–280.

————, 1898–1899.—"Species Hepaticarum". V. 1. (Geneva.)

Trevisan de Saint Leon, V., 1874.—Nuovo censo delle Epatiche Italiane. *R. Ist. Lombardo di Sci. e Lett. Milano*, 2 (7): 776–786.

————, 1877.—Schema di Una Nuova Classificazione Delle Epatiche Italiane. *R. Ist. Lombardo di Sci. e Lett. Milano*, 3 (4): 383–451.

EXPLANATION OF PLATES

Plate xi

Fig. 1. Longitudinal section through a gemmiferous branch of *Aneura kaguaensis* showing developing exogenous gemmae and ventral mucilage papillae. × 100. Fig. 2. Isolated gemma of *A. kaguaensis.* × c.525. Fig. 3. Mycorrhizal hyphae released by sectioning from a cell of *Aneura cerebrata.* Note septum. × c.1310. Fig. 4. Mycorrhizal hypha in rhizoid of *Aneura rodwayi.* × c.1310. Fig. 5. Mycorrhizal hypha passing through cell wall of *Aneura alterniloba* var. *gigantea.* × c.1310. Fig. 6. Spores of *Aneura eachamensis.* Surface (left) and transverse section (right). × c.1310. Fig. 7. Spores of *Aneura cerebrata.* Surface (left) and transverse section (right). × c. 1310. Fig. 8. Spores of *Aneura alterniloba* var *gigantea.* Surface (left) and transverse section (right). × c.1310. Fig. 9. Spores of *Aneura alterniloba* var *robusta.* Surface (left) and transverse section (right). × c.1310.

Plate xii

Fig. 1. Capsule wall thickenings of *Aneura eachamensis.* Tranverse section (left), surface view of outer row of cells, (centre), surface view of inner row of cells (right). × c.282. Fig. 2. Capsule wall thickenings of *Aneura cerebrata.* Surface view of outer row of cells (left), surface view of inner row of cells (right). × c.282. Fig. 3. Capsule wall thickenings of *Aneura alterniloba* var *gigantea.* Transverse section (left), surface view of inner row of cells (centre), surface view of outer row of cells (right). × c.282. Fig. 4. Capsule wall thickenings of *Aneura alterniloba* var *robusta.* Transverse section (left), surface view of inner row of cells (centre), surface view of outer row of cells (right). × c.282 Fig. 5. Capsule wall thickenings of *Aneura athertonensis.* Surface view of outer row of cells (left), surface view of inner row of cells (right). × c.282.

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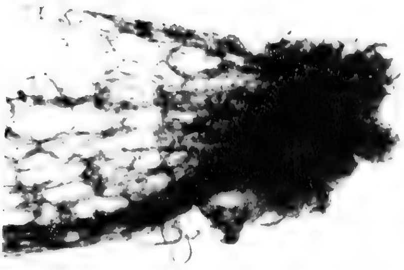

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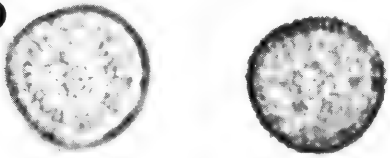

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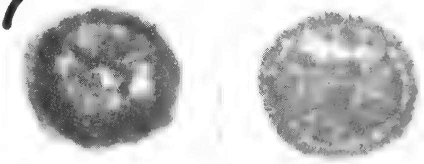

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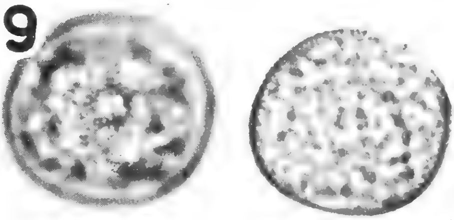

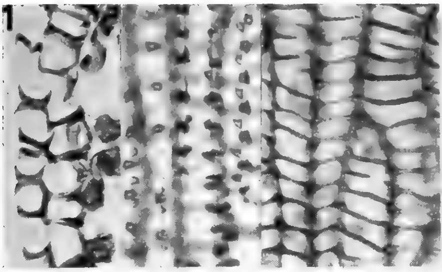
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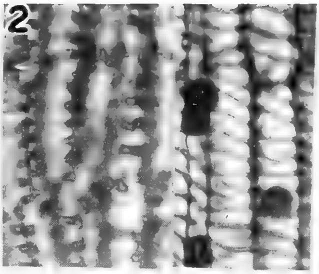
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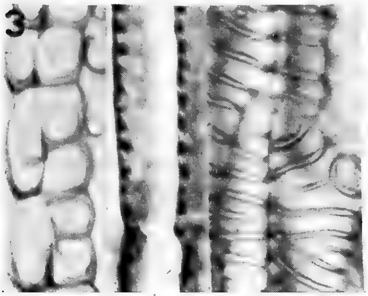
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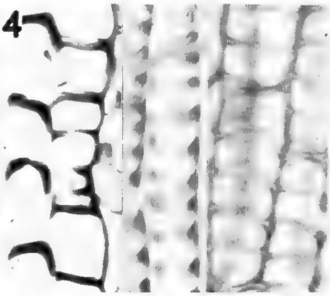
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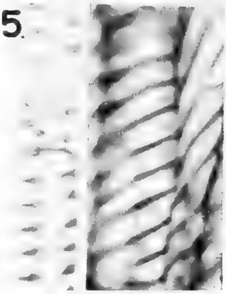
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OBSERVATIONS ON THE BIOLOGY OF *PALLIDOTETTIX NULLARBORENSIS* RICHARDS (RHAPHIDOPHORIDAE : ORTHOPTERA) FROM THE NULLARBOR PLAIN.

AOLA M. RICHARDS
School of Zoology, University of New South Wales, Sydney

(One text figure)

[Read 24th September 1969]

Synopsis

The complete life cycle of *Pallidotettix nullarborensis* Richards probably takes up to two and a half years: about 11 to 12 months being required for the development of the egg; 11 to 12 months for the nymphal instars; and possibly five to six months for the adult. Females mature in late summer and males in autumn. Oviposition occurs during the winter months. First instar nymphs appear in late autumn, so embryos probably undergo a summer diapause. Seven pre-adult instars are passed through. Usually only one generation is present in the population. *P. nullarborensis* is the first species of Macropathinae to exhibit signs of cave adaptation. Although scavengers, *P. nullarborensis* are primarily carnivorous and arthropods are their main food source. They will feed on both live and dead tissues. Their predation on newly hatched chicks is only the second record of such behaviour by Rhaphidophoridae. Activity rhythms are similar to those of other Australasian Macropathinae.

INTRODUCTION

The Nullarbor Plain is a low plateau of Tertiary limestone about 75,000 square miles in extent, situated in south-western Australia. Only one species of Rhaphidophoridae, *Pallidotettix nullarborensis* Richards (Richards, 1968*b*), is known from the Nullarbor Plain. It has been collected from 24 caves, and observed in three others. Its distribution ranges from White Wells Cave (N14)* in the far east, to Gecko Cave (N51) at the western extremity of the limestone, a distance of about 450 miles, and as far north from the coast as Lynch Cave (N60) near Loongana on the Transcontinental Railway. So far no specimens have been collected from caves on the Roe Plain to the south. *P. nullarborensis* appears to be confined to the limits of the Nullarbor Limestone.

The country immediately to the west of the Plain consists of low hills on crystalline Precambrian rocks with shallow overhangs, but lacking tunnels, while vegetation is semi-arid mallee. Although there are large areas of limestone southwest of the Plain, this combination of vegetation and geology appears to form an effective barrier against westward migration of Rhaphidophoridae. To the east of the Plain dune limestone occurs, stretching east to Lake Hamilton. Although it is possible there are caves in this limestone, the nearest recorded caves are approximately 300 miles to the south-east, and no Rhaphidophoridae have been collected from them. To the north of the Plain is the barrier of the Great Victoria Desert, while to the south lies the Great Australian Bight. The closest known Rhaphidophoridae come from the Adelaide district.

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*The Nullarbor caves and dolines have been indexed by the Australian Speleological Federation, and the numbers are prefixed by the letter N. This system is used throughout this paper (Hill, 1967).

P. nullarborensis is very abundant in some caves and poorly represented in others. In Moonera Tank Cave (N53), Murra-el-elevyn Cave (N47) and Horseshoe Cave (N59) large populations have been recorded one season and small ones the next. This may be explained by possible migration of the insects from one cave system to another (Richards, in press). In most caves they occur in the twilight zone close to entrances, but they have also been observed in regions of total darkness. In shallow caves they may extend throughout the whole cave system, and in deep caves they may occur up to 0·5 miles from the entrance. They have been observed on bat guano mounds 150 feet and 650 to 700 feet inside Murra-el-elevyn Cave, and they have also been collected from the large, steep doline leading down to this cave. In Cocklebiddy Cave (N48) they have been taken from the main chamber, and also from the island in the lake, 800 feet inside the cave (Lowry, 1964).

During 1965, 1966, and 1968, D. C. and J. W. Lowry collected representative samples of all instars of *P. nullarborensis* for the author from 13 of the Nullarbor caves, and made many valuable observations on its biology. In early 1968, the author visited 12 of the caves, and further observations were made on the life cycle and activity rhythms of the rhaphidophorids. As a result, it has been possible to determine the complete life cycle and number of pre-adult instars, food preferences and reactions to different epigean climatic conditions. This information has been compared with previous findings by the author (Richards, 1961, 1962, 1965, 1968*a*) and overseas workers (Chopard, 1959; Remy, 1931) on the biology of the Rhaphidophoridae.

LIFE CYCLE

P. nullarborensis has not been reared under observation from egg to adult. However, comparison of a series of measurements of selected anatomical features in a sample of 100 specimens shows that it is possible to divide the insects into a series of distinct groups ranging from first instar nymphs to adult insects. Sizes of individuals within each instar vary slightly, so mean values have been used in all cases. These indicate that seven pre-adult instars are passed through by both male and female insects (Figure 1). The appendage undergoing the greatest increase in growth at each ecdysis is the ovipositor. Not appearing until the third instar, by the time the adult instar is reached the ovipositor is 0·8 the length of the body.

To check whether an instar had been overlooked, the logarithm of the linear measurements of the hind femora were plotted against instars. Calculated values were obtained from fitted regression lines and are given in Table 1. The approximation of observed to calculated measurements is sufficiently close to remove the possibility of an instar having been overlooked.

Nymphs form the largest portion of any rhaphidophorid population. Table 2 shows the seasonal distribution of instars among a representative sample of *P. nullarborensis* specimens collected from Nullarbor caves during 1965, 1966 and 1968. The monthly sample size is variable, and the numbers of specimens collected at certain times of the year are admittedly small. Most samples were taken during 1966. All months are represented except March and July. The table does not show the abundance of each instar in relation to the total population, but the more abundant instars form the major portion of the larger samples. No difference in instar size or abundance of specific instars were observed in samples collected from different caves at the same period.

In the December and January sample, the sex ratio of nymphs is approximately equal, 29 females: 34 males, and most nymphs are in fifth or sixth instars. Few adults are present during these two months, and only females have been collected. Although searched for, no males have been observed. Only two penultimate instar males have been collected, both in January.

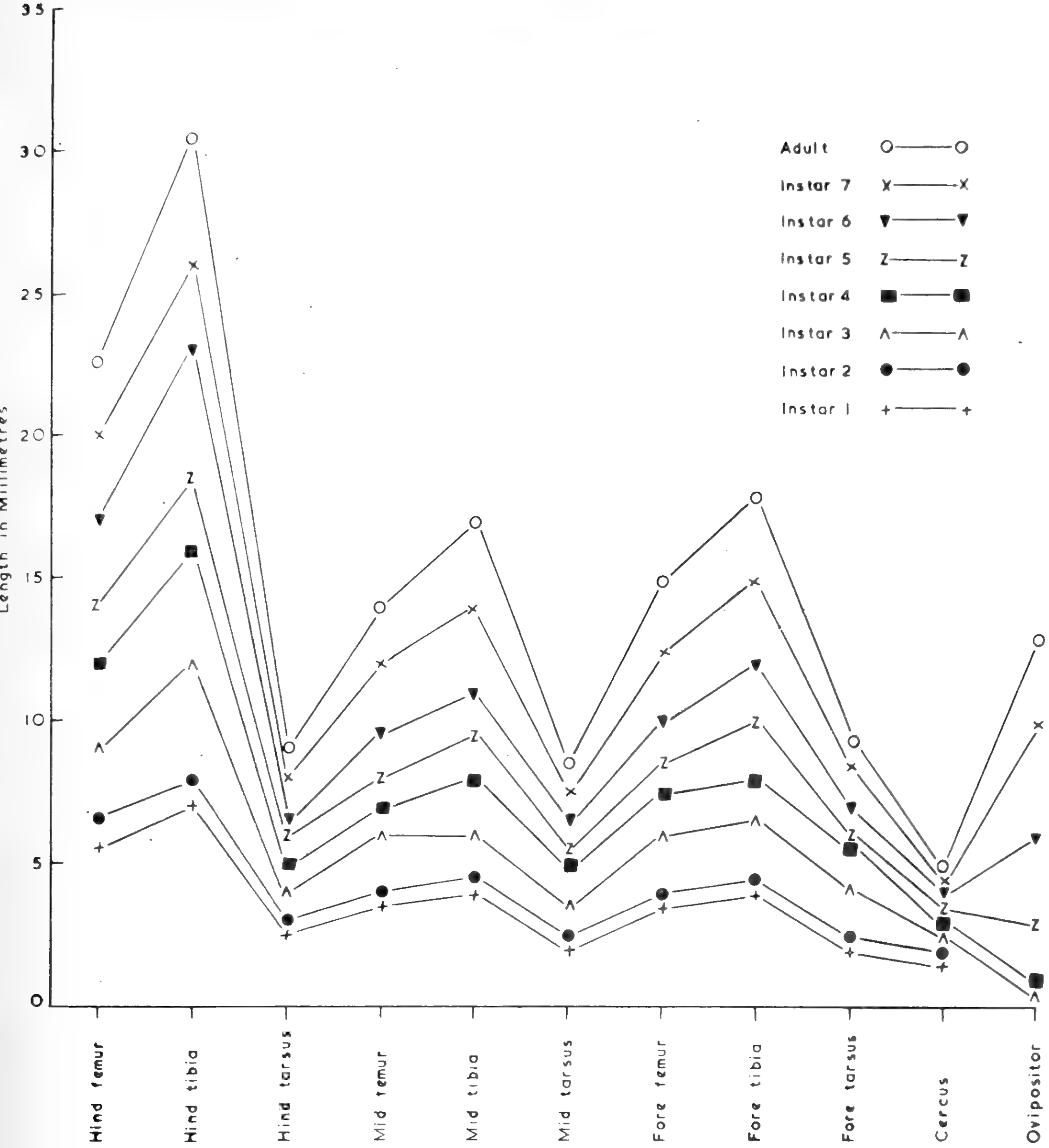


Fig. 1. Length of bodily structures in the several instars of *Pallidotettix nullarborensis* Richards.

In early February, the sex ratio of nymphs is again approximately equal. Most nymphs are in sixth instar, but a few females have moulted to seventh instar. In February 1968, only two adults, a male and a female, were observed out of a sample of 150 insects studied in three caves. They were in the preliminary mating attitude. There were no signs of oviposition.

In autumn, the proportion of adults in the population increases. Adult and seventh instar males and females have been taken in late April, May and June. During this period the number of nymphs decreases markedly, and the whole population is considerably smaller. First instar nymphs appear in May and June, and from then on they form the major part of the population.

TABLE 1

Fit of Dyar's Law to instar measurements of hind femora in P. nullarborensis

Instar	Observed Length (mm.)	Calculated Length* (mm.)
1	5·5	5·8
2	6·5	7·1
3	9·0	8·7
4	12·0	10·8
5	14·0	13·3
6	17·0	16·3
7	20·0	20·1
Adult	22·5	24·8

Proportionality constant : 1·23.
* From regression line.

By September and October, the population has noticeably increased in numbers, and consists mainly of fourth and fifth instar nymphs. They gradually increase in size till they become adult the following autumn. Dead adults have been found in the caves in October. Odd specimens belonging to any instar may occur in the population, for example one adult female collected in early December, but they cannot be considered as part of the general pattern of the life cycle.

TABLE 2

Seasonal distribution of instars

Month	Total Sample	Nymphal Instars							Adult
		1	2	3	4	5	6	7	
May	8	—	3	—	—	—	2	1	2
June	5	1	—	1	—	—	1	—	2
August ..	2	—	—	1	—	1	—	—	—
September ..	4	—	—	—	2	1	—	—	1
October ..	33	—	—	3	13	11	3	2	1
November ..	12	—	—	1	4	4	2	1	—
December ..	14	—	—	—	2	5	4	1	2
January ..	64	—	—	1	7	26	23	2	5
February ..	150	—	—	—	—	40	99	9	2
April	4	—	—	—	—	—	2	1	1

After the final ecdysis, a maturation period of several weeks must elapse while the gonads mature. The ovaries of 13 adult females have been examined. Two females taken in early December and early January had small ovaries and no mature eggs. Other females collected in late December, early January, May, September and October were gravid, with one large, fully developed egg. The egg is of a cream colour, oval in shape, 5 mm. in length and 2 mm. in width. It fills the greater part of the abdominal cavity. A female collected in May was the only exception to this rule, with five mature eggs inside its abdomen. It is not suggested that only one egg is laid by each female, but that usually only one egg matures at a time. Maturation, mating and oviposition occur in the cooler part of the year, and mating and oviposition may continue for several months. As first instar nymphs do not appear till late autumn, embryonic development must take about 11 to 12 months, and because of high temperatures during the summer months, embryos may undergo a summer diapause.

The length of the nymphal period varies. In some nymphs an instar may extend over a longer period than in others, so it is common to find several different instars in the population at the same time. However, except during the winter months, usually only one generation of nymphs is present (Table 2). The duration of time spent in nymphal instars is about 11 to 12 months.

The adult life span is not known. However as adults are present in reasonable numbers in April, May and June, and dead adults have been found in October, this suggests a possible life span of five to six months. Thus the complete life cycle from oviposition to death is probably about two and a half years, or about 18 months from eclosion to death.

DEVELOPMENT OF CAVERNICOLOUS CHARACTERS

Pallidotettix nullarborensis shows a greater tendency towards cave adaptation than related species in southern and south-eastern Australia, but should still be classed as a troglophile. No degeneration of the eyes has been observed, but a loss of pigmentation has occurred in both nymphs and adults, so that it is the palest Australian rhaphidophorid species known (Richards, 1968*b*). There has also been a narrowing and elongation of the limbs.

All Australian Rhaphidophoridae examined by the author have very elongated appendages, and all but one occur in limestone caves. *Australotettix montanus* Richards, the largest known Australian species, is an epigean form from the Blue Mountains of New South Wales. With a body length of 15 mm., the ratio of length of hind leg to length of body in the adult male *A. montanus* is 6: 1. By comparison, the adult male *P. nullarborensis* with a similar body length has a ratio of 4·8 : 1.

A comparison of the range and mean of total leg length in eight species of Australian Rhaphidophoridae (Table 3) shows that *P. nullarborensis* has the fourth highest mean among males, and the third highest mean among females. However, using the ratio of total leg length to maximum width of the hind femur, and allowing for sexual dimorphism in most species, Table 3 also shows that *P. nullarborensis* has a much higher ratio than any of the other species. This is due to longer fore and middle legs, and a narrower hind femur.

A comparison of increase in leg length from instar to instar can be made between nymphs of *P. nullarborensis* (Figure 1) and those of *Micropathus cavernicola* Richards and *M. tasmaniensis* Richards, two rhaphidophorids of comparable size from Tasmania (Richards, 1968*a*). *M. cavernicola* has the largest tarsus mean length, while *P. nullarborensis* shows the largest femur means, but although these two features are fairly consistent over the fore leg, middle leg and hind leg, and the eight instars, their magnitudes are only of the order of 1 mm. even in the later instars. *P. nullarborensis* very consistently has the largest tibia means, and in the last three instars, the means of the hind leg are about 5 mm. greater than those for the other two species. The consistency, but not the magnitude of these three features are shown in Table 4, which gives for each segment the number of occasions (out of 24 = 3 × 8) that the named species had the highest, or equal highest mean.

TABLE 3

Comparison of leg length and attenuation in eight species of Australian Rhaphidophoridae

Species	Number of Specimens		Total Leg Length (mm.)				Total Leg Length/Max. Width Hind Femur				S.D.
			Range		Mean		Range		Mean		
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
Pallidotettix nullarborensis	12	14	142·0–150·0	132·5–141·0	146·0	136·1	45·5–52·2	44·2–47·0	49·8	45·4	1·5
Australotettix montanus ..	16	12	183·0–203·5	139·5–148·5	194·2	144·5	38·8–45·2	28·7–33·0	42·1	31·6	1·9
Novotettix naracoortensis	18	12	143·0–160·0	121·5–129·0	155·5	126·0	38·6–43·1	30·4–32·3	39·5	31·5	0·9
Australotettix carraiensis	14	16	161·5–179·0	131·0–144·0	172·1	137·1	35·9–39·7	29·1–32·0	38·2	30·4	1·0
Micropathus tasmaniensis	14	14	121·0–128·0	119·0–130·5	125·4	125·5	30·3–32·0	29·8–32·8	31·4	31·4	0·8
Cavernotettix buchanensis	16	18	111·0–121·5	87·0–101·0	116·4	95·3	27·8–30·4	23·9–26·8	29·1	25·3	0·8
Cavernotettix wyanbenensis	12	8	104·0–119·5	90·5–98·5	114·2	99·3	27·8–30·3	23·8–26·0	29·2	25·1	0·9
Cavernotettix montanus ..	16	12	108·0–117·0	95·0–105·0	112·5	99·3	24·8–29·3	23·8–26·3	28·0	24·9	0·9

TABLE 4

Comparison of leg segment length in three species of Australian Rhaphidophoridae

Species	Leg Segment	Highest Mean	Equal Highest Mean
Micropathus cavernicola	Tarsus	17	6
Pallidotettix nullarborensis ..	Femur	19	4
Pallidotettix nullarborensis ..	Tibia	21	3

FOOD PREFERENCES

Crop contents from specimens of *P. nullarborensis* collected from nine Nullarbor caves have been analysed. Both live and preserved specimens were examined from Murra-el-elevyn Cave (N47), and preserved specimens from all other caves. All specimens were well nourished, and the full alimentary canals in all but one specimen indicated a plentiful food supply. A wide variety of plant and animal food is available in the caves and around the entrances, but marked preferences were noted for animal tissues (Table 5).

TABLE 5

Crop Content of P. nullarborensis *from nine Nullarbor Caves*

Caves	Number of Specimens Examined	Crop Content			
		Vertebrate Faeces and Tissues	Arthropod Tissues	Fungus	Angiosperm Tissues
N47	6	0	5	1	0
N38	4	0	5	1	1
N2	4	2	5	1	0
N59	6	0	3	2	3
N60	5	3	1	3	1
N48*	2	0	5	0	0
N51	3	0	5	0	0
N56	2	1	4	1	0
N140	1	0	0	0	3

The abundance of each category was rated on an arbitrary scale from 0 (absent) to 5 (very abundant).

* From island in lake.

1. *Arthropods*

These form the main source of food for *P. nullarborensis.* Live arthropods are preyed on, and those found dead due to natural causes may also be eaten. Cannibalism is known to occur. It was not possible to identify any arthropod tissues precisely because of the small size of the particles; but no scales or parts of wings were detected.

2. *Vertebrates*

(*a*) ***Faeces.*** In most caves the walls, floor and talus slope beneath the roosting sites of birds are covered with faecal material. Mounds of bat guano also occur in a number of caves. They may be more extensive, but are not as common as bird guano. Of the 19 caves listed in Table 6, *P. nullarborensis* has been collected from 12, and in seven of these it was associated with bats. In a few caves it has been found on bat guano. Although guanobia may be commonly eaten, few traces of faecal material have been found in the crops of these rhaphidophorids (Table 5).

(*b*) *Carcases.* Some caves act as animal traps, and carcases of vertebrates form another food source for *P. nullarborensis* (Table 6). The remains of small animals brought into caves by dingoes, foxes and other predators may also be eaten.

TABLE 6

Occurrence of vertebrate carcases in 19 Nullarbor Caves

Caves	Bat	Dingo	Fox	Wombat	Rabbit	Cat	Rat	Bird	Snake	Lizard
N1	+	—	—	—	—	—	—	+	—	—
*N2	+	+	—	—	—	—	—	—	—	—
N3	+	+	—	—	—	—	+	+	+	—
*N4	+	—	—	—	—	—	—	+	+	—
*N7	—	—	+	+	+	—	—	—	—	—
N37	+	—	—	—	—	—	—	—	+	—
*N38	+	—	—	—	—	—	—	—	—	—
N45	—	—	—	—	—	—	—	+	—	—
*N47	+	—	—	—	+	—	—	—	—	—
*N48	+	—	—	—	+	—	—	+	—	—
*N49	+	—	—	—	—	—	—	—	—	—
*N51	—	—	—	—	—	—	—	—	—	+
*N53	+	—	—	—	—	—	—	—	—	—
*N59	—	—	—	—	+	+	—	—	—	—
*N60	—	—	—	—	+	—	—	+	—	+
N62	+	—	—	—	—	—	—	—	+	—
N63	+	+	—	+	+	—	+	+	+	+
N70	—	+	—	—	—	—	—	—	—	—
*N83	—	+	—	—	—	—	—	+	—	—

* *P. nullarborensis* also occur in the cave.

(*c*) *Living Prey. P. nullarborensis* will also prey on small live vertebrates. In October 1966, they were observed to kill four unprotected kestrel chicks, *Falco cenchroides* Vigors and Horsfield, in a nest in the entrance shaft of Lynch Cave (N60). The rhaphidophorids attacked the backs of the chicks, and for two successive nights swarmed over and fed on the carcases (Lowry, pers. comm.).

3. *Plants*

(*a*) *Fungi.* In the high humidity of the Nullarbor caves fungi grow readily on faeces and rotting wood. They are commonly eaten by *P. nullarborensis,* although usually not in large quantities.

(*b*) *Algae and Bryophytes.* Near cave entrances blue-green algae have become established on the walls, and lichens and bryophytes may also occur. No traces of these plants have been found in the crop of *P. nullarborensis.*

(*c*) *Angiosperms.* Large quantities of decaying vegetation, consisting of branches, twigs and leaf litter, have been washed into most caves, but angiosperm tissues are not commonly eaten. Traces of them were found in the crop of one rhaphidophorid from Walpet Cave (N38) and one from Lynch Cave (N60), and large quantities in the crop of one rhaphidophorid from Horseshoe Cave (N59). Part of an anther and masses of pollen belonging to a species of Chenopodiaceae were the only contents in the crop of a rhaphidophorid collected near the entrance to Unnamed Cave (N140).

ACTIVITY RHYTHMS

During the day *P. nullarborensis* are immobile in domes, alcoves or on walls of caves, but at night they move about over the walls and floors. In October 1966, on two consecutive nights between 18.00 hours and 5.00 hours, Lowry (pers. comm.) made a series of observations on activity levels in Lynch Cave (N60). Sunset was timed at 18.29 hours Central Standard Time, and sunrise at 5.41 hours. On both nights the insects became active between 19.00 hours and midnight. On the first night activity was again observed at 4.15 hours, and had ceased by 5.00 hours. On the second night no activity was observed after midnight. Temperature and relative humidity were measured with a whirling hygrometer. During the whole period of activity the mean temperature in the main chamber was 55·5°F. (range 53°–58°F.) and the mean relative humidity 79% (range 75–84%), while outside the cave the mean temperature was 53·5°F. (range 42°–62°F.) and the mean relative humidity 63% (range 35–87%) (Lowry, 1967). Although observed in the entrance shaft, none of the insects emerged from the cave.

In February 1968, temperature and relative humidity readings were taken in three caves using a thermohydrograph and an Assmann psychrometer. The general behaviour of the rhaphidophorids in these caves agrees very closely with Lowry's 1966 records.

In Murrawijinie No. 1 Cave (N7), where a large collapse doline encroaches on it, the greater part of the cave is exposed to light. Here *P. nullarborensis* disappear into cracks in the limestone during daylight, and emerge onto the cave walls at dusk. In February emergence was timed at 19.30 hours Central Standard Time. Between 50 and 60 insects were observed on the walls until midnight. During this period the temperature ranged between 66° and 68°F., and the relative humidity from 80 to 86%.

At Murra-el-elevyn Cave (N47) between 21.30 and 22.30 hours, 12 *P. nullarborensis* were observed in the large doline outside the cave. Some had climbed about 200 feet up the steep talus slope almost to the surface. The night was calm and rain was falling. The cave temperature was 62° to 66°F., gradually rising further from the entrance, and the relative humidity ranged between 84 and 88%. The temperature in the doline was 62°F. and the relative humidity 98%. While little difference was noted between doline and cave temperature, in the doline there was a rise of 10% in relative humidity. Most rhaphidophorids appeared to have emerged from the cave, and the few inside were all close to the entrance.

At Lynch Cave (N60) four *P. nullarborensis* were observed at 4.00 hours moving about on the surface a short distance from the cave entrance. The night was fine, calm and dark, the temperature 60·5°F. and the relative humidity 94%. Other rhaphidophorids were observed in the entrance shaft of the cave. During the following day they remained inactive on the cave walls, and although they became active at night, and a few were seen in the entrance shaft about midnight, they did not emerge onto the surface. The second night epigean climatic conditions were less favourable for them. The surface temperature was 70°F. at midnight, and fell to a minimum of 67°F. at 6.00 hours. The relative humidity reached a maximum of 78% at midnight, and between then and 6.00 hours fluctuated between 71 and 78%. At the same time the cave temperature was constant at 68°F. and the relative humidity ranged between 93 and 95%. The difference between cave and surface temperature is not significant, so the drop of about 20% in humidity was probably an important factor in inhibiting the activity of the rhaphidophorids. A similar drop in humidity in October 1966 could have prevented the insects from leaving the cave. This suggests that when a humidity gradient is set up at night between the cave and the surface, the rhaphidophorids move to or stay in the region of higher humidity.

Discussion

Pallidotettix nullarborensis is the third Australian species of Macropathinae for which the number of instars has been determined. Unlike some New Zealand species (Richards, 1961), sexual dimorphism in the number of instars is absent in all three Australian species, and both sexes pass through seven instars (Richards, 1968*a*). Comparison of the results in Table 1 with those obtained for *Micropathus cavernicola* and *M. tasmaniensis* shows that the fit of observed and calculated measurements for *P. nullarborensis* is not quite as good as that obtained for the other two species. The figures used in Table 1 are based on insects collected at various times of the year, whereas the Tasmanian specimens were all collected on the same day. Thus the results obtained for *P. nullarborensis* may partly be governed by variations in environmental conditions.

In all other Macropathinae examined by the author, the female develops several mature eggs at any one time, although only one egg is laid at each insertion of the ovipositor into the substratum. The egg of *P. nullarborensis* is larger than those in species of *Micropathus* Richards, *Cavernotettix* Richards and *Pallidoplectron* Richards and this may partly explain the reduction in number of eggs present.

The seasonal cycle of *P. nullarborensis* is quite different from that in *Micropathus cavernicola* and *M. tasmaniensis.* Although the numbers of specimens of *P. nullarborensis* collected at certain times of the year are small, a comparison with New Zealand species of Macropathinae (Richards, 1961) shows that while there is a difference of six months in the appearance of the various nymphal stages, the complete life cycle is of comparable length. The period of embryonic development is about seven months in *Gymnoplectron waitomoensis* (Richards), and about eight months in *Pallidoplectron turneri* Richards, as compared with a period of 11 to 12 months in *P. nullarborensis.* The duration of nymphal instars in *G. edwardsii* (Scudder), then known as *Pachyrhamma fascifer* (Walker), and *G. waitomoensis* is 15 to 16 months, as compared with about 11 to 12 months in *P. nullarborensis,* but there is a nymphal diapause between April and October in the New Zealand species, females remaining in sixth instar and males in seventh instar. The length of the adult instar ranges from six to nine months in *G. waitomoensis* and is about seven months in *G. edwardsii,* as compared with possibly five to six months in *P. nullarborensis.* Thus *P. nullarborensis* spends a longer period in the embryonic stage, and a shorter period in the nymphal instars. This may be explained by the possibility of the embryo undergoing a summer diapause, and the absence of a winter diapause during nymphal instars of this species. It is possible that climatic conditions in the Nullarbor caves (Richards, in press) may have influenced the seasonal cycle of *P. nullarborensis* as temperatures throughout the year are up to 10°F. higher than those recorded from New Zealand caves (Richards, 1956). While two generations are nearly always present in populations of *G. edwardsii* and *G. waitomoensis*, usually only one generation is represented in populations of *P. nullarborensis.*

The food available to *P. nullarborensis* is similar to that eaten by rhaphidophorids in other parts of the world (Chopard, 1938, 1959; Gangwere, 1961; Remy, 1931; Richards, 1962, 1968*a*). Rhaphidophorids are usually omnivorous scavengers, and Gangwere (1961) claims the variety of their diet is second to none except cockroaches and possibly field crickets. Table 5 suggests that *P. nullarborensis* is primarily carnivorous and does not normally go outside cave entrances at night to feed on surrounding vegetation. The absence of algae and bryophytes, and the almost complete absence of higher plant tissues from its diet may be due to the unsuitability of the species of plants growing on the Plain and in the dolines (Richards, in press), unfavourable climatic conditions outside the caves, a plentiful food supply in the caves, or a preference for animal tissues. The latter is considered the most likely, as in Waitomo Cave, New Zealand, rhaphidophorids fed on decaying vegetation and grasses swept into the cave during floods and left stranded on the walls or floating on the surface of the underground stream (Richards, 1962).

As with other Macropathinae (Richards, 1962, 1968*a*), no lepidopterous remains have been found in the crop content. This is surprising, as *Monopis* sp. is associated with bird guano in some Nullarbor caves, *Agrotis infusa* Boisd. may sometimes occur inside caves, and the remains of *Dasypodia selenophora* Guenée are dropped in caves by bats. In Europe, Trichoptera and Lepidoptera are the main arthropods eaten by rhaphidophorids (Remy, 1931).

Although the normal animal portion of the diet of rhaphidophorids consists of arthropods, they will also feed on carcases of bats and birds (Chopard, 1959). Predation on vertebrates has been recorded for only two species, *P. nullarborensis* and *Rhaphidophora oophaga* Chopard (Chopard, 1959), and in both cases unprotected, newly hatched birds have been attacked.

More information is needed on the activity rhythms of *P. nullarborensis*. As with other Australian rhaphidophorids (Richards, 1965), rapidly changing light intensity at dusk and dawn has initiated the development of a bimodal activity rhythm. This consists of a period of activity commencing shortly after sunset, a quiescent period during the night, a renewed period of activity shortly before dawn, and a further quiescent period during daylight. However, the period of activity after sunset lasts for about five hours instead of three. Temperatures are similar to other records taken during periods of activity, but relative humidity may be up to 15% lower. Fluctuations in humidity influence the behaviour of *P. nullarborensis,* and they have not been observed in the epigean region unless the humidity was over 90%. Rain does not inhibit their activities, and the rise in humidity together with the absence of moonlight cause them to emerge from the cave.

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to Mr. D. C. Lowry, Geological Survey, Perth, and his wife Jacky for collecting specimens of *P. nullarborensis* from various caves on the Western Australian portion of the Nullarbor Plain, and also for observing and recording the behaviour of these insects under natural conditions. I should also like to thank Mr. A. G. Elliott, Department of Statistics, University of New South Wales, Sydney, for statistical assistance. I am grateful to Mr. E. G. Anderson and Mr. H. Dengate for assistance in the caves in January and February, 1968. Finally I wish to thank Dr. Phyllis L. Robertson, University of New South Wales, Sydney, for making helpful comments.

References

CHOPARD, L., 1938.—*La Biologie des Orthoptères.* Paul Lechevalier, Paris, pp. 541.

————., 1959.—Sur les Moeurs d'un *Rhaphidophora* cavernicole. *Annales de Spéléo.*, 14: 181-184.

GANGWERE, S. K., 1961.—A Monograph on Food Selection in Orthoptera. *Trans, Amer. Ent. Soc.*, 87: 67–230.

HILL, A. L., 1967.—Checklist of Caves and Related Features. *Caves of the Nullarbor* (Ed. J. R. Dunkley and T. M. L. Wigley). The Speleological Research Council Ltd., University of Sydney, Sydney.

LOWRY, D. C., 1964.—The Development of Cocklebiddy Cave, Eucla Basin, Western Australia. *Helictite*, 3: 15–19.

————., 1967.—The Origin of Blow-holes and the Development of Domes by Exsudation in Caves of the Nullarbor Plain. *Geol. Surv. W.A. Record No. 1967/12*, 19 pp.

REMY, P., 1931.—Observations sur les Moeurs de quelques Orthoptères cavernicoles. *Ann. Sci. Nat.-Zool.*, (10) 14: 263–274.

RICHARDS, Aola M., 1956.—The Systematics, Ecology and Life History of two Species of Rhapidophoridae (Orthoptera) at Waitomo Caves. Ph.D. Thesis in Library Victoria University, Wellington, New Zealand.

————., 1961.—The Life History of some Species of Rhaphidophoridae (Orthoptera). *Trans. Roy. Soc. N.Z. Zoology*, 1 (9): 121-137.

————., 1962.—Feeding Behaviour and Enemies of Rhaphidophoridae (Orthoptera) from Waitomo Caves, New Zealand. *Trans. Roy. Soc. N.Z. Zoology*, 2 (15): 121–129.

————., 1965.—The Effect of Weather on Rhaphidophoridae (Orthoptera) in New Zealand and Australia. *Annales de Spéléo.*, 20: 391–400.

————., 1968*a*.—Notes on the Biology of two Species of Rhaphidophoridae (Orthoptera) in Tasmania. PROC. LINN. SOC. N.S.W., 92 (3): 273–278.

————., 1968*b*.—The Rhaphidophoridae (Orthoptera) of Australia. Part 7. A New Genus from the Nullarbor Plain, South-western Australia. PROC. LINN. SOC. N.S.W., 93: 46–51.

————., In Press.—An Ecological Study of the Cavernicolous Fauna of the Nullarbor Plain, South-western Australia.

APPENDIX 1.

Caves referred to by their index number in Tables 5 and 6 are as listed below. A map showing their location may be found in Richards (in press).

N 1	Warbla Cave
N 2	Weebubbie Cave
N 3	Abrakurrie Cave
N 4	Koonalda Cave
N 7	Murrawijinie No. 1 Cave
N37	Mullamullang Cave
N38	Walpet Cave
N45	Winbirra Cave
N47	Murra-el-elevyn Cave
N48	Cocklebiddy Cave
N49	Pannikin Plain Cave
N51	Gecko Cave
N53	Moonera Tank Cave
N56	Tommy Grahams Cave
N59	Horseshoe Cave
N60	Lynch Cave
N63	Thylacine Hole
N70	Firestick Cave
N83	Old Homestead Cave
N140	Unnamed Cave

A NEW SPECIES OF MARGINASTER (*ASTEROIDEA: PORANIIDAE*) FROM TASMANIA

A. J. Dartnall
The Tasmanian Museum, Hobart

(Plate XIII and Text-figures 1–2)

[Read 24th September, 1969]

Synopsis

A new species of *Marginaster* (Asteroidea: Poraniidae) is described and recorded from the littoral of S.E. Tasmania. It is compared with other members of the genus which are all known from offshore waters. Initial examination of the digestive system suggests that the species is a partial particulate feeder aided by mucous sheets.

Introduction

The sea star genus *Marginaster* was first recorded from Australian waters by Miss A. M. Clark (1962) from a single specimen taken off Maria Island, Tasmania, by the 1929–31 B.A.N.Z.A.R. Expedition. Miss Clark described the specimen, but did not name the species, commenting on its resemblance to *Marginaster paucispinus* Fisher.

It is of interest to record a new species of *Marginaster* from the littoral of S.E. Tasmania.

Following the keys provided by Sladen (1889), Fisher (1911) and A. M. Clark (1962) the genus *Marginaster* appears to be the only one which will accommodate the species described below. Future studies will show whether its familial or generic placing is correct but it may be apposite to record that this author at first regarded this form as an aberrant member of the Asterinidae.

Subclass Asteroidea

Family Poraniidae Perrier

Genus Marginaster Perrier 1881

Marginaster littoralis sp. nov.

(Pl. XIII; Text-figs 1–2)

Description

A bluntly stellate sea star; $R:r = 1{\cdot}5:1$; *br.* is approximately equal to R where the rays join the disc.

Actinal surface nearly plane, slightly tumid; abactinal surface convex, the interradial areas being slightly depressed and the arm bases slightly swollen. The body is covered with a thick, investing epidermis which conceals the skeletal plates. Details of skeletal structure are only apparent when the epidermis is cleared or macerated.

The plates of the abactinal surface form an open reticulum and a regular arrangement can be discerned at the centre of the disc (Fig. 1). Some plates of the disc and carinal areas carry up to seven spinelets but on the remaining abactinal plates there are rarely more than four spinelets. The spinelets of the disc and carinal areas are granular, between 0·25 and 0·5 mm. in length and slightly broader at the base (*c.* 0·19 mm.) than at the blunt tip (*c.* 0·14 mm.). The spinelets of the abactinal surface are carried on a raised boss on each plate (Fig. 1).

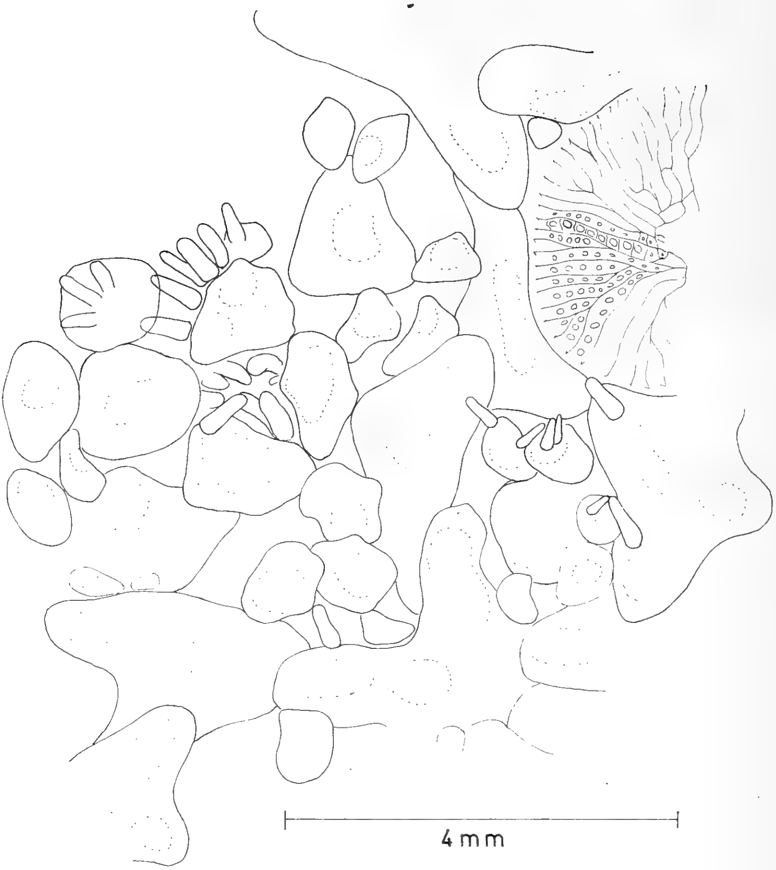


Fig. 1. *Marginaster littoralis* sp. nov. Arrangement of plates at centre of abactinal surface. Madreporite at top right. Plates denuded and raised bosses shown by broken lines.

Large papulae are placed singly in the skeletal meshes. In some large specimens a group of papulae is conspicuous near to the tip of the ray, accommodated in an open space without skeletal plates (Fig. 2).

The terminal plate of the ray is quite distinct and may carry up to ten spinelets.

The madreporite is interradial in position, just eccentric from the centre of the disc. It is slightly ovoid and about 1 mm. across its long axis.

The superomarginal plates are not distinct. The inferomarginals form a prominent fringing edge to the body, each bearing between two and five small pointed tubercles on the upper surface and a fan of two to four (most often three) webbed spinelets, up to 0·9 mm. in length, on the margin.

The plates of the actinal intermediate areas are slightly imbricate and small secondary ossicles may be present towards the margin. The actinal surface is more spinous in larger individuals but each plate rarely carries more than one spine. The skin covering the interradial actinal areas is marked with furrows extending from the adambulacral plates to the margin and, in some specimens, partly on to the abactinal surface of the disc.

The adambulacral plates each have two furrow spines and one subambulacral spine. The furrow spines taper and may attain 0·94 mm. in length. The subambulacral spines vary between 0·7 and 0·9 mm. in length and are slightly broader at the base (*c.* 0·35 mm.) than the tip (*c.* 0·3 mm.). Flattening of the spines of the ambulacral armature is not significant. The oral plates carry two to three oral spines and may or may not carry a single suboral spine. Variation in suboral spinulation is observable between specimens and between oral plates of the same specimen.

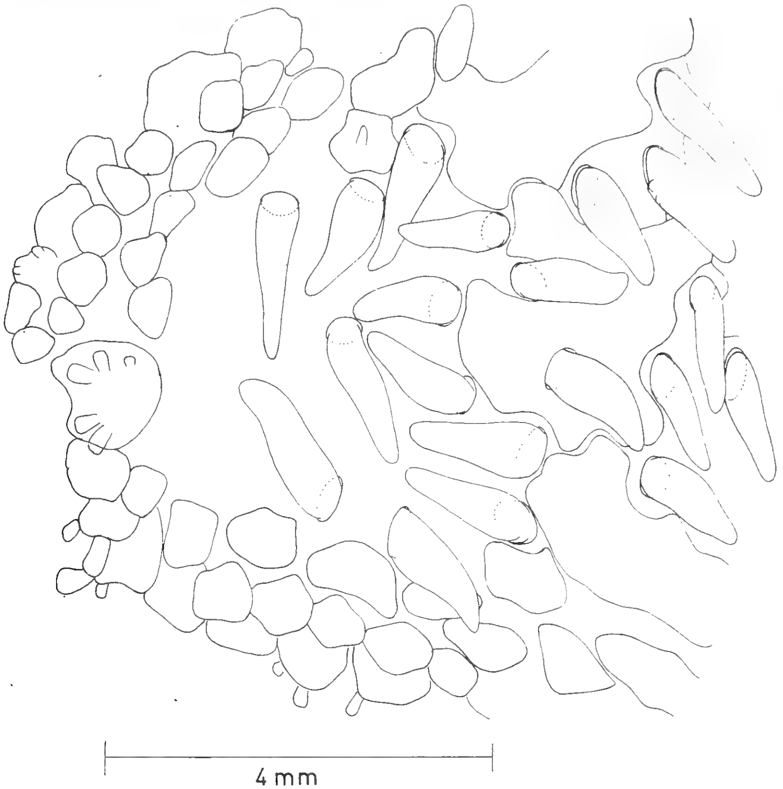


Fig. 2. *Marginaster littoralis* sp. nov. Tip of arm of specimen with papular tuft. Plates denuded. Terminal plate left centre.

Colour. When alive the animal is greenish brown on the abactinal surface bordered by an off-white band, defining the outline of the body. The actinal surface is off-white. Under low power magnification the epidermis of the abactinal surface appears bluish-green with brown pigmentation around the bases of the spinelets.

Type locality. Rocky midlittoral, near Powder Jetty, River Derwent, near Hobart, S.E. Tasmania.

Holotype. A dried specimen R = 17 mm. from type locality. 2.v.1969. Collected by A. J. Dartnall. Tasmanian Museum Reg. No. H 468.

Paratypes. Twelve spirit specimens from Cornelian Bay, River Derwent, S.E. Tasmania. 31.iii.1969. Collected by J. L. Hickman. Tasmanian Museum Reg. No. H 469.

Five spirit specimens from the type locality. 2.v.1969. Collected by E. Turner and A. J. Dartnall. Tasmanian Museum Reg. No. H 470.

Further paratypes are housed in the collections of the Australian Museum, Sydney (Australian Museum Reg. Nos. J 7733 and J 7734). Voucher material is also held by the British Museum (Natural History), London.

Affinities

Marginaster littoralis sp. nov. is most like *Marginaster capreensis* (Gasco) from European waters in possessing spinelets on the abactinal surface. However, the new species attains a larger size than other species attributed to the genus and the ambulacral and oral armature is quite distinct (see Table 1).

TABLE 1

Oral and Ambulacral Spinulation of Species of Marginaster

Species	Maximum R (mm.) recorded	Number of oral spines	Number of suboral spines	Number of furrow spines per plate	Number of sub-ambulacral spines per plate	Source of information
M. littoralis sp. nov.	17	2–3	0–1	2	1	Type series
Marginaster sp. (cf. *M. paucispinus* Fisher)	9	4	2	1	2	A. M. Clark (1962)
M. paucispinus ..	11	4	2	2–1	2	Fisher, 1919
M. echinulatus ..	5	—	—	4–5	2–3	Perrier, 1881
M. capreensis ..	11–12*	—	—	2	2	Sladen, 1889 *A. M. Clark (pers. comm.)
M. pentagonus ..	—	—	—	1	2–3	Fisher, 1919

Geographically its nearest relation is the specimen of *Marginaster* cf. *M. paucispinus* Fisher described by A. M. Clark (1962). Again the ambulacral and oral spinulation differs and that specimen, at R = 9 mm., possessed no actual spinelets. Also *M. littoralis* possesses a more dense and heavier skeletal structure than the other species attributed to the genus.

Field identification

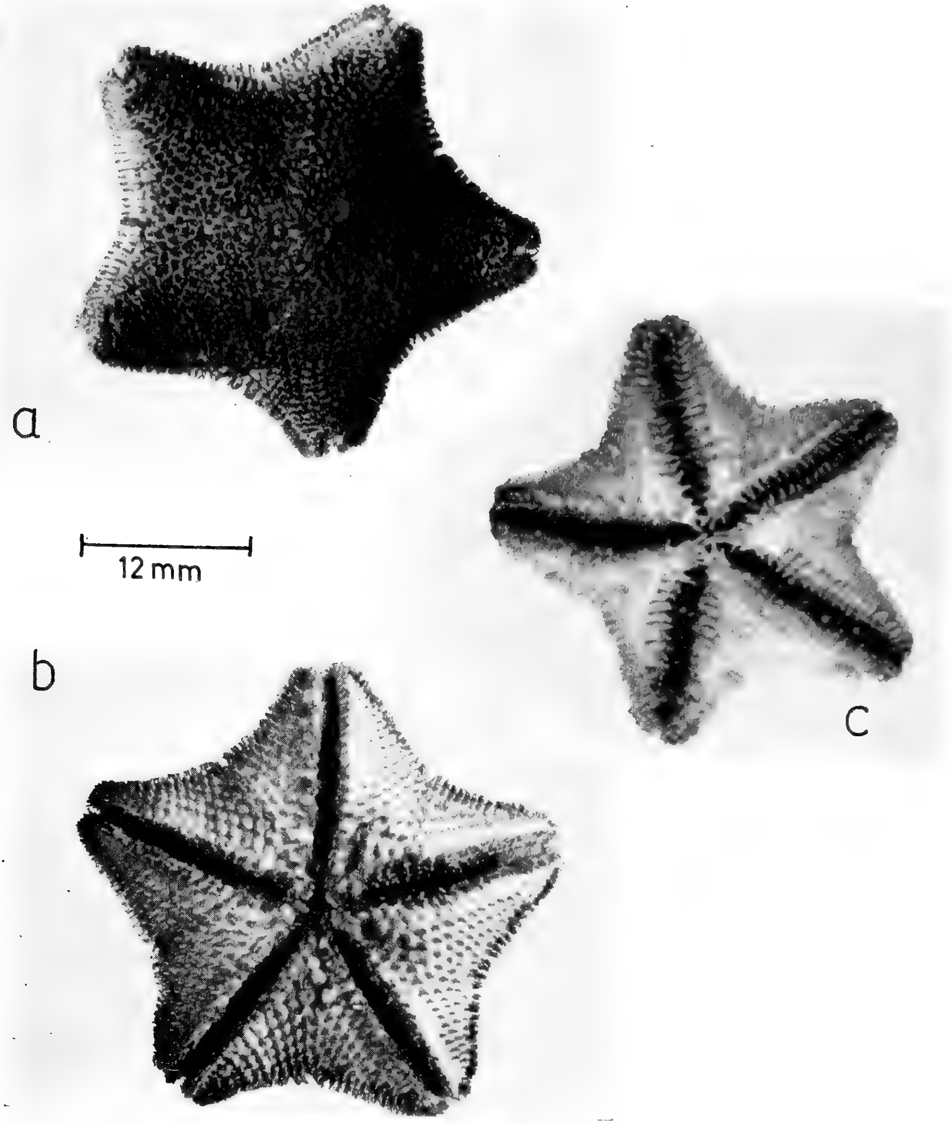
Marginaster littoralis sp. nov. is found associated with the asterinid *Patiriella regularis* (Verrill) in the type locality and may, at first, be confused with that species. The pale fringing border to the body and the large papulae which extend far on to the distal areas of the interradii are good field characters with which to distinguish *M. littoralis*.

Comments

Marginaster littoralis sp. nov. is recorded from a mid-littoral habitat at both stations from which it is known. Other species of *Marginaster* are known from greater depths (Table 2).

M. littoralis has variable but distinct grooves in the epidermis of the actinal surface as is also reported by Miss A. M. Clark (1962) in *Marginaster capreensis*. Subsequent dissection of *M. littoralis* revealed prominent rectal caecae and large channelled Tiedemann's pouches below the digestive diverticula. The cardiac stomach is extensible and surface mucus is abundant

PLATE XIII



and it is suggested that the species is a particulate feeder/algae grazer showing some functional similarities to *Porania pulvillus* (see Anderson, 1966). Detritus and algal fragments are the only food remains that have been observed in the stomachs examined.

TABLE 2

Distribution of Species of Marginaster

Species	Locality	Depth (metres)	Substrate	Reference
M. littoralis sp. nov.	S.E. Tasmania	Midlittoral	Rock	——
Marginaster sp. (cf. *M. paucispinus* Fisher)	B.A.N.Z.A.R.E. Station 113. Off Maria Island, Tasmania	174–155	—	A. M. Clark, 1962
M. paucispinus ..	China Sea (vicinity of Hong Kong)	157	Sand and shells	Fisher, 1919
M. echinulatus ..	Off Barbados	108	—	Sladen, 1889
	Cuba	—	—	H. L. Clark, 1941*
M. capreensis ..	North of Ireland and Rockall	2,125	—	Sladen, 1889
	Mediterranean	—	—	Tortonese, 1965*
M. pentagonus ..	Atlantic (Talisman Station 37)	342	—	Sladen, 1889

* References marked thus are not available to this author.

Acknowledgements

I wish to thank Dr. J. L. Hickman of the University of Tasmania who first drew my attention to the existence of *Marginaster littoralis.* I also wish to record my gratitude to Miss A. M. Clark of the British Museum (Natural History) who provided information not available to me in Tasmania and advised on the generic status of the animal.

References

ANDERSON, J. M., 1966.—Aspects of Nutritional Physiology. In *Physiology of Echinodermata.* Boolotian Ed., John Wiley, New York: 344–353.

CLARK, A. M., 1962.—Asteroidea. *B.A.N.Z. Antarctic Research Expedition Reports*, B, IX: 7, 9, 99.

CLARK, H. L., 1941.—Rept. Atlantis Expdns. The Echinoderms (other than Holothurians). *Mem. Soc. cubana Hist. nat.*, 15: 1–54.

FISHER, W. K., 1911.—Asteroidea of the North Pacific and adjacent waters. *Bull. U.S. Nat. Mus.*, 76: 1–419.

————, 1913.—New starfishes from the Philippine Is., Celebes and Moluccas. *Proc. U.S. Nat Mus.*, 46: 216.

————, 1919.—Starfishes of the Philippine Seas and adjacent waters. *Bull. U.S. Nat. Mus.*, 100 (3): 407–409, Pl. 131, figs. 2, 2a.

PERRIER, E., 1881.—Description sommaire des espèces nouvelles d'Astéries. *Bull. Mus. Comp. Zool.*, 9 (1): 16–17.

SLADEN, W. P., 1889.—Asteroidea. *Rep. Sci. Res. Challenger, Zool*, 30: 364–366, Pl. 58. fig. 4–6.

TORTONESE, E., 1965.—Echinodermata. *Fauna d'Italia.* Bologna 6: xv + 422.

EXPLANATION OF PLATE XIII

Marginaster littoralis sp. nov. (a) Abactinal surface of Holotype. Tasmanian Museum Reg. No. H 468. (b) Actinal surface of Holotype. (c) Actinal surface of live specimen to show enveloping epidermis and channels running from the inferomarginal fringe to the adambulacral plates.

A NEW SPECIES OF ERODIUM L'HÉR. FROM AUSTRALIA

R. C. Carolin
School of Biological Sciences, University of Sydney

[Read 24th September, 1969]

Synopsis

Erodium angustilobum is described and collections cited.

Erodium Angustilobum, sp. nov.

Herba annua adscendens ad 15 cm alta. Folia in rosula basili erecta vel adscentente et paribus oppositis caulinis disposita. Folia basales 15–45 mm. longa 10–20 mm. lata profunde pinnate 5–7–lobata pubescentia ambitu ovati vel elliptici lobus unusquisque oblongus vel anguste oblongus margine inferiore grosse dentato. Stipulae membranaceae late ovato-deltoideae vel ovato-anguste deltoideae pubescentes. Cincinnus floribus paucis vel duabus. Pedunculus pedicellisque pilis recurvatis simplicibus. Sepala elliptica vel anguste elliptico-oblonga 9 mm. longa 2·5–3·5 mm. lata dense pubescentia mucronata. Petala caerulea raro rosea. Filamenta staminum ca. 2–plo longiora quam staminodia. Mericarpia anguste obovoidea 6·5–7 mm. longa pilis longis subpatentibus et pilis brevioribus plus minusve appressis: fovea base aristatae plicis duabus indistinctis et serie pilorum in labio. Rostrum 40–50 mm. longum.

Annual herb up to 30 cm. high with a thin but distinct tap-root. *Leaves* arranged in an erect or ascending basal rosette and in opposite or nearly opposite cauline pairs: basal leaves; laminae ovate to elliptic in outline, 15–45 mm. long, 10–20 mm. wide, deeply pinnately lobed with 6 (rarely 4) lateral lobes and one terminal lobe each lobe oblong to narrow-oblong and deeply toothed or even lobed on the lower margin, pubescent with antrorsely curved simple hairs on both surfaces but slightly denser on the lower surface: petioles 25–65 mm. long, pubescent with variously curved simple hairs; cauline leaves smaller and somewhat narrower sometimes with fewer lobes; stipules membranous, broad-ovate-deltoid to ovate-deltoid, 2–3 mm. long, 2·5–1·5 mm. wide, pubescent, acute or obtuse. *Stems* ascending, pubescent with retrorse arcuate simple hairs. *Flowers* arranged in few- (frequently reduced to 2-) flowered monochasial umbels; peduncles up to 65 mm. long but usually ca. 15 mm. long, pubescent with recurved simple hairs; bracts ovate, 1·5 mm. long, 1–1·5 mm. wide, similar to the stipules; bracteoles lanceolate, ca. 1 mm. long and 0·4 mm. wide, similar to bracts; pedicels similar to peduncles, ca. 15 mm. long, geniculate at the base in the fruiting stage. *Sepals* elliptic to narrow-elliptic-oblong, 9 mm. long, 2·5–3·5 mm. wide, densely pubescent with short recurved simple hairs outside, glabrous inside, mucronate with a short (1 mm.) awn, more or less membranous and ciliate at the margin. *Petals* blue or rarely pinkish, obovate, slightly longer than the sepals. *Stamens*: filaments lanceolate, 3·5–4 mm. long, 1·5 mm. wide. *Staminodes* lanceolate, ca. 2 mm. long and 0·6 mm. wide. *Fruit*: mericarps narrow-obovoid, 6·5–7 mm. long, ca. 1·5 mm. wide, covered with long spreading stiff simple hairs curved upwards towards the top but not distinctly parted at the suture and also some shorter more appressed hairs; pit present at the base of the awn with two distinct folds beneath it and a line of hairs on the lip: awns gyred to the base with long silky-white hairs on the inside surface: rostrum 40–65 mm. long.

Range: South-western Queensland and into South Australia.

Habitat: Stony soils in open scrub communities.

Typification: *E. angustilobum* sp. nov.—Holotype—Nockatunga, South-western Queensland, R. Carolin no. 4158, 12.viii.1964 (NSW 118249)—Isotype—(SYD). Named after the lobes of the leaf which are narrower than in other Australian species.

Specimens Examined: *South Australia.* Ca. 1·5 km. south of Ten-Mile Dam, T. R. N. Lothian no. 4583, 26.vii.1968 (AD96840204): Musgrave Park, R. T. Lange no. 3, Aug. 1963 (AD96927235): 9 miles north of Warrina, T. R. N. Lothian no. 1375, 7.vii.1963 (AD96338066): 5 km. south of Warrina, T. R. N. Lothian no. 4907, 31.vii.1968 (AD96845282): Kingoonya to Coober Pedy, 6 km. south of Bon Bon Station, T. R. N. Lothian no. 4336, 19.vii.1968 (AD96840136): 84 km. south of Coober Pedy, T. R. N. Lothian no. 2278, 16.viii.1963 (AD96343233): 84 miles south of Coober Pedy, T. R. N. Lothian no. 2296, 16.viii.1963 (AD 96343234): 84 miles south of Coober Pedy, T. R. N. Lothian no. 2277, 16.viii.1963 (AD96343225): Mt. Eba Homestead, P. G. Wilson no. 2295, 28.vii.1962 (AD96317033): Tarcoola, E. H. Ising no. 1191, 5.ix.1920 (BRI1001873).

DISCUSSION

This species belongs to the endemic group previously dealt with (Carolin, 1958). It differs from *E. crinitum* Carolin in the sepal shape, shorter arcuate-retrorse hairs, the narrower lobes to the leaves, the shorter staminodes and the hairs on the lip of the pit at the base of the mericarp awn. From *E. cygnorum* ssp. *glandulosum* Carolin it differs in the simple indementum. Indeed, it shows most similarity to *E. cygnorum* Nees in Lehm. ssp. *cygnorum* but can be distinguished from it by the leaf-lobes and the pubescent pedicel. An occasional specimen of this last sub-species may have a more or less pubescent pedicel but the hairs are then coarser and much less arcuate; moreover the narrower leaf-lobes of *E. angustilobum* are apparently never found in *E. cygnorum.*

The type collection was found growing amongst specimens of *E. crinitum* and a few hundred yards from a colony of *E. cygnorum* ssp. *glandulosum.* No intermediates were found between any of these taxa despite a search for them.

ACKNOWLEDGEMENTS

I am indebted to Dr. Hj. Eichler for identifying and sending to me some specimens of this species located in the State Herbarium of South Australia. Also to Miss P. Baxter of the Queensland Herbarium for identifying the specimen located at Brisbane.

Reference

CAROLIN, R. C. 1958.—the species of the Genus *Erodium* L'Hér. Endemic to Australia. PROC. LINN. SOC. N.S.W., 83: 92.

FURTHER NEW SCOLYTOIDEA FROM THE TERRITORY OF PAPUA AND NEW GUINEA. 267. CONTRIBUTION TO THE MORPHOLOGY AND TAXONOMY OF THE SCOLYTOIDEA.

KARL E. SCHEDL,
Lienz, Osttirol Austria.
(Communicated by Dr. D. T. Anderson)

[Read 24th September, 1969]

Synopsis

In this paper twenty-nine new species of Scolytoidea are described and descriptions are given of *Cryphalus confusus* Egg. masc. nov., *Crossotarsus biconcavus* Schedl, fem. nov. and *Platypus semiopacus* Strohm., fem. nov.

INTRODUCTION

This paper is a continuation of a series on the Scolytidae and Platypodidae in the Territory of Papua and New Guinea collected by the Entomology Section, Department of Forests. All collections, except one, were made by members of the section during a survey of Scolytoidea in the Territory.

In this paper seven new species of Scolytidae, and *Cryphalus confusus* Egg. masc. nov., and twenty-two new species of Platypodidae, and *Crossotarsus biconcavus* Schedl, fem. nov. and *Platypus semiopacus* Strohm., fem. nov., are described. The numbers following the collectors name refer to the consignment number allocated to the specimens by the Department of Forests and the Department of Agriculture, Stock and Fisheries. The following abbreviations are used: E.H.D. (Eastern Highlands District), S.H.D. (Southern Highlands District), W.H.D. (Western Highlands District), Dist. (District) for other districts, D.N. (dialect name). The latter abbreviation has been employed to note the dialect name of the host plant as used by the natives in the collection area. These dialect names are usually quite reliable at the family level.

DESCRIPTION OF NEW SPECIES

(*a*) *Scolytidae*

CRYPHALUS ARAUCARIAE n. sp.

Piceous, 1·0 mm. long, 2·1 times as long as wide. Of about the same size as *Cryphalus papuanus* Schedl, but more cylindrical, the apex of the pronotum more broadly rounded, the disc more strongly convex, the asperities more pointed, the apical margin with four pointed remotely placed asperities, and the elytra with the vestiture more scale-like.

Front convex, moderately shining, minutely punctulate, somewhat indistinctly punctured.

Pronotum wider than long (12·4 : 11·0), postero-lateral angles rectangular and feebly rounded. the sides subparallel on the basal fourth, thence feebly obliquely narrowed, apex broadly-rounded, apical margin with four very small pointed and remotely placed asperities; summit high, anterior area steeply convex, with scattered pointed asperities on a rather wide area.

basal area long, densely granulate-punctate, with scattered fine erect short hairs, also, as far as present, with inclined fine and slender scales. Scutellum not clearly defined.

Elytra slightly wider than and 1·8 times as long as the pronotum, sides parallel on the basal half, thence gradually incurved, apex broadly rounded, declivity commencing in the middle, rather strongly convex; disc fairly shining, densely and finely punctured, the punctures of both series, the main rows and interstices of about the same size, the interstrial punctures seem to bear short, semierect hairs in the basal half of the elytra, these becoming replaced by hair-like scales towards and on the declivity (largely abraded in both specimens), between these hair-like scales with numerous minute and inclined pale hairs on the declivity.

Holotype in the Australian National Insect Collection in Canberra, one paratype in collection Schedl.

Type-locality: New Guinea, Bulolo, Morobe Dist., 22.x.1966, virgin forest in branchlets of *Araucaria cunninghamii,* B. Gray.

CRYPHALUS CONFUSUS Egg., masc. nov.

The type of *Cryphalus confusus* Egg., Treubia 9, 1927 p. 395 is a female from which we have a good series from Bulolo, Morobe District, 12.ii.1968, in stump of dead hardwood, B. Gray & Bereima. Along with several females there have been collected also some males. The latter vary in size from 2·1 to 2·3 mm., the pronotum being more triangular in outline, the anterior margin more narrowly rounded, the subapical constriction more distinct and less longitudinally convex.

Allotype in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

This species has been described from southern Sumatra, and has not been recorded from other places.

XYLEBORUS ARIES n. sp.

Female—Piceous, 3·1 mm. long, 2·9 times as long as wide. More Closely allied to *Xyleborus discrepans* Schedl, but much more slender, the interstices of the elytral disc uniseriately punctured, near the declivity these punctures as large as those of the main striae, the declivity more oblique, more densely covered with medium sized punctures.

Front convex, silky shining, minutely punctulate, a very short polished longitudinal carina in the centre, a few setose punctures on the anterior half, epistomal margin rimlike elevated, above with a transverse impressed line from which arise short erect bristles originating in medium sized punctures.

Pronotum distinctly longer than wide (33: 31), widest short behind the centre, postero-lateral angles strongly rounded, the sides subparallel on the second fifth counted from the base, thence gradually incurved, apex rather narrowly rounded, a subapical constriction hardly noticeable apical margin armed with minute low asperities; summit distinctly before the centre, anterior area obliquely convex, very densely covered with very small asperities, basal area brightly shining and finely not closely punctured, pubescence nearly absent. Scutellum of moderate size, impunctate.

Elytra slightly wider than (32 : 31) and 1·8 times as long as the pronotum, widest after the basal two fifths, sides straight and feebly divergent at first, little more convergent behind, apex somewhat angulately rounded, apical margin finely carinate, declivity commencing in the middle, very obliquely convex; disc shining, with very regular rows of medium sized punctures in subimpressed striae, interstices of moderate width, each with a less regular row of punctures being but little smaller than those of the striae, the punctuation of the disc continued on the declivity but appearing more dense and the punctures somewhat finer, the suture wide, feebly elevated, polished, with two to three remotely placed conical tubercles, two similar tubercles on the third interstices, one on the fifth.

Holotype in the Australian National Insect Collection in Canberra, one paratype in the collection of the Department of Forests in Bulolo and another one in Collection Schedl.

Type-locality: Awande, E. H. D. 12.ii.1968, in dead stump of hardwood sp., F. R. Wylie & S. Auno (nr. 10, 11).

XYLEBORUS DECLIVISPINATUS n. sp.

Female—Fusco—ferrugineous, elytra darker, 4·5 mm. long, 2·2 times as long as wide. This new species might be placed close to *Xyleborus superbus* Schedl, but is much smaller, has no longitudinal impression on the elytral declivity, the latter being very obliquely convex, and armed with serrations and spines.

Front feebly convex, silky shining, minutely punctulate, logitudinally wrinkled and coarsely punctured, with a median wide polished and longitudinal callosity commencing on the anterior margin and extending to the centre, the wrinkles and punctures fading away towards the vertex.

Pronotum slightly wider than long (14·7 : 14·0), subquadrate, posterlateral angles measuring little more than 90 degrees and very feebly rounded, sides slightly divergent on the basal third, thence feebly and obliquely narrowed, apex nearly transverse when viewed from above, antero-lateral angles well developed, anterior margin with very low and wide asperities and shallowly arcuate in the middle; summit very high, situated in the centre of the pronotum, anterior area very steeply convex, subperpendicular in front, very densely covered with rather small asperities, these asperities gradually changing to small punctures on the basal area, pubescence sparse and erect.

Elytra slightly wider than (15·3 : 14·7) and 1·5 times as long as the pronotum, widest in the middle, the sides feebly divergent on the basal half, to the same extent covergent behind, apex very broadly rounded, declivity commencing in the middle, very ebliquely convex; disc shining, striate-punctate, the striae distinctly impressed, the strial punctures of moderate size (on the first striae coarser) and not closely placed, the interstices plano-convex, polished and subimpunctate; on the declivity the strial punctures very large but hardly impressed, transverse, and very closely placed, the interstices 1 (not regular), 2, 3, 4 and 5 ceasing on the commencement of the declivital face with a short pointed tubercle, on the declivital face the first interstices (the suture) very narrow above, with a row of closely placed pointed tubercles increasing in size towards the apex below, the second interstices reduced to a narrow line above, narrowly elevated and armed with a few larger tubercles below, their size decreasing from the middle of the lower half of the declivity towards the apical margin, the third interstices reduced to a narrow zig-zag line but bearing in the upper third a smaller conical tooth thence a very large somewhat curved spine, the fifth interstices also reduced to a narrow line throughout, the seventh and ninth each with a row of pointed teeth increasing in size on the upper part of the declivity, the apical margin with numerous pointed tubercles.

Holotype in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-locality: New Guinea, Karamui, Chimbu District, 12.vi.1968, boring into log Derebe D.N. "ME" and boring into freshly fallen log Derebe D.N. "Sawodisay", B. Gray (nr. S204, S218).

XYLEBORUS INCERTUS n. sp.

Female.—Piceous, legs testaceous, 2·1 mm. long, 2·1 times as long as wide. Closely allied to *Xyleborus consimilis* Egg., probably a local form of it, but smaller, the pronotum more cylindrical in the basal two fifths, elytra feebly more elongate, the declivity less shining, the interstices smooth except the fine tubercles on the third and fifth.

Front convex, subopaque, minutely punctulate, also with shallow large punctures from which arise long setae, a fringe of such hairs also along the epistomal margin. Eyes stout, narrowly emarginate in front.

Pronotum but slightly longer than wide (29: 28), widest short behind the middle, postero-lateral angles rounded, the sides but feebly divergent on the basal third, thence gradually incurved, apex moderate broadly rounded, subapical constriction merely indicated, apical margin with numerous small and closely placed asperities; summit in the centre, convex and densely covered with small asperities in front, finely and sparingly punctured behind, pubescence sparse and erect. Scutellum large, triangular and polished.

Elytra but slightly wider than (29: 28) and 1·4 times as long as the pronotum, widest in the middle, the sides subparallel on the basal half, very little incurved behind, apex very broadly rounded, apical margin finely carinate up to the seventh interstices, declivity commencing in the middle, rather strongly, obliquely convex; disc shining, with fairly regular rows of punctures, those near the suture being somewhat larger, at the sides smaller and more remotely placed, the interstices rather wide, each with a row of setose punctures not quite as large as those of the main rows, the punctures replaced on the interstices 1, 3, and 5 by small pointed setose granules towards and on the upper part of the declivity, usually the last granules on the first interstices and two lower ones on the third interstices larger, declivital face with the punctures of the main rows large and situated in impressed striae, the suture feebly convex and somewhat elevated, the third interstices more strongly so, the second feebly impressed, subimpunctate above, usually with one minute pointed granule below.

Male.—Smaller, somewhat hump-shaped, 1·7–1·8 mm long, twice as long as wide.

Front rectangular before the eyes, feebly convex, silky shining, minutely punctulate, also a few fine punctures with long fine setae.

Pronotum about as wide as long, postero-lateral angles rounded, the sides subparallel in the median third, apex very broadly rounded, so that the antero-lateral angles become rather distinct, longitudinally rather feebly convex, in the anterior half more strongly so but without a distinct summit, surface subshining, minutely punctulate, anterior half with extremely small asperites which are of the same size all over, but gradually disappearing on the basal half, Scutellum polished, of moderate size.

Elytra distinctly wider than and 1·8 times as long as the pronotum, widest after the basal fifth of the elytra, thence feebly convergent, apex rather abruptly broadly rounded, declivity commencing after the basal two fifths, gradually obliquely convex, disc with the punctuation similar as in the female, the declivity more oblique, the apical margin more narrowly rounded, without any impressed striae, the strial punctures reduced in size, rather small, the suture and the third interstices less elevated, the longitudinal sulci along the second interstices shallow, on the first and third interstices with some fine punctures bearing short setae.

Holotype and allotype in the Australian National Insect Collection in Canberra, one male and several females paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-locality: New Guinea, Jimi Valley Rain Forest, W.H.D., 19.iv.1968, boring stem *Harpullia* sp., F. R. Wylie & S. Kaoko (nr. S273, S274).

XYLEBORUS PERPLEXUS n. sp.

Female. Piceous, 4·9 mm. long, 2·2 times as long as wide. Closely allied to *Xyleborus insulindicus* Egg. but smaller, the elytra less shining, the interstices on the upper part of the declivital convexity densely granulate-punctate, densely covered with shallow disclike punctures below, and the rim-like raised apical margin of the declivity extending higher up on the sides.

Front convex, silky shining, minutely punctulate, remotely and rather finely punctured, the punctures bearing medium long semierect hairs.

Pronotum as long as wide, widest at the commencement of the basal third, postero-lateral angles broadly rounded, the sides feebly divergent on the basal third, thence gradually and rather strongly incurved, apex rather narrowly rounded, apical margin with numerous extremely low but wide asperities, summit distinctly behind the centre, rather high, anterior area vary obliquely convex, very densely covered with low and rather small asperities, these gradually changing into fine transverse scratches on the basal area, pubescence restricted to the sides and the anterior area, moderate long and erect. Scutellum small, impunctate, polished.

Elytra distinctively wider than (65:59) and 1·6 times as long as the pronotum, widest close to the postero-lateral angles, sides nearly straight, apex abruptly incurved and very broadly rounded, declivity commencing after the basal third of the elytra, more slightly sloping above, steeper below, apical margin rimlike elevated up to the seventh interstices; disc short, shining, with rows of small punctures in hardly impressed narrow lines, interstices very wide, finely and irregularly punctured, the density of the punctures corresponding to about a double row; after the basal third of the elytra the punctuation of the interstices becomes more dense and at least some of the shallow punctures are being replaced by very small setose granules, the strial punctures becoming little larger and more disc-like, in the lower part of the declivity the punctuation more confused, the minute granules less abundant.

Holotype in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests and in collection Schedl.

Type-locality: Kerevat, New Britain Dist., 8.v.1968, ex fallen log *Pometia pinnata,* F. R. Wylie (nr. S155).

New Guinea: Tari Sawmill, S.H.D., 5.vi.1968, boring into freshly cut *Araucaria cunninghamii* logs, B. Gray (nr. S168). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log, Chimbu D.N. "Yumba", B. Gray & Sine (nr. S178). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into fallen log Chimbu, D.N. "Muroo", B. Gray & Sine (nr. S181). Wabag, W.H.D., 6.iii.1968, in Hardwood sp., D. H. Jeffers (nr. S260).

XYLEBORUS PERSPHENOS n. sp.

Female. Piceous, 2·0 mm. long, three times as long as wide. A new species with a cuneiform shape of the elytra similar to *Xyleborus sphenos* Samps. from Africa, but much smaller, the elytral disc more coarsely punctured, the pointed tubercles of the declivity replaced by small granules and the first interstices without an extension at the apical margin.

Front feebly convex, subopaque, minutely punctulate, on the anterior half rather coarsely punctured and with few long setae, more strongly convex towards the vertex.

Pronotum longer than wide (21: 20), widest in the middle, posterolateral angles rounded, the sides feebly divergent up to the middle, apex very broadly rounded, a subapical constriction hardly noticable, summit distinctly before the centre, the basalt part silky shining, minutely punctulate, very fine and somewhat indistinctly punctured, anterior part convex, densely covered with small asperities. Scutellum small.

Elytra feebly narrower than (20: 19) and 1·8 times as long as the pronotum, sides parallel on the basal half, thence strongly cuneiform, the extreme apex very narrowly rounded, declivity commencing in the middle, obliquely convex behind; disc silky shining, minutely chagrined, with rows of rather large punctures, interstices rather narrow, transversely wrinkled, each with a median row of extremely fine punctures bearing (as far as not abraded) semi-erect yellowish hairs; declivity with the strial punctures indistinct but in impressed striae, on the interstices the punctures replaced by regularly placed uniseriate setose pointed granules, those of the third interstices somewhat larger, the apex transverse between the third interstices.

Holotype in the Australian National Insect Collection in Canberra, one paratype in collection Schedl.

Type-locality: New Guinea: Simbai, Madang District, 18.vi.1968, boring into log Simbai D.N. "Cheramde", B. Gray (nr. S185). Simbai 2,500 m., Madang District, 18.vi.1968, boring into fallen log. S.D.N. "Contrabe", B. Gray (nr. S237).

XYLEBORUS VENUSTULUS n. sp.

Female. Piceous, very shining 6·4 mm. long, 2·2 times as long as wide, Allied to *Xyleborus insulindicus* Egg., but more slender, the cordiform depression of the elytral declivity more strongly developed, distinctly separated from the disc above, the punctuation coarser etc.

Front narrow between the very large eyes as in *Xyleborus insulindicus* Egg., but broadly convex (not concave), rather densely and coarsely punctured below, the punctures becoming smaller and more remotely placed above, with a broad fringe of fuscous hairs directed downwards below.

Pronotum feebly wider than long (22: 21), widest shortly before the base, postero-lateral angles rounded, sides feebly divergent on the basal fourth, thence obliquely incurved, with a very distinct subapical constriction, apical margin narrowly rounded and extended by a sharp erect carina; summit at the commencement of the basal third of the pronotum and fairly high, anterior area obliquely convex, very densely covered by medium sized low asperities, which become distinctly smaller around the summit and extend up to the base, with few scattered short hairs near the apex and along the side margins. Scutellum relatively small, polished, impunctate.

Elytra as wide and 1·4 times as long as the pronotum, widest in the middle, sides feebly divergent on the basal half, feebly incurved behind, very broadly rounded at the apex, the apical margin narrowly rimlike elevated and each elytron feebly separately rounded, declivity commencing short behind the basal half, anterior to it with an indistinct transverse depression of the disc, obliquely truncate, the truncate face broadly cordiform in outline and very shallowly depressed; disc shining, with rather small punctures in narrow feebly impressed lines, the striae more distinct near the suture and towards the base of the elytra, interstices fairly wide, densely and irregularly covered with punctures about of the same size than those in the main rows, the density of the interstitial punctuation corresponding to about a double row, declivital face with the strial punctures much larger but shallow, disc-like, the interstitial punctures similar but less numerous on account of the narrower interspaces, the suture feebly elevated towards the apical margin.

Holotype in the Australian National Insect Collection in Canberra, two paratypes in the collection of the Department of Forests in Bulolo, two paratypes in collection Schedl.

Type-locality: New Guinea: Jimi Valley Rain Forest, W.H.D., 19.ix.1968, boring in stem of *Harpullia* sp., F. R. Wylie (nr. S272.)

(*b*) *Platypodidae.*

CROSSOTARSUS ABDOMINALIS n. sp.

Male—Piceous, brightly shining, 9·1 mm. long, 2·7 times as long as wide. The largest species so far described of the *Crossotarsi barbati* and easily recognized by the apex of the elytra on which none of the interstices is produced into a spine or blunt process.

Front flat, shining, coarsely punctured towards the antero-lateral angles, similar punctuation within the eyes above, the punctures becoming smaller towards the vertex which is separated from the front by rather acute angles, in the centre with an impressed striga, shortly beneath a low polished and impunctate elevation from which extend feebly raised transverse lines towards the insertion of the antennae, a longitudinal impunctate space from the central striga to the vertex; a short erect pubescence restricted to the antero-lateral angles and on the extreme sides above.

Pronotum little wider than long (24: 22), lateral femoral emarginations shallow, disc brightly shining, sparsely and very finely punctured, median sulcus fine and short, continued anteriorly by a fine impressed line, a row of large setose punctures along the anterior margin.

Elytra but little wider than (26: 24) and 1·8 times as long as the pronotum, widest short behind the basal half, sides very feebly convergent towards the base, a little more so towards the apex, the latter transverse and wide, very feebly convex towards the suture, postero-lateral angles well defined and rectangular; disc shining, feebly convex in the distal half, very finely striate-punctate, the striae very narrow, the strial punctures extremely fine and very closely placed, the interstices very wide, nearly impunctate, but with some crowded larger punctures short before the apex, the declivity indicated by a sub-perpendicular narrow lunate face which is impunctate and separated from the posterior part of the declivital disc by an impressed arcuate line.

Abdomen opaque, ascending, last sternite with a very large triangular tooth on each side near the lateral border.

Female—little larger than the male, 9·5 mm. long, but with similar proportions, front broadly impressed between the eyes, brightly shining and minutely punctulate towards the vertex, coarsely and densely punctured and with erect reddish pubescence on the antero-lateral angles, the punctures fading out along a broad median longitudinal space and towards the eyes on the sides, a seam of long bristles along the inner edge of the eyes, a very gradually raised line extending from the center to the vertex in the middle, separation of vertex and front angulatey rounded, when viewed from above feebly biconcave. Antennal scape more elongate than in the male, about 1·5 times as long as wide. Pronotum as in the male, the elytra little more convex behind, the strial punctures less distinct, interstices 3 and 5 feebly elevated and finely granulate on a rather long space before the base, the striae and strial punctures fading away towards the apex, the interstices becoming silky shining, minutely punctulate and each with a short row of minute inclined hairs, the perpendicular lunate face of the declivity similar as in the male but more coarsely sculptured. Abdomen convex, opaque, without any armature.

Holotype, allotype in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-localities: New Guinea: Karamui, Chimbu District, 11.vi.1968, boring into fallen log. Derebe D.N. "Sape", B. Gray (nr. S191).

Karamui, Chimbu Dist., 12.vi.1968, boring into fallen log. Derebe D. N. "Pnugusea", B. Gray (nr. S198). Karamui, Chimbu Dist., 12.vi.1968, boring into freshly fallen log. Derebe D.N. "Sapae", B. Gray (nr. S207). Karamui, Chimbu Dist., 12.vi.1968, boring into fallen log Derebe D.N. "Sauroo", B. Gray (nr. S211). Karamui, Chimbu Dist., 12.vi.1968, boring into fallen log Derebe D.N., "Waade", B. Gray (nr. S214). Karamui, Chimbu Dist., 12.vi.1968, boring into freshly fallen log Derebe D.N. "Carpburu", B. Gray (nr. S220). Karamui, Chimbu Dist., 13.vi.1968, boring into fallen log. Derebe D.N. "Spa're", B. Gray (nr. S228).

CROSSOTARSUS BICONCAVUS Schedl, fem. nov.

Female—Piceous, 8·6 mm. long, 3·3 times as long as wide. General shape, proportions and even details of the sculpture very similar to *Crossotarsus mniszechi* Chap. except the antennal scape, which is much more slender, about three times as long as wide, forming a equilateral triangle and bearing on its upper edge a flat, slender and inwards directed appendage instead of the small pointed tooth in *Crossotarsus mniszechi* Chap. The pubescence of the front, usually abraded, consists of a plush of curled hairs on the lower outer parts of the frontal cavity, a seam of similar downwards curled hairs along the carina separating the front from the vertex, a seam of still longer hairs on the lower secondary carina on the sides and a seam of long hairs along the outer edge of the antennal scape.

The description is based on three specimens with complete pubescence, formerly erroneously identified as *Crossotarsus mniszechi* Chap. in my collection, originating from the following localities: Papua, Kokoda, 1300 ft, ix.1933, L. E. Cheesman; N.E. Papua, Mt. Lamington, 1300–1500 ft, C. T. McNamara; N. Guinea, Simbang, Huon Gulf, 1899, Biro.

A good number of females received from Mr. Barry Gray from various localities compare very well with these three specimens, but their pubescence is more or less abraded so that they can hardly be used for designation as types.

CROSSOTARSUS SUBOPACUS n. sp.

Male—Piceous, shining, 4·9 mm. long, 3·1 times as long as wide. Of a similar general shape as in *Crossotarsus lacordairei* Chap. but larger, the elytral declivity somewhat more sloping, opaque, the strial punctures reduced to obsolate, the interstices with remotely placed minute punctures bearing long fuscous hairs and the sutural angles on each side of the emargination not rounded but pointed.

Front flat, minutely chagrined, covered with somewhat remotely placed medium sized punctures bearing long semierect setae, feebly angulate towards the vertex.

Pronotum wider than long (42:39), widest before the moderately deep femoral emarginations, disc fairly shining, minutely chagrined, irregularly covered with small punctures of varying size, median sulcus long but very fine.

Elytra distinctly wider than (42:39) and 1·9 times as long as the pronotum, sides subparallel on little more than the basal half, apex angulately rounded, with a similar triangular sutural emargination as in *Crossotarsus lacordairei;* disc shining, with regular rows of rather small but very distinct punctures, the interstices wide, each one with some irregularly placed punctures of the same size as those of the striae, these punctures more crowded near the base, especially on the feebly elevated and triangularly widened third interstices; declivity commencing far behind the basal half of the elytra, obliquely convex, opaque, the striae reduced, entirely fading out towards the apical margin, each interstice with a regular row of minute punctures bearing long fuscous hairs more prominent in the upper half of the declivity. Abdomen horizontal.

Female—but little larger than the male, of similar proportion, coloration, shape and sculpture of the front and the pronotum; the elytral declivity more uniformely convex, opaque like in the male, the striae and strial punctures becoming entirely obsolate behind, the interstial punctures still smaller, the pubescence very sparse and short, apical margin broadly rounded without the sutural emargination of the male.

Holotype and allotype in the Australian National Insect Collection in Canberra, four paratypes in the collection of the Department of Forests in Bulolo, 1 female, 2 male paratypes in collection Schedl.

Type-locality: New Guinea: Watut Valley 1200 metres, Morobe Dist., 1.iii.1968, in fallen log of *Aglaia* sp., Bereima and S. Auno. Karamui, Chimbu Dist., 12.vi.1968, boring into freshly fallen log Derebe D.N. "Jar'kare", B. Gray (nr. S216).

CROSSOTARSUS VENTRISPINIS n. sp.

Male—Piceous, brightly shining, 3·2 mm. long, 3·3 times as long as wide. A new species belonging in the neighbourhood of *Crossotarsus nipponicus* Blandf. but much smaller, the elytra with rows of extremely fine punctures in hardly impressed lines, the sloping declivity relatively shorter and the second abdominal sternite with two spines in the middle, the upper one smaller, slender and pointed at the tip, the other one much longer, bent upwards and tridented at the tip.

Front flat, convex towards the vertex, shallowly areolate-punctate, with some very short hairs above. Antennal scape small, feebly longer than wide.

Pronotum little wider than long (27:26), widest at the anterior extremity of the well developed femoral emarginations, the latter angulate on both sides, disc silky shining, minutely chagrined, median sulcus long, with a row of small setose punctures along the anterior margin, a transverse band of coarser punctures near the base.

Elytra little wider than (29: 27) and twice as long as the pronotum, widest at the commencement of the declivity, sides straight and feebly divergent, apex with pointed lateral extensions as usual in the *Crossotarsi subdepressi,* apical margin between these extensions transverse; disc brightly shining, with rows of very fine punctures in hardly impressed lines, declivity restricted to the distal fourth of the eyltra, convex, the striae deeply impressed but without visible punctuation, interstices becoming carinate at first, gradually decreasing in height below, the entire declivity silky shining, minutely punctulate. Abdomen in the middle of the second sternite with two spines, the upper shorter one slender and pointed, the lower one much longer, bent upwards and tridented at the tip, the entire abdomen opaque.

Female—of the same colour, size and proportions as in the male, but the interstices of the elytral declivity less strongly carinate, the lateral extensions shorter and blunt at their tips, and the second abdominal sternite with a single long, slender spine being bent upwards at the tip.

Holotype and allotype in the Australian National Insect Collection in Canberra, male paratypes in the collection of the Department of Forests in Bulolo, a pair of paratypes in collection Schedl.

Type-localities: New Guinea: Kum 11 miles from Mt. Hagen W.H.D., 8.vi.1968, boring into freshly cut log. Chimbu D. N. "Muroo", B. Gray & Sine (nr. S175). Kum 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log. Chimbu D.N. "Yumba", B. Gray & Sine (nr. S179). Wabag, W.H.D., 6.iii.1968, in hardwood sp., D. H. Jeffers (nr. S262).

DIAPUS PUER n. sp.

Male—Castaneous, underside and legs largely testaceous, 2·8 mm. long, 3·2 times as long as wide. More closely allied to *Diapus aculeatus* Blandf., but somewhat larger, the front with a small longitudinal carina in the middle just above the epistomal margin, the antennal scape stout and flattened, the pronotum with a wide transverse band of closely placed pores along the basal margin, the three spines at the extremity of the elytra blunt, etc.

Front trapezoid in outline, widest above, flat, silky shining, minutely chagrined, remotely rather coarsely punctured, the punctures bearing medium long hairs, convex towards the vertex, the latter with the usual three polished longitudinal vitae, the median one terminating in front more abruptly thus looking like a small tubercle. Antennal scape stout, flattened, but little longer than wide.

Pronotum longer than wide (28: 25), widest behind the well developed femoral emarginations, disc brightly shining, near the base with a wide transverse band of closely placed medium sized pores.

Elytra slightly wider than and 1·6 times as long as the pronotum, sides subparallel, disc horizontal, with three blunt spines at the extremity, the first one but little shorter than the second, the third obliquely connected with the side margin of each elytron, the ninth interspace indicated by a more or less distinct small and blunt toothlike extension; disc rather shining, minutely chagrined, with rows of fine and remotely placed punctures, the latter obscured on the sides near the apex, between the upper dentate margin and the lower extremity of each elytron narrowly sulcate, the lower margin with a small pointed tooth in the continuation of the third interstices, the teeth of the upper margin with fine and long setae. Last abdominal sternite wide, feebly concave, opaque, finely punctulate.

Holotype in the Australian National Insect Collection in Canberra, 7 cotypes in the Department of Forests, Bulolo and 3 ♂ ♂ in collection Schedl.

Type-locality: New Guinea: Oomsis, Morobe Dist., 15.ii.1968, boring into fallen log (1 Month) of *Anisoptera* sp., B. Gray (nr. 12).

DIAPUS SPINIFER n. sp.

Male—Piceous, a transverse band near the base of the elytra castaneous, 2·3 mm. long, 4·0 times as long as wide. A peculiar new species of the genus *Diapus* easily recognised by four spines of the elytral declivity.

Front flat, silky shining, with a few coarse punctures on the antero-lateral angles and in the middle above, some other setose punctures along the convexity towards the vertex. Antennal scape long and slender, club-shaped.

Pronotum longer than wide (21:17), widest behind the strongly incurved femoral emarginations, disc shining, a punctuation nearly obsolate except a row of setose small punctures along the anterior border, median sulcus fine but rather long, the sensory pittings near the base, common in all species of *Diapus,* straight, narrow and moderately long.

Elytra as wide and twice as long as the pronotum, sides parallel in the basal half, very feebly convergent behind, apex transverse, with a lateral process on each side having the shape of a slender triangular tooth; disc shining, strial punctures nearly obsolate in the central portion, those of the first striae more distinct, sometimes also a few very fine punctures of the second row, a few such punctures also visible from other rows near the base; declivity abruptly perpendicular and rather low, apical margin broadly arcuate, at the commencement of the declivity on each side of the suture with a long and slender tooth surpassing in length the postero-lateral processes. Last abdominal sternite concave, brightly shining, coarsely punctured, the punctures near the margins bearing long fine hairs.

Female—similar in size to the male, the pronotum and elytra but slightly stouter, the head somewhat larger, the front and antennal scape as in the male, but with very large mandibular appendages, these being nearly as long as the pronotum, directed straight forward, laterally compressed, three times as long as wide, somewhat twisted near the base, the sides feebly narrowed on the anterior third and rounded, blunt at the tip. Pronotum as in the male, the elytra without any teeth at the apex, apical margin transverse, the postero-lateral angles rounded, the disc more silky shining, minutely chagrined, with rows of very fine punctures in feebly impressed striae, the interstices with scattered punctures of similar size to those of the main striae. Last abdominal sternite not quite as wide as in the male.

Holotype and allotype in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-localities: New Guinea: Porotop L. M. Station, W.H.D., 6.iii.1968, in *Syzygium* sp., D. H. Jeffers (nr. S253). Porotop L. M. Station, W.H.D., 6.iii.1968, in *Podocarpus* sp. D. H. Jeffers (nr. S257). Porotop L. M. Station, W.H.D., 6.iii.1968, in *Nothofagus* sp., D. H. Jeffers (nr. S258). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log. Chimbu D.N. "Yumba", B. Gray & Sine (nr. S176). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log. Chimbu D.N.

"Yumba", B. Gray & Sine (nr. S179). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into fallen log Chimbu D.N. "Muroo", B. Gray & Sine (nr. S182). Kum, 11 miles from S. Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log Chimbu D.N. "Da'me", B. Gray (nr. S184). Simbai, Madang, Dist. 18.vi.1968, boring into log Simbai D.N. "Cheramde", B. Gray (nr. S185). Kum, 11 miles S. Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly cut log. Chimbu D.N. "Nogare", B. Gray & Sine (nr. S186).

DIAPUS PAPUANUS Schedl, ROBUSTUS n. sp, ELONGATUS n. sp. and NANUS n. sp.

Among the males of the genus *Diapus* known from New Guinea there are two species having the elytra horizontal, carinate at the apex, the carina extending to the postero-lateral angles, therefore arcuate at their lateral extremity and joining the side margins at their tip. The elytral declivity is perpendicular below the carina, more convex below, the apical margin broadly arcuate. The sensatory pittings near the base of the pronotum are straight, narrow and rather long in *Diapus pusillimus*, much shorter, wider and arcuate on each side, with the arch directed towards the base in *Diapus papuanus* and its relatives discussed below. The main differences in the males of the *papuanus* group are manifest in the size, the proportions of the elytra and in the shape of the postero-lateral angles of the elytra, while the antennal scape is always club-shaped, the insertion of the funicle situated at the tip; in the females in the shape of the antennal scape and the mandibular appendages, while the general appearance and the sculpture of these closely allied species is very much the same. The specific differences can best be learned from the following key.

1\. Sensatory pittings near the base of the pronotum in both sexes straight, narrow and relatively long, male elytra with the postero-lateral angles pointed but not produced, declivity with a pointed tubercle in continuation of the third interstices near the apical border, female antennal scape club-shaped, mandibular appendages fork-like. 1·9–2·0 mm. .... *pusillimus* Chapuis

1\. Sensatory pittings near the base of the pronotum in both sexes short, wide, arcuate in each half γ[1] the arch directed towards the base of the pronotum, male elytral declivity without large tubercle in continuation of the third interstices near the apical border, sometimes with a few setose punctures below the carina 2

[1] γ (similar to the Greek letter omega).

2\. Male postero-lateral angles of the elytra drawn out into well developed triangular projections being as long as or slightly longer than the arcuate apical margin of the elytra, female not known yet. 2·6–2·8 mm.
Type-locality: New Guinea: Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log. Chimbu D. N. "Yumba", B. Gray & Sine (S176, S179). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log, Chimbu D.N. "Muroo", B. Gray & Sine (S716). Simbai, Madang Dist., 18.vi.1968, boring into log, Simbai D.N. "Cheramde", B. Gray (S185). .... *robustus* n. sp.

2′. Male postero-lateral angles of the elytra angulate, sometimes pointed but without remarkable triangular extensions and shorter than the arcuate apical margin of the elytra, small to moderately large species. 1·7–2·2 mm. 3

3\. Male elytra slender, 2·0–2·1 times as long as wide, female antennal scape slender and clubshaped, insertion of the funicle at the tip of the antennal scape, mandibular appendages cast off in the females available. 1·9–2·1 mm.
Type-localities: New Guinea: Marafunga 2800 m., E.H.D., 1.vi.1968, in freshly fallen log. *Cryptocarya* sp. B. Gray (S158). Marafunga 2800 m., E.H.D., 2.vi.1968, in freshly cut log *Podocarpus* sp., B. Gray (S160). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log. Chimbu D.N. "Yumba", B. Gray & Sine (S176). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into fallen log Chimbu D.N. "Muroo", B. Gray & Sine (S182). .... *elongatus* n. sp.

3′. Male elytra stouter, 1·7–1·9 times as long as wide 4

4\. Larger, 1·9 to 2·2 mm. long, female antennal scape long, triangularly widened distally, insertion of funicle at the outer corner, inner lobe large, with an appearance of long curled hairs, mandibular appendages short, much shorter than the antennal scape, somewhat fork-shaped.
Type-localities: New Guinea: Porotop L. M. Station, W.H.D., 6.iii.1968, in *Podocarpus* sp., D. H. Jeffers (S257). Porotop L. M. Station, W.H.D., 7.iii.1968, in

log, D. H. Jeffers (S265). Kum, 11 miles S. from Mt. Hagen, W.H.D., 8.vi.1968, boring into fallen log. Chimbu D.N. "Coonape", B. Gray (S183). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, "Muroo", B. Gray & Sine (182).. *papuanus* Schedl.

4′. Smaller, 1·7–1·9 mm. long, female antennal scape clubshaped, insertion of funicle at the tip, mandibular appendages cast off.
Type-localities: New Guinea: Erave pine forest, S.H.D., 14.viii.1967, in log *Castanopsis acuminatissima*, B. Gray (19). Virgin Forests, Manki, 1300 m. Bulolo, Morobe Dist., 1.iii.1968, in fallen (5 months) log *Araucaria cunninghamii*, B. Gray & S. Auno & Bereima (30). Tari Sawmill, S.H.D., 5.vi.1968, boring into freshly cut log, Huri D.N. "Bia", B. Gray. Baiyer River Sanc. W.H.D., 7.vi.1968, in freshly fallen hardwood log, Baiyer dialect name "Karup", B. Gray (S173). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into fallen log, Chimbu D.N. "Muroo", B. Gray & Sine (S182). Karamui Chimbu Dist., 12.vi.1968, boring into fallen log. Derebe D.N. "Pn'ugusea", B. Gray (S199). Manki Range, 1300 m.a.s.l. Bulolo, Morobe Dist., 10.viii.1968, attracted to freshly fallen *Castanopsis acuminatissima*, B. Gray (S250)................................. *nanus* n. sp.

Holotypes and allotypes as far known in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

PLATYPUS FASTUOSUS n. sp.

Male—Piceous, brightly shining, 5·6 mm. long, 3·2 times as long as wide. Allied to *Platypus biformis* Chap., but the elytra more coarsely punctured, the apex much more narrowly rounded, the declivity more obliquely convex, the lower part of it impunctate and the two teeth on each side more separated from each other.

Front flat, hardly noticably impressed, densely covered with punctures of varying size, the greater part of them rather coarse, all bearing very fine and long semi-erect hairs radiating from the centre, in the latter with a small impressed striga. Antennal scape small, about one and half times as long as wide.

Pronotum feebly wider than long (13 : 12), widest behind the very shallow femoral emarginations, disc shining, covered with sparsely placed extremely fine punctures bearing long but very fine hairs, median sulcus moderately long and fine.

Elytra slightly wider than (14·3 : 13·0) and 2·3 times as long as the pronotum, widest at the commencement of the declivity, sides straight and very little divergent, gradually incurved on the distal half, apex rather narrowly rounded, declivity commencing short behind the basal half, very obliquely convex; disc shining, finely and very regularly striate-punctate, the strial punctures distinctly coarser and more closely placed on the first three rows, much finer and more remotely placed on the sides, interstices moderately wide, minutely granulate near the base, with fine setose punctures arranged in irregular rows behind, usually at least part of the pubescence abraded; towards the declivital convexity the interstitial punctures replaced by fine uniseriately arranged granules bearing longer fuscous hairs, lower half of the convexity polished, transversely impressed shortly before the apical margin, impunctate except a few setose granules on the first interstices, in the middle of the convexity on the junction of interstices three and five with a conical tooth, another but slightly smaller one on the ninth interstices a short distance behind. Abdomen ascending convex, densely and finely punctures.

Holotype in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-localities: New Guinea: Marafunga 2800 m., E.H.D., 2.vi.1968, in freshly cut log *Podocarpus* sp., B. Gray (nr. S161). Porotop L. M. Station, W.H.D., 6.iii.1968, in *Podocarpus* sp., D. H. Jeffers (nr. S256).

PLATYPUS MIRANDUS n. sp.

Male—Piceous, pronotum and head more reddish brown, 4·0 mm. long, 3·3 times as long as wide. This new species being a member of the *Platypi subsulcati* holds a rather isolated position especially on account of the armed fourth abdominal sternite.

Front flat, opaque, minutely punctulate, sparsely and very finely punctured, more distinctly so on the sides and towards the vertex, the punctures bearing semierect fine and long hairs, with a very fine longitudinal striga in the centre. Antennal scape small, feebly wider than long.

Pronotum longer than wide (35·0 : 32·5), widest at the posterior angulate extremity of the moderately deep femoral emarginations, disc shining, with scatered fine punctuation, the punctures more crowded around the short median sulcus, but not forming a distinctly limited patch as common in some species of the *Platypi subsulcati*, some setose punctures along the anterior margin.

Elytra somewhat wider than (36·0 : 32·5) and 1·9 times as long as the pronotum, sides subparallel on the basal three fifths, thence gradually incurved, apex broadly rounded, declivity restricted to the distal third of the elytra, obliquely convex; disc sulcate punctate, the sulci rather narrow and shallow near the base becoming deeper but not very wide behind, the punctures in the sulci indistinct, the interstices moderately wide and rather low, near the base more narrowly carinate and with some fine punctures towards the declivity, the interstices 1, 2, 4, 5 and 6 finely serrate and each with a row of short semi-erect hairs on the upper part of the declivity fading away below, the third interstice drawn out into a rather long, horizontal, cylindrical, tooth bifid at the tip, the seventh interstice forming a short carinae ceasing abruptly, declivital face opaque, minutely punctulate, with a conical tooth near the apical margin in continuation of the fifth interstice. Abdomen opaque, minutely punctulate, the fourth sternite with a transverse row of three to five conical teeth.

Holotype in the Australian National Insect Collection in Canberra, one paratype in collection Schedl.

Type-locality: New Guinea: Karamui, Chimbu Dist., 13.vi.1968, boring into fallen log. Derebe D.N. "How'wa", B. Gray (nr. S230).

PLATYPUS OPACIDECLIVIS n. sp.

Male—Piceous, brightly shining, elytral declivity opaque, 4·4 mm. long, 3·2 times as long as wide. Allied to *Platypus semiopacus* Strohm. but smaller, pronotum without regular patch of punctures around the median sulcus, elytral declivity shorter, more strongly convex and without transverse depression before the declivity.

Front flat, subopaque, minutely punctulate, with scattered very fine punctures bearing semi-erect hairs. Antennal scape stout, but little wider than long.

Pronotum little longer than wide (41 : 37), widest at the posterior angulate extremity of the moderately deep femoral emarginations, disc shining, polished, very sparsely and extremely fine punctured in the anterior half, the punctures rather crowded and distinctly larger behind, median sulcus long and fine, a series of setose punctures along the anterior margin.

Elytra somewhat wider than (41 : 37) and not quite 1·9 times as long as the pronotum, widest shortly behind the middle, the sides straight and feebly divergent on little more than the basal half, gradually incurved behind, apex angulately, rather narrowly rounded, declivity commencing short behind the basal half, obliquely convex; disc shining up to the commencement of the declivity, finely striate-punctate, the strial punctures very small, indistinct in part, the striae extremely narrow, interstices wide, with scattered minute punctures; declivity opaque, minutely punctulate, for a short space irregularly granulate, lower down the sparsely placed granules indicating the interstices, all granules with long semi-erect hairs, shortly before the apical margin usually with a distinct, sometimes with an obscured larger tubercle. Abdomen nearly horizontal.

Female—little larger and more elongate than the male, the apical margin of the elytra broadly rounded, the elytral declivity shorter. Front armed with two parallel longitudinal lamellae on the anterior half similar as in the allied species; the pronotum with a very large cordiform patch of closely placed small punctures surrounding the median sulcus; elytra elongate, cylindrical, declivity restricted to the distal fourth and rather strongly convex, disc brightly shining, very finely striate-punctate, the interstices very wide, subimpunctate, the base of the third and fifth triangularly elevated and finely rugose, on the declivity all interstices with not very densely placed semi-erect long hairs originating from very fine punctures, this pubescence more dense on the lower triangular and perpendicular face characteristic to the females of a great number of Platypodids.

Holotype and allotype in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-localities: New Guinea: Tari Sawmill, S.H.D., 5.vi.1968, boring into freshly cut hardwood log, B. Gray (nr. S164). Tari Sawmill, S.H.D., 5.vi.1968, boring into freshly cut *Araucaria cunninghamii* logs, B. Gray (nr. S167). Tari Sawmill, S.H.D., 6.vi.1968, boring into stem live *Macaranga* sp. B. Gray (nr. S169). Karamui, Chimbu Dist., 12.vi.1968, boring into freshly fallen log. Derebe D.N. "Carpburu", B. Gray (nr. S220).

PLATYPUS PRAECELLENS n. sp.

Male—Piceous, brightly shining, 3·8 mm. long, 4·1 times as long as wide. Closely allied to *Platypus praepositus* n. sp., but more slender, the pronotum with an elongate cordiform patch of closely placed punctures around the median sulcus, the elytral declivity shorter and the lunate face nearly perpendicular, the apical margin between the large triangular lateral processes (not visible when viewed from above) about semicircular.

Front flat, subopaque, minutely punctulate, irregularly and coarsely punctures, a median longitudinal carina extending from the centre of the beginning of the vertex, on the latter scattered setose punctures. Antennal scape small, about one and a half times as long as wide.

Pronotum longer than wide (33: 26), widest at the posterior angulate of the well developed femoral emarginations, disc shining, with scattered very small punctures displaced rather irregularly, median sulcus long and very fine, surrounded by an elongate cordiform patch of closely placed distinct punctures.

Elytra feebly wider than (28: 26) and 1·8 times as long as the pronotum, widest at the commencement of the declivity, the sides straight and nearly parallel, apical margin feebly arcuate, with blunt rectangular poster-lateral angles and with blunt tubercles in continuation of the third interstices when viewed from above, when inspected from behind the ninth interstices produced into minute teeth at the outer edge of the large triangular and pointed lateral processes, between the latter semicircularly emarginate; disc brightly shining, the strial punctures extremely fine, situated in impressed lines near the base, the first row impressed throughout; the declivity short, measuring about one fifth of the total length of the elytra, abruptly convex, on the upper part of the declivital convexity the striae distinctly impressed, the interstices rugose and each with a row of short semi-erect bristles, the lower perpendicular lunate face polished, with a few setose fine punctures and separated from the upper convex part of the declivity by a low rimlike elevation. Abdomen ascending convex.

Holotype in the Australian National Insect Collection in Canberra, one paratype in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-localities: New Guinea: Porotop L. M. Station, W.H.D., 6.iii.1968, in *Nothofagus* sp., D. H. Jeffers (nr. S259). Porotop L. M. Station, W.H.D., 7.iii.1968 in log, D. H. Jeffers (nr. S268).

PLATYPUS PRAEPOSITUS n. sp.

Male—Piceous, brightly shining, 4·2 mm long, four times as long as wide. This new species might belong in the neighbourhood of *Platypus kokodaensis* Schedl, but is more elongate, the elytral disc being more finely striate-punctate, with the postero-lateral processes shorter, triangular, blunt at their tips, apical margin between the processes wider than long, trapezoid the lateral processes double notched, as in some species of the *Platypi cupulati*.

Front flat, subopaque, minutely punctulate, shallowly punctured and with some longitudinal wrinkles and a longitudinal carina in the centre, pubescence sparse, more or less restricted to the punctures near and on the vertex. Antennal scape small, not quite twice as long as wide.

Pronotum longer than wide (40 : 29), femoral emarginations short and moderately deep, angulate behind, disc shining, with numerous very fine punctures of varying density, median sulcus very fine and long, not quite extending to the centre.

Elytra feebly wider than (31 : 29) and 1·7 times as long as the pronotum, widest shortly before the middle, sides somewhat divergent at first, a little more convergent behind, the postero-lateral processes large, triangular, blunt at their tips and visible when viewed from above, the apical margin between in outline, with a short triangular extension in continuation of the third interstices of the elytra thus forming a secondary u-shaped notch at the suture; disc brightly shining, regularly striate—punctate, the striae very narrow but well impressed, the strial punctures small, elongate and closely placed, interstices moderately wide, each with some scattered minute punctures; declivity restricted to the distal two-fifths of the entire elytra, feebly convex above, the convexity with more irregularly placed coarse punctures bearing short semi-erect hairs, perpendicular face of the declivity lunate as in the allied species, the upper margin angulate but not carinate, the lunate face shining, concave, with a few setose punctures near the upper margin, the ninth interstices indicated shortly before the beginning of the postero-lateral processes by very small toothlike edges. Abdomen ascending convex.

Holotype in the Australian National Insect Collection in Canberra, paratypes in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-localities: New Guinea: Watut Valley 1200 metres, Morobe Dist., 1.iii.1968, in fallen log of *Xanthophyllum* sp., B. Gray & F. R. Wylie (nr. 26). Karamui, Chimbu Dist., 11.vi.1968, boring into fallen log. Derebe D.N. "Kero", B. Gray (nr. S193). Karamui, Chimbu Dist., 11.vi.1968, boring into fallen log. Derebe D.N. "Pn'ugusea", B. Gray (nr. S197).

PLATYPUS PRAETERITUS Schedl.

Male—Piceous, brightly shining, 4·9 mm. long, 3·1 times as long as wide. Somewhat allied to *Platypus crassiusculus* Schedl, but smaller, the interstices 1, 4–9 not carinate towards the declivity and not produced into small spines, but gradually declivous.

Front feebly concave from eye to eye and from the anterior margin to the vertex, cavity silky shining, rather finely reticulate-punctate in the middle above, the punctures larger, more sparsely placed and with long fuscous hairs along the eyes and towards the vertex, a few more setose punctures on the sides below, the lower half more shining, minutely punctulate and sparsely covered with some medium sized punctures. Antennal scape small, club-shaped.

Pronotum slightly wider than long (39: 36), widest before the moderately deep femoral emarginations, disc shining, with remotely placed very fine punctures, those along the anterior margin with long erect hairs, median sulcus fine and long extending to the centre of the pronotum, anterior to it with a cordiform patch of densely placed fine punctures looking as if pierced with a needle.

Elytra distinctly wider than long (47: 39), widest at the commencement of the declivity, sides straight and feebly divergent on the basal three fifths, thence gradually and rather strongly incurved, apex rather narrowly rounded, declivity commencing short behind the basal half, obliquely convex; disc shining, striate-punctate, the striae distinctly impressed, the strial punctures extremely fine, interstices feebly convex, 2–5 finely granulate near the base, on the remaining space each with a few scattered fine punctures, interstices 1, 4 to 9 feebly serrate and with semi-erect setae towards the declivity, the second interstices drawn out into short horizontal and very pointed spines, the third ones with a similar but much shorter pointed tooth, declivital face opaque, minutely punctulate, the striae and serrations of the interstices gradually becoming obsolete, in continuation of the third interstices with a large conical spine in the lower third of the declivity. Abdomen ascending convex, densely punctured and with sparse long pubescence.

Female—Similar in size, proportions and sculpture to the male, the pubescence somewhat more dense on the front, the elytra with the striae more strongly impressed towards and on the upper part of the declivity, the interstices feebly convex, rather wide, each with a few scattered fine punctures, the third triangularly widened, somewhat elevated and densely granulate at the base, interstices 1, 2, 4 and 5 with a series of granules only; all interstices more convex on the upper part of the declivital convexity, each one with a series of minute granules bearing rather long semi-erect bristles, a small conical tubercle on the junction of interstices three and seven.

Holotype and allotype in the Australian National Insect Collection in Canberra, one male paratype in the collection of the Department of Forests in Bulolo, one pair of paratypes in the collection Schedl.

Type-localities: New Guinea: Porotop L. M. Station, W.H.D., 6.iii.1968, in *Syzygium* sp., D. H. Jeffers (nr. S254). Wabag, W.H.D., 6.iii.1968, in hardwood sp., D. H. Jeffers (nr. S263).

PLATYPUS SEMIOPACUS Strohm., fem. nov.

Female—Piceous, 4·7 mm. long, 3·7 times as long as wide. Easily distinguished from the allied females by size, the more remotely placed frontal lamellae, the rather long rugose base of the third interstices of the elytra and the subtuberculate elytral declivity.

Front flat, subimpressed in the centre. opaque, minutely punctulate, with scattered very fine punctures bearing long erect setae, somwhat longitudinally wrinkled on the sides below, a small impressed striga in the centre, with two low, rather remotely placed longitudinal lamellae on the anterior half, similar to the allied species.

Pronotum longer than wide (13·0: 11·5), femoral emarginations shallow, somewhat angulate behind, disc brightly shining, with scattered minute punctures on the anterior half, the punctures a little larger towards the base, median sulcus moderately long, surrounded by a very large cordiform patch of fine and closely placed punctures, an irregular row of setose punctures along the anterior margin.

Elytra feebly wider than (12·5: 11·5) and 2·2 times as long as the pronotum, the sides parallel on the basal two thirds, apex broadly rounded, declivity short, restricted to the apical third of the elytra; disc shining, with rows of hardly visible minute punctures, the interstices wide, third interstice carinate-granulate on a rather long space before the base, thence triangularly widened and granulate and connected with the fifth interstices by a granulate band, the fifth also with a short granulate carina; towards the declivity the strial punctures more distinct, the interstices each with a few minute granules bearing long semi-erect setae, the lower triangular and more perpendicular face of the declivity finely and densely punctured and densely pubescent.

Allotype in the Australian National Insect Collection in Canberra, one paratype in collection Schedl.

Type-localities: New Guinea: Porotop Lutheran Mission Station. W.H.D., 7.iii.1968, in log, D. H. Jeffers. Porotop Lutheran Mission Sawmill, W.H.D., 11.viii.1967, in log of *Podocarpus* sp., B. Gray.

PLATYPUS SEMISULCATUS n. sp.

Male—Dark reddish brown, 3·7 mm. long, 3·3 times as long as wide. Allied to *Platypus truncatigranosus* Schedl, but the pronotum with a large transversely cordiform patch of closely placed punctures, the elytra opaque except near the extreme base and the wide third interstices, the striae indistinctly punctured near the base becoming rather widely impressed and minutely rugose behind, the interstices more narrow, feebly elevated and flat on top, except the third ones which are shining, rather wide near the base, more strongly elevated and distinctly decreasing in width towards the declivity, the latter truncate as in *Platypus truncatigranosus* Schedl but the apical margin not uniformly rounded, but feebly and widely incurved near the suture, the interstices of the disc not so abruptly ceasing at the commencement of the truncate declivity.

Front flat, opaque, minutely punctulate, a few setose and fine punctures on the anterior third, a short median longitudinal striga in the centre. Antennal scape small, about one and a half times as long as wide.

Pronotum longer than wide (32:29) widest at the pointed posterior extremities of the well developed femoral emarginations, disc brightly shining, with few scattered extremely fine punctures, a series of larger and setose ones along anterior margin, median sulcus fine and long, surrounded by a large transversely cordiform patch of closely placed fine punctures.

Elytra somewhat wider than (33:29) and twice as long as the pronotum, widest at the commencement of the truncate declivity, the sides straight and distinctly divergent on the basal four-fifths, apex very broadly rounded and with a shallow impression in the centre; disc with indistinct rows of fine punctures near the base, after the basal fourth with rather wide, impressed striae being minutely punctulate, therefore of a silky texture and with clearly defined side margins, the interstices narrower than the sulci of the striae, of the same texture, the 5th, 7th and 9th with a few pointed serrations, these more closely placed near the base, the third interstices shining, wide near the base, diminishing in width towards the declivity which is obliquely truncate, all interstices becoming covered with setose granules short before the commencement of the declivity and continued on the declivital face by uniseriate rows of blunt granules, more irregularly and more densely placed below, in the middle of the declivital face in continuation of the third interstices with an acute pointed tubercle. Abdomen nearly horizontal.

Holotype in the Australian National Insect Collection in Canberra, one paratype in the collection of the Department of Forests in Bulolo, another one in collection Schedl.

Type-localities: New Guinea: Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly cut log. Chimbu D.N. "Muroo", B. Gray & Sine (nr. S175). Kum, 11 miles from Mt. Hagen, W.H.D., 8.vi.1968, boring into freshly fallen log. Chimbu D.N. "Yumba", B. Gray and Sine (nr. S176).

PLATYPUS SPINIVENTRIS n. sp.

Male—Testaceous, head and elytral declivity somewhat darker, 2·9 mm. long, 4·1 times as long as wide. This new species may be placed in the neighbourhood of *Platypus hospes* Schedl but is easily distinguished by the irregular length of the spines of the alternate interstices at the commencement of the elytral declivity.

Front flat, convex towards the vertex, opaque, minutely punctulate, very finely and rather scattered punctured, the punctures bearing very short semi-erect hairs. Antennal scape very small, little longer than wide.

Pronotum longer than wide (23:17), widest behind the well developed femoral emarginations, disc shining, minutely chagrined, with some scattered very fine punctures, median sulcus long, extending up to the centre, in its anterior half surrounded by a cordiform patch of densely placed punctures.

Elytra distinctly wider than (21:17) and 2·3 times as long as the pronotum, widest at the declivity, sides straight, distinctly divergent towards the apex, apical margin broadly emarginate and with well developed triangular lateral extensions; disc silky shining, minutely chagrined, first row of very fine punctures in a narrowly impressed line, the others obsolete on the basal three fourths, thence becoming distinct and also in gradually impressed lines; declivity restricted to the distal fourth of the elytra, obliquely, first interstices ceasing on the upper margin of the declivity in small pointed teeth, third interstice much longer, carinate, extending a good deal over the declivital face, shaped as a slender spine blunt at its tip, fifth and seventh interstices forming together a blunt plate being but little longer than the spine of interstice three, ninth interstice drawn out into a short tooth nearly as long as the lateral processes, the short obliquely convex declivital face dull and with a short pointed tubercle in continuation of interstice three shortly before the apical margin. Abdomen ascending, dull, fourth sternite with two pointed tubercles near the posterior border.

Holotype in the Australian National Insect Collection in Canberra, one paratype in the collection of the Department of Forests in Bulolo, one paratype in collection Schedl.

Type-localities: New Guinea: Kum, 11 miles from Mt. Hagen W.H.D., 8.vi.1968, boring into freshly fallen log. Chimbu D.N. "Yumba", B. Gray and Sine (nr. S176). Simbai, 2500 m, Madang Dist., 18.vi.1968, boring into fallen log. of S.D.N. "Contrabe", B. Gray (nr. S238). Simbai, Madang Dist., 18.vi.1968, boring into fallen log, Simbai D.N. "Cheramde", B. Gray (nr. S185).

PLATYPUS STRENUUS n. sp.

Male—Dark brown, 2·7 mm. long, 3·6 times as long as wide. Among the *Platypi oxyuri* with long and slender elytral processes, like *Platypus solidus* Walk., this new species may be recognised by its small size and the strongly striate-punctate elytra shortly before the declivital convexity.

Front flat, rugose, densely areolate-punctate, the punctures bearing minute semi-erect hairs.

Pronotum but little longer than wide, femoral emarginations short but relatively deep, disc silky shining, minutely chagrined, with some scattered very fine punctures, median sulcus fine and short.

Elytra little wider than (22:21) and twice as long as the pronotum, of the same general shape as in *Platypus solidus* Walk., fairly shining up to the commencement of the declivity, finely striate-punctate near the base, the striae strongly deepened behind, the interstices flat at first, becoming somewhat transversely convex behind and each with an irregular row of fine punctures, distal half of the elytra opaque, the striae and strial punctures fading out on the declivital convexity, the interstices each with a median row of yellow inclined hairs originating from indistinct small punctures, apical process long and slender. Abdomen ascending and convex.

Holotype in the Australian National Insect Collection in Canberra, one paratype in collection Schedl.

Type-locality: New Guinea: Togoba, W.H.D., 11.ix.1968, in stem *Eucalyptus grandis,* F. R. Wylie (nr. S271).

PLATYPUS SUBPRONUS n. sp.

Male—Fuscous, 3·2 mm. long, 3·8 times as long as wide. Closely allied to *Platypus angustior* Schedl, but the pronotum without the patch of densely placed punctures surrounding the median sulcus, the elytra more strongly narrowed behind, the declivity more obliquely convex, the tubercles close to the suture smaller and the postero-lateral processes shorter.

Front flat, faintly transversely depressed below, sub-opaque, minutely punctulate, shallowly reticulate-punctate in the upper two thirds, pubescence sparse, medium long and semi-erect.

Pronotum distinctly longer than wide (31:25), widest at the posterior angulate extremity of the femoral emarginations, disc shining, with scattered extremely fine punctures, medium sulcus long and very fine.

Elytra as wide and 1·6 times as long as the pronotum, sides parallel on the basal half, thence very gradually and slightly narrowed, postero-lateral processes slender, apical margin between them transverse, apical emargination wider than long when seen from behind; disc brightly shining, with rows of extremely fine punctures, the first row situated in an impressed line; the declivity short, restricted to the posterior third, feebly and obliquely convex, the strial punctures becoming larger and placed in impressed lines, the interstices each with a row of medium-sized punctures bearing short semi-erect setae, the narrow perpendicular face lunate, as common in this group of the genus, the upper margin distinctly carinate towards the sides, with a very small tubercle in continuation of the third interstices. Abdomen ascending convex.

Holotype in the Australian National Insect Collection in Canberra, one paratype in collection Schedl.

Type-localities: New Guinea: Watut Valley 1200 metres, Morobe Dist., 1.iii.1968, in fallen log of *Aglaia* sp., Bereima and S. Auno (nr. 21). Karamui, Chimbu Dist., 12.vi.1968, boring into freshly fallen log Derebe. N.D. "Sawodisay" B. Gray (nr. S218).

PLATYPUS UNIFORMIS n. sp.

Male—Piceous, 3·6 mm. long, 3·4 times as long as wide. Closely allied to *Platypus semiopacus* Strohm., but distinctly smaller in size, the cordiform patch of punctures around the median sulcus of the pronotum much larger and more transverse, the punctures also being more densely placed and smaller, the brightly shining part of the elytral base extending triangularly into the opaque portion, the opaque declivity more finely granulate, the tubercle on the third interstices less prominent.

Front flat, very shallowly impressed below, minutely punctulate, coarsely punctured on the antero-lateral corners, a small median strigae in the centre, convex towards the vertex, the latter with a transverse row of fine punctures bearing long erect hairs. Antennal scape small, about one and a half times as wide as long.

Pronotum about as long as wide, femoral emarginations long and deep, posterior extremity tooth-like extended and pointed, disc shining, with scattered very fine punctures, these a little larger and more crowded in the basal third, median sulcus long, surrounded by a stout (little wider than long) patch of fine, very densely placed punctures.

Elytra little wider than (31: 29) and twice as long as the pronotum, widest at the commencement of the declivity, sides straight and feebly divergent on the basal three-fifths, thence gradually incurved, somewhat cuneiform, apex narrowly rounded; disc brightly shining on the basal half of the elytra, opaque behind, the shining part triangularly extended on the third interstices, with rows of extremely small punctures on the basal shining part, the interstices very wide and minutely chagrined; the declivity commencing shortly behind the middle, obliquely convex, irregularly covered with very small granules bearing long semi-erect hairs, as in *Platypus semiopacus* Strohm. Abdomen nearly horizontal.

Female—Of the same colour as the male, but somewhat larger and more slender, 4·1 mm. long and 3·5 times as long as wide. Front flat, opaque, minutely punctulate, and indistinctly, sparsely and finely punctured, the punctures bearing long fine setae, in the centre with two parallel longitudinal lamellae as is common in the *Platypi semiopaci*. Pronotum with the patch of punctures surrounding the median sulcus much larger, the posterior extremity of the femoral emarginations angulate but not pointed. Elytra more slender, the sides parallel on the basal three-fourths, the apex short, more broadly rounded, disc shining, strial punctures obscure, interstices three and five somewhat elevated and transversely rugose near the base; declivity restricted to the distal fourth of the elytra, more strongly and uniformly convex above, with a triangular perpendicular plate below, irregularly and rather coarsely punctured above and indistinctly below, all punctures giving rise to fuscous rather long hairs.

Holotype and allotype in the Australian National Insect Collection in Canberra, paratype in the collection of the Department of Forests in Bulolo and in collection Schedl.

Type-localities: New Guinea: Porotop L. M. Station W.H.D., 6.iii.1968, in *Syzygium* sp., D. H. Jeffers (nr. S255). Wabag, W.H.D., 6.iii.1968, in hardwood sp., D. H. Jeffers, (nr. S262). Porotop, L. M. Station, W.H.D., 7.iii.1968, in log D. H. Jeffers, (nr. S267). Porotop L. M. Station, W.H.D., 7.iii.1968, in log, D. H. Jeffers (nr. S268). Porotop L. M. Station, W.H.D., 7.iii.1967, in log, D. H. Jeffers (nr. S264). Porotop L. M. Station, W.H.D., 15.iii.1968 in log, D. H. Jeffers (nr. S269). Marafunga 2800 m, E.H.D., 1.vi.1968, in freshly fallen log *Cryptocarya,* B. Gray (nr. S158). Marafunga 2800 m. E.H.D., 2.vi.1968, in freshly cut log *Podocarpus* sp., B. Gray (nr. S159).

PLATYPUS USTUS Schedl. fem. nov.

Female—Dark reddish brown, 4·6 mm. long, 3·5 times as long as wide.

Front flat, a very shallow transverse depression above the anterior third, opaque, minutely punctulate, indistinctly areolate-punctate, in the upper two thirds, a few fine punctures with long erect hairs at the commencement of the vertex. Antennal scape small, triangular, little wider than long.

Pronotum distinctly longer than wide (41:33), widest near the apical margin, femoral emargination short and moderately deep, disc subshining, minutely chagrined, with scattered fine punctures, a few setose ones along the anterior margin and on the sides in front, median sulcus long and fine, surrounded by a large kidney-shaped patch of densely placed fine punctures.

Elytra somewhat wider than (36:33) and 1·8 times as long as the pronotum, widest at the commencement of the declivity, sides straight and feebly divergent on the basal three-fifths, apex broadly rounded, declivity restricted to the distal third, obliquely convex; disc shining, finely striate-punctate, the striae narrow and feebly impressed near the base, somewhat deeper towards the declivity, the fine strial punctures indistinct in part, interstices moderately wide, subinpunctate 3, 4 and 6 with rows of fine granules near the base, those of interstice 3 longest, a few granules also on interstice 2; short before the declivity the strial punctures somewhat larger, the oblique declivital face shining, irregularly granulate-punctate and with short pubescence.

Holotype in the Australian National Insect Collection in Canberra, one paratype in collection Schedl.

Type-locality: Papua: Brown River Timber Co. Port Moresby, 3.vii.1968, ex *Pterocymbium beccarrii,* log C. Levy (Department of Forests, Konedobu, (118.34, 118.37, 118.40).

PLATYPUS UTER n. sp.

Male—Dark reddish brown, pubescence fuscous, 5·5 mm. long, 3·5 times as long as wide. A remarkable new species of the *Platypi subsulcati* with a patch of densely placed punctures around the median sulcus of the pronotum, a very steep elytral declivity, a broadly rounded and finely carinate apical margin of the elytra and the interstices regularly alternate at the commencement of the declivity.

Front wide, flat, opaque, minutely punctulate, indistinctly finely punctured, a few semi-erect setae on the antero-lateral angles, and on the sides towards and on the vertex. Antennal scape stout, but feebly wider than long.

Pronotum distinctly longer than wide (13·5: 11·0), widest at the posterior extremity of the short but deep femoral emarginations, which are rectangular and pointed, disc polished, with some scattered very fine punctures, a few somewhat coarser ones bearing long setae along the anterior margin, median sulcus short and fine, surrounded by a small triangular patch of densely placed punctures.

Elytra somewhat wider (12·2: 11·0) and 1·8 times as long as the pronotum widest at the middle of the declivity, apical margin very broadly rounded, declivity short, restricted to the posterior third of the elytra, very steeply convex, subperpendicular in the lower half; disc rather finely striate-punctate in the basal third, thence the striae gradually becoming strongly widened and deeply sulcate, the first interstices narrow throughout, finely serrate in the distal half, the second, fourth and sixth wide near the base becoming very low, narrow and with a few serrations behind, with a few semi-erect very short hairs at the commencement of the declivity, the first, third and fifth interstices wider, feebly carinate behind and ceasing abruptly at the declivity, declivital face convex in both directions, opaque, covered with irregularly placed warty granules, the interstices 1, 3, 5 continued on the upper third of the declivital face by densely placed and semi-erect fuscous hairs arranged like a crest, half way down in continuation of the third interstices with large humplike elevation, apical margin finely carinate up to the seven interstices, Abdomen shining, finely punctured.

Holotype in the Australian National Insect Collection in Canberra, one paratype in collection Schedl.

Type-locality: New Guinea: Karamui, Chimbu Dist., 12.vi.1968, boring into freshly fallen log. Derebe D.N. "Ebe", B. Gray (nr. S219).

THE DISTRIBUTION OF ALKALOIDS IN ORCHIDS FROM THE TERRITORY OF PAPUA AND NEW GUINEA

L. J. Lawler and M. Slaytor
Department of Biochemistry, The University of Sydney,
Sydney, N.S.W. 2006, Australia
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Synopsis

Three hundred and fourteen orchids from the Territory of Papua and New Guinea have been screened for alkaloids. The uses of those employed in native medicine are recorded and the screening results are discussed from a taxonomic viewpoint.

Introduction

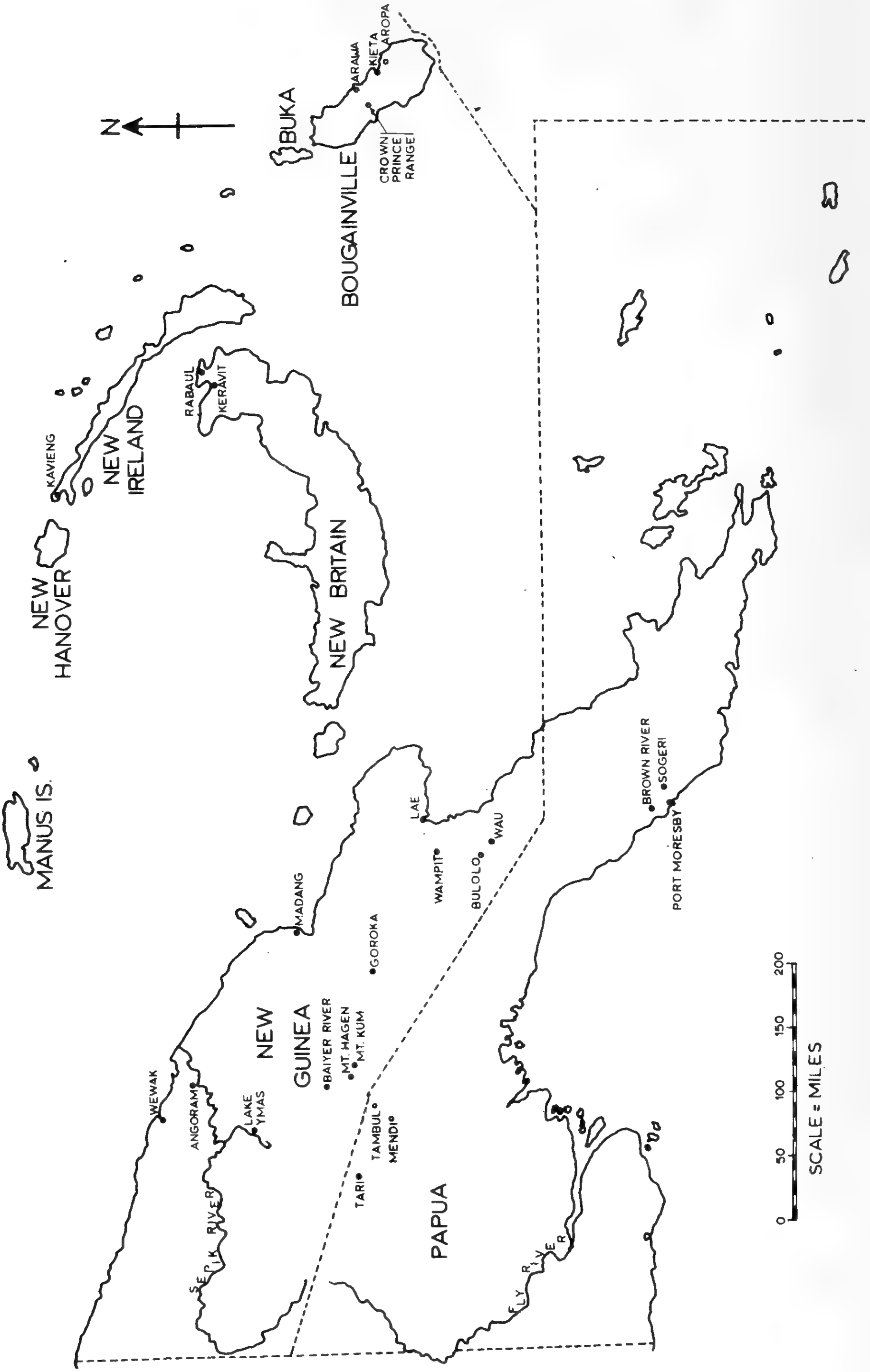
Following the screening of 200 orchids from New South Wales and Queensland for alkaloids by Lawler and Slaytor (1969), it was decided to extend the survey of the *Orchidaceae* to the Territory of Papua and New Guinea. It was hoped that this information would be useful taxonomically and that something might be found of the uses of local orchids in native medicine. Medicinal uses of orchids in the Indo-Malaysian area have been summarized by Smith (1927), Caius (1936), van den Brink (1937), Hawkes (1943, 1944) and Arditti (1966). Four additional orchids which have been used medicinally are reported here, and the systematic significance of alkaloid distribution within the New Guinean orchids is discussed.

Results

Three field trips were made to Papua and New Guinea in July, 1967 and January and July, 1968. Collecting and testing was done in each of the twenty localities shown in Map 1, including Lake Ymas, where a joint expedition with members of the Lae Herbarium was made. In addition, 84 species were tested in the New Guinea Biological Foundation's live collection at Arawa. Collection areas were chosen so as to permit sampling of as many different orchid populations as possible and encompassed the following climatic and geographical localities:

Wet, low level, coastal—Bougainville, New Britain and New Ireland.
Monsoonal, low level, coastal—Port Moresby area.
Lacustrine and swamp—East Sepik district.
2,000′ to 4,000′—Morobe district and Bougainville.
5,000′ to 8,000′—Western and Southern Highlands.

All testing was carried out in the field using the portable kit described by Culvenor & Fitzgerald (1963). The reagents used for testing were Mayer's reagent and Scheibler's reagent. These were prepared according to Cromwell (1955). When available, portions of root, leaf and stem or pseudobulb were included in the test sample. The results are presented in Tables 1 and 2. In Table 1 the results are arranged according to tribe and genera. Because of incomplete identification of the majority of the orchids, they are listed as alkaloid positive, indicating any precipitate with the reagents and, where applicable, alkaloid-rich, indicating an alkaloid concentration of at least



Map 1: Collection localities.

TABLE 1

Alkaloid Distribution at Generic Level

Tribe	Genus	Alkaloid-rich species	Alkaloid-positive species
Cypripediloideae			
Subtribe Cypripedileae	Paphiopedilum	—	1/1
Ophrydoideae			
Subtribe Habenarieae	Habenaria	1	2/3
Polychondreae			
Subtribe Cryptostylideae	Cryptostylis	1	1/1
Vanilleae	Vanilla	—	1/1
Physureae	Anoectochilus	—	1/1
	Cheirostylis	—	0/1
	Goodyera	—	3/3
	Hetaeria	—	1/2
	Macodes	—	1/1
	Zeuxine	1	2/2
	Lepidogyne	—	1/1
Tropidieae	Corymborkis	—	1/1
Kerosphaereae			
Subtribe Liparideae	Liparis	4	8/8
	Malaxis	6	9/9
	Hippeophyllum	1	1/1
	Oberonia	—	5/8
Collabieae	Mischobulbum	—	1/1
Coelogyneae	Coelogyne	—	8/9
	Pholidota	—	1/3
	Dendrochilum	—	1/1
Dendrobieae	Cadetia	—	1/2
	Dendrobium	1	40/90
	Diplocaulobium	—	0/4
	Ephemerantha	—	3/4
	Eria	1	8/10
Glomereae	Ceratostylis	—	3/6
	Agrostophyllum	—	5/6
	Epiblastus	—	1/2
	Glomera	—	3/7
	Giulanetta	—	1/1
	Mediocalcar	—	2/3
	Glossorhyncha	—	1/2
Podochileae	Podochilus	—	3/3
	Appendicula	—	4/4
Phajeae	Calanthe	—	2/3
	Phaius	—	3/5
	Plocoglottis	2	2/2
	Spathoglottis	—	2/4
Bulbophylleae	Bulbophyllum	4	30/50
Cymbidieae	Dipodium	—	0/1
	Grammatophyllum	—	0/1
Thelasieae	Phreatia	—	3/15
Thecosteleae	Acriopsis	—	1/1
Sarcantheae	Thrixspermum	—	2/3
	Sarcochilus	—	0/1
	Vanda	—	1/1
	Renanthera	—	1/1
	Saccolabium	1	2/2
	Taeniophyllum	1	1/2
	Tricholglottis	—	1/2
	Luisia	—	1/3
	Pomatocalpa	1	2/3
	Vandopsis	1	7/9
	Schoenorchis	—	1/1
	Ascoglossum	—	0/1
	Porphyrodesme	—	1/1

0·1%. This was estimated by comparison with dendrobine from *Dendrobium nobile*. A number of these incompletely identified alkaloid-rich species, including a *Dendrobium* sp. (section *Monanthos*) are now growing in the Departmental collection, and will be identified or described later. In Table 2 are, listed alphabetically, all those orchids which could be identified down to species level. Here, it seems justified to record the alkaloid concentration more accurately.

TABLE 2

Alkaloid Distribution at Species Level

Ascoglossum colopterum, 0 ; *Bulbophyllum fritillariiflorum*, 0 ; *B. lycastoides*, 0 ; *B. macranthum*, 0 ; *B. macrophyllum*, 0 ; *Calanthe chrysantha*, 1 ; *C. engleriana*, 0 ; *Coelogyne aspulata*, 1 ; *C. pustuloga*, 2 ; *Cryptostylis fulva*, 4 ; *Dendrobium antennatum*, 0 ; *D. appendiculata*, 0 ; *D. bambusaefolium*, 0 ; *D. conanthum*, 0 ; *D. chrysotoxum*, 0 ; *D. d'albertisii*, 0 ; *D. erectifolium*, 2 ; *D. gouldii*, 0 ; *D. gouldii* v. *acutum*, 0 ; *D. hollrungii*, 1 ; *D. johnsonii*, 0 ; *D. musciferum*, 0 ; *D. ophioglossum*, 0 ; *D. ostrinoglossum*, 0 ; *D. quadrangulare*, 0 ; *D. sophronites*, 0 ; *D. spectabile*, 0 ; *D. tangerinum*, 0 ; *D. veratrifolium*, 0 ; *D. wardianum*, 0 ; *D. williamsianum*, 0 ; *Dendrochilum longifolium* v. *papuanum*, 2 ; *Dipodium pandanum*, 0 ; *Ephemerantha comatum*, 2 ; *Eria hirsuta*, 0 ; *Goodyera papuana*, 2 ; *Grammatophyllum scriptum*, 0 ; *Habenaria papuana*, 3 ; *Macodes sanderiana*, 1 ; *Paphiopedilum violascens*, 1 ; *Phaius montanus*, 1 ; *Pomatocalpa marsupiales*, 2; *Porphyrodesme papuanum*, 1 ; *Renanthera eldfeldii*, 2 ; *Thrisxpermum arachnites*, 1 ; *Vanda hindsii*, 1 ; *Vandopsis longicaulis*, 1 ; *V. muelleri*, 0 ; *V. wracquianum*, 1.

Precipitates were graded as follows: 4 ($>0{\cdot}1\%$), 3 ($0{\cdot}1\%$), 2 ($0{\cdot}01\%$), 1 ($<0{\cdot}01\%$), 0 (no alkaloid detectable); the alkaloid content in brackets being estimated by comparison with dendrobine from *Dendrobium nobile*.

DISCUSSION

Five of the orchids which have been tested for alkaloids have been used for medicinal purposes. These are a *Dendrobium* sp. (section *Monanthos*) used in Bougainville to treat internal bleeding; a *Diplocaulobium* sp. used by the natives to treat infected wounds; *Dipodium papuanum*, an aqueous infusion of the leaves of which is drunk for respiratory infections in Bougainville; a *Vanilla* sp. used as a vermifuge for domestic swine in Bougainville and *Grammatophyllum scriptum*, the seeds of which are mixed with coconut milk and used in Bougainville to treat skin infections in children. The medicinal use of this orchid in the Malay Peninsula has been reported by Smith (1927). Of these, only the *Dendrobium* contains a significant amount of alkaloid. This orchid has been collected in quantity and the isolation and testing of its alkaloids is being carried out. The concentration of alkaloids in the *Vanilla* is too low for normal isolation.

The classification of the *Orchidaceae* in this paper follows that of Schlecter as summarized by Withner (1959). A major difficulty in working with New Guinean orchids is the lack of means of identification of the plants tested due to the large number of species in the area and to the lack of comprehensive taxonomic work there. Despite the problems of identification the results from New Guinea are interesting in that they supplement the data already found by Lüning (1964, 1967) and Lawler and Slaytor (1969). The orchids under discussion fall into four tribes, *Crypripediloideae, Ophrydoideae, Polychondreae* and *Kerosphaereae*. Only species from a single genus have been tested in each of the first two tribes. *Habenaria papuana* is the only alkaloid-rich species which has so far been found in the tribe *Ophrydoideae*. In the tribe *Polychondreae*, there is a random distribution of alkaloid-rich species. These occur in *Cryptostylis* and *Zeuxine*. The alkaloids from *Cryptostylis fulva* have since been characterized by Leander and Lüning (1968) and contain the same 1-phenyl-1, 2, 3, 4-tetrahydroisoquinoline skeleton as those from the Australian *C. erecta* (Slaytor, 1969). Most of the alkaloid-rich species come from the tribe *Kerosphaereae*. This tribe contains the subtribe *Lipariedeae* which has the greatest concentration of alkaloid-rich species which has been found in any subtribe. Four genera, *Liparis, Malaxis, Hippeophyllum* and *Oberonia* contain high percentages of alkaloid-rich species. The subtribe *Coelogyneae*, considered by Lüning (1966) almost alkaloid-free, has at least 10 species containing low levels of alkaloids. The other subtribes show only scattered alkaloid-rich species. These are, in the subtribe *Dendrobieae, Eria* and sections *Monanthos* and *Grastidium* of the genus *Dendrobium; Agrostophyllum, Mediocalcar* and *Glossorhyncha* in the subtribe *Glomereae; Podochilus* in the subtribe *Podochileae; Plocoglottis* in the subtribe *Phajeae; Bulbophyllum* in the subtribe *Bulbophylleae; Saccolabium, Taeniophyllum, Pomatocalpa* and *Vandopsis* in the subtribe *Sarcantheae*.

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References

Arditti, J., 1966.—Orchids. *Scientific American*, 214 (1): 70–78.

Van Den Brink, R. C. B., 1937.—Synopsis of the Vernacular Names and the Economic use of the Indiginous Orchids of Java. *Blumea Suppl.*, 1: 38–51.

Caius, J., 1936.—The Medicinal and Poisonous Orchids of India. *J. Bombay Nat. Hist. Soc.*, 38: 791–799.

Cromwell, B. T., 1955.—In "Modern Methods of Plant Analysis, " IV Edited by K. Paech and M. V. Tracey, Springer-Verlag, Berlin.

Culvenor, C. C. J., and Fitzgerald, J. S., 1963.—A Field Method for Alkaloid Screening of Plants. *J. Pharm. Sciences*, 52: 303–304.

Donau, 1968.—Personal Communication at Arawa Plantation, Bougainville.

Hawkes, A. D., 1943.—Economic Importance of the Orchidaceae. *Am. Orchid Soc. Bull.*, 11: 412–415.

————, 1944.— Economic Importance of the Orchidaceae II. *Am. Orchid Soc. Bull.*, 13: 56–58.

Lawler, L. J., and Slaytor, M., 1969.—The Distribution of Alkaloids in New South Wales and Queensland *Orchidaceae*. *Phytochemistry*, in press.

Leander, K., and Lüning, B., 1968.—Studies in Orchidaceae Alkaloids IX *Tetrahedron Letters*, 1393–4.

Lüning, B., 1964.—Studies on *Orchidaceae* Alkaloids I. *Acta Chem, Scand.*, 18: 1507–1516.

————, 1966.—Chemotaxonomy in a *Dendrobium* Complex. *Proc. Fifth World Orchid Conf.*, 211–215.

————, 1967.—Studies of *Orchidaceae* Alkaloids IV. *Phytochemistry*, 6: 857–861.

McKillop, F., 1968.—Personal Communication.

Millar, A., 1968.—Personal Communication.

Ona, 1968.—Personal Communication at Arawa Plantation Bougainville.

Slaytor, M., 1969.—To be published.

Smith, J. J., 1927.—Orchids of Utility. *Orchid Review*, 35: 323.

Withner, C., 1959.— "*The Orchids: A Scientific Survey*," The Ronald Press Company, New York.

AN INTERIM ACCOUNT OF THE MIDDLE DEVONIAN TIMOR LIMESTONE OF NORTH-EASTERN NEW SOUTH WALES

A. E. H. Pedder*, J. H. Jackson† and D. W. Ellenor
University of New England, Armidale, New South Wales

(Plates xiv–xxiv and Text-figures 1–15)

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Synopsis

The outcrop of the Timor Limestone is between six and seven miles long and up to two miles wide. It is controlled by the Timor Anticlinorium and consequently has the same north-north-west south-south-east trend.

The account is based primarily on seven surface sections. A type section, 1150 feet thick, is chosen. North-westwards from the type section the limestone thins to zero over a distance of just less than four miles; depositional limits in other directions are not exposed.

Preliminary petrographic studies of specimens from the type section indicate that the limestone varies essentially from a coarse, locally argillaceous, calcilutite with abundant biogenic debris in the lower part, to an intraclastic biogenic calcarenite with a medium to very coarsely crystalline sparry calcite cement in the upper part. Microstylolites with iron stained argillaceous concentrations along their sutures are ubiquitous in the lower beds of the type section and in places are developed to such an extent that the rock appears brecciated. Two distinct groups of cherty units are present. Detrital quartz is a significant clastic contributor in the upper half of the section.

Initial faunal studies have led to the recognition of four conodont and four tetracoral assemblages. In ascending order these are the *Icriodus corniger*, *Polygnathus kockelianus australis*, *P. kockelianus-robusticostatus* and *P. varcus* conodont assemblages and the *Stringophyllum*, *Xystriphyllum* (?) *giganteum*, *Grypophyllum* cf. *denckmanni* and *Stringophyllum* cf. *isactis* tetracoral assemblages. All faunas are of Middle Devonian age, but one of the most important results is that several conodonts have demonstrably longer ranges in Australia than has previously been ascribed to them in Europe. This introduces some difficulty into establishing precise correlations of the Timor Limestone. Approximately, we believe that the *corniger*, *australis* and *varcus* assemblages correspond to the German *corniger*, *bidentatus* and *varcus* Zones respectively and that the *kockelianus-robusticostatus* assemblage is equivalent to the combined *kockelianus*, *eiflius* and *robusticostatus* Zones of Germany. There is no evidence of the presence of the German *hermanni-cristatus* Zone, it is therefore concluded that full sections of the Timor Limestone range from early Eifelian to late, but not latest, Givetian. The north-west extending tongue of the limestone is late Givetian.

Most of the important conodonts and tetracorals are figured. *Polygnathus kockelianus australis* is proposed as a new subspecies of conodont. Two new genera, *Amaraphyllum* and *Blysmatophyllum*, and three new species of tetracorals, *A. amoenum*, *B. isisense* and *Sanidophyllum etheridgei* are erected. The term sanidophylloid is introduced for a distinctive form of corallum for which there is no name in existing glossaries.

I. Introduction

The Timor Limestone which is situated approximately 16 miles north-east of Murrurundi (Text-fig. 1) is the thickest of the known limestone members of the Yarrimie Formation of north-eastern New South Wales.

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* Current address: Institute of Sedimentary and Petroleum Geology, 3303—33rd Street, N.W., Calgary 44, Alberta, Canada.

† Current address: Shell Development (Australia) Pty. Ltd., 155 William St., Melbourne, Victoria.

Preliminary studies of its rich conodont and coral faunas indicate that where it is fully developed it may span all Eifelian and most Givetian time and that it certainly embraces the interstage boundary. From a biostratigraphical standpoint therefore, it is one of the most important Devonian carbonates in eastern Australia. It is also likely to be important as a source of data concerning the origin and diagenesis of limestones within sequences exhibiting many of the features characteristic of turbidite sedimentation. Hitherto it has been described only superficially and in some respects inaccurately. It is hoped that the present work will go some way towards remedying this and that it will serve as a springboard for subsequent studies.

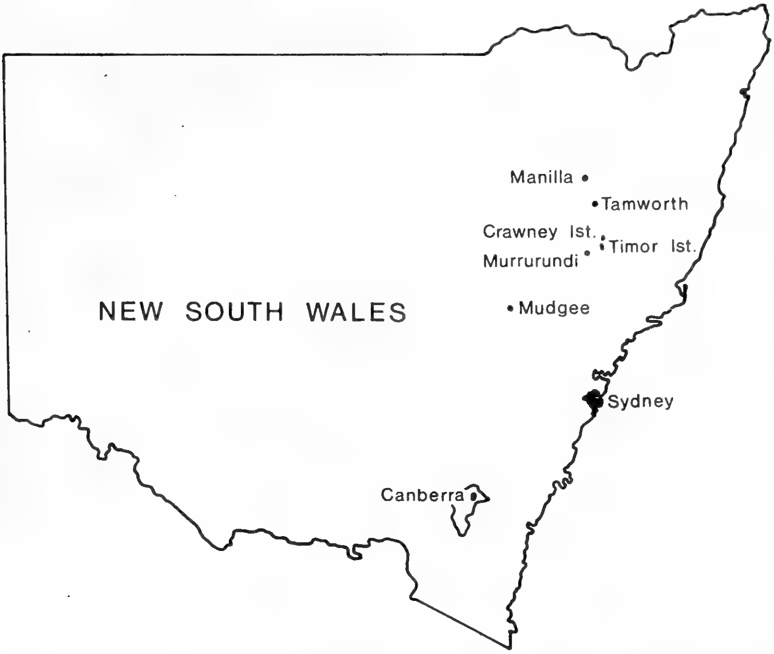


Fig. 1. Map of New South Wales showing the location of the Timor and Crawney Limestone outcrops. Other Middle Devonian limestones occur near Mudgee (Mount Frome Limestone) and between Tamworth and Manilla (Sulcor, which is mostly Emsian, and Moore Creek Limestones).

II. Previous Work

The Timor Limestone was evidently known to several geologists and collectors (Etheridge, 1898, 1902; Dun, 1901; Benson, 1913, 1918) prior to the publication of the work in which it was first named, described and analysed (Carne and Jones, 1919). Its outcrop was originally mapped by Osborne *et al.* (1950, Pl. 22) in a paper dealing with the structure and stratigraphy of the upper Isis River area, and was again discussed by Osborne (1950, pp. 49–52) in a broader work on the Hunter-Manning-Myall region. A sketch map of the limestone has also been given by Crook (1961, sheet 4). The most detailed map yet published is that of Manser (1968).

Fossils listed by Dun (1901) from the Parish of Crawney, County of Brisbane, constitute the first published faunal list from the Timor Limestone. Later lists given by Benson (1913, pp. 498, 499; 1918, p. 595; 1922) include forms from both the Timor and Crawney Limestones of present usage. This unfortunate confusion stemmed partly from Benson's mistaken belief that the two limestones are continuous beneath the Tertiary basalts of the Liverpool Range and partly from the fact that there are two parishes named Crawney in the area, in which similar, but nevertheless distinct, Devonian limestones outcrop. One of these parishes lies to the north of the Liverpool Range in the County of Parry; the only limestone exposed in it is the Crawney Limestone. The other is south of the range in the County of Brisbane; in it the limestone exposed is the Timor Limestone of current usage. The *Tryplasma* listed by Etheridge (1907, p. 102) from the County of Brisbane and the *Heliolites porosus* (Goldfuss) identified by Jones and Hill (1940, p. 204) from the Isis River are presumably Timor Limestone fossils.

In addition to these listed fossils five Timor species have been described and figured, *viz*: the corals *"Endophyllum" schlueteri* (Etheridge, 1898; David and Browne, 1950, Pl. 25, Figs *b, c*), *Bensonastraea praetor* Pedder (1966, pp. 185, 186) and *"Cystiphyllum (? Microplasma) australaisica"* Etheridge (1902, pp. 256–258, Pl. 40 Fig. 4), and the gastropods *Burdekinia axionoides* (Etheridge, 1921, pp. 1, 2) and *Euomphalus isisensis* (Etheridge, 1921, p. 2; Knight, 1941, pp. 34, 35), which is the type species of *Amphelissa.*

Summaries of the most recent biostratigraphic work on the limestone have been given by Philip and Pedder (1967, pp. 236, 237; 1968, p. 1034) and Pedder (1968, pp. 139, 140). These publications pointed out that the Timor Limestone attains a greater thickness than was formerly realised and that it is quite discrete from the Crawney Limestone. They also showed that it includes older and younger beds than the Moore Creek or Crawney Limestones with which it had previously been correlated.

Besides proposing three members within the Timor Limestone, Manser (1968) has erected a new formational name (Busches) for the strata overlying it and another (Lilberne) for the beds that underlie it. But as the Busches and Lilberne Formations are similar—a point Manser himself makes—and are almost certainly continuous beneath the basalts of the Liverpool Range with the well known Yarrimie Formation to the north, and as the Timor Limestone is lensoidal, we believe that the Busches and Lilberne Units are better referred to the Yarrimie Formation and that the Timor Limestone should be regarded as a member of the same formation. Manser's Timor Limestone members are essentially based on cherty horizons within the limestone. Our work indicates that these are not as continuous as Manser's publication indicates, therefore we feel that there is no need at this time to formally recognise further divisions within the Timor Limestone Member.

III. GENERAL GEOLOGY OF THE TIMOR LIMESTONE

Structure and outcrop: The Timor Limestone is exposed on both flanks of a north-north-west south-south-east trending anticlinorium named the Timor Anticline by Osborne *et al.* (1950). Its outcrop is between six and seven miles long and at the widest point, between Isaacs and Perrys Creeks (Text-fig. 2 and Pl. A), is approximately two miles across. West of the Isis River, between "North Glen Dhu" Homestead and Isaacs Creek, the limestone maintains a dip of about 25° to the south-west. Southwards this mass passes beneath alluvium. Northwards it thins and finally lenses out just north of "Minto" Homestead, but is dissected in the vicinity of "North Glen Dhu" Homestead by an intricate fault system called the "Glen Dhu Complex" by Osborne (1950). East of the Isis River the limestone is complexly folded and the north-eastern part of its outcrop is fault-bounded. To the south-east it dips at 15° to 18° and disappears beneath overlying beds of the Yarrimie Formation.

Complete sections of the limestone (e.g. sections 7, 2, 3 and 4) can be measured at a number of points north of "Allston" Homestead, but to the south of it (e.g. section 1 and Crook's "representative section") alluvium invariably obscures the lowermost beds. Because of structural complexity good sections are fewer to the east of the Isis River, only two have been measured (sections 5 and 6) of which only one (section 6) exposes the entire limestone.

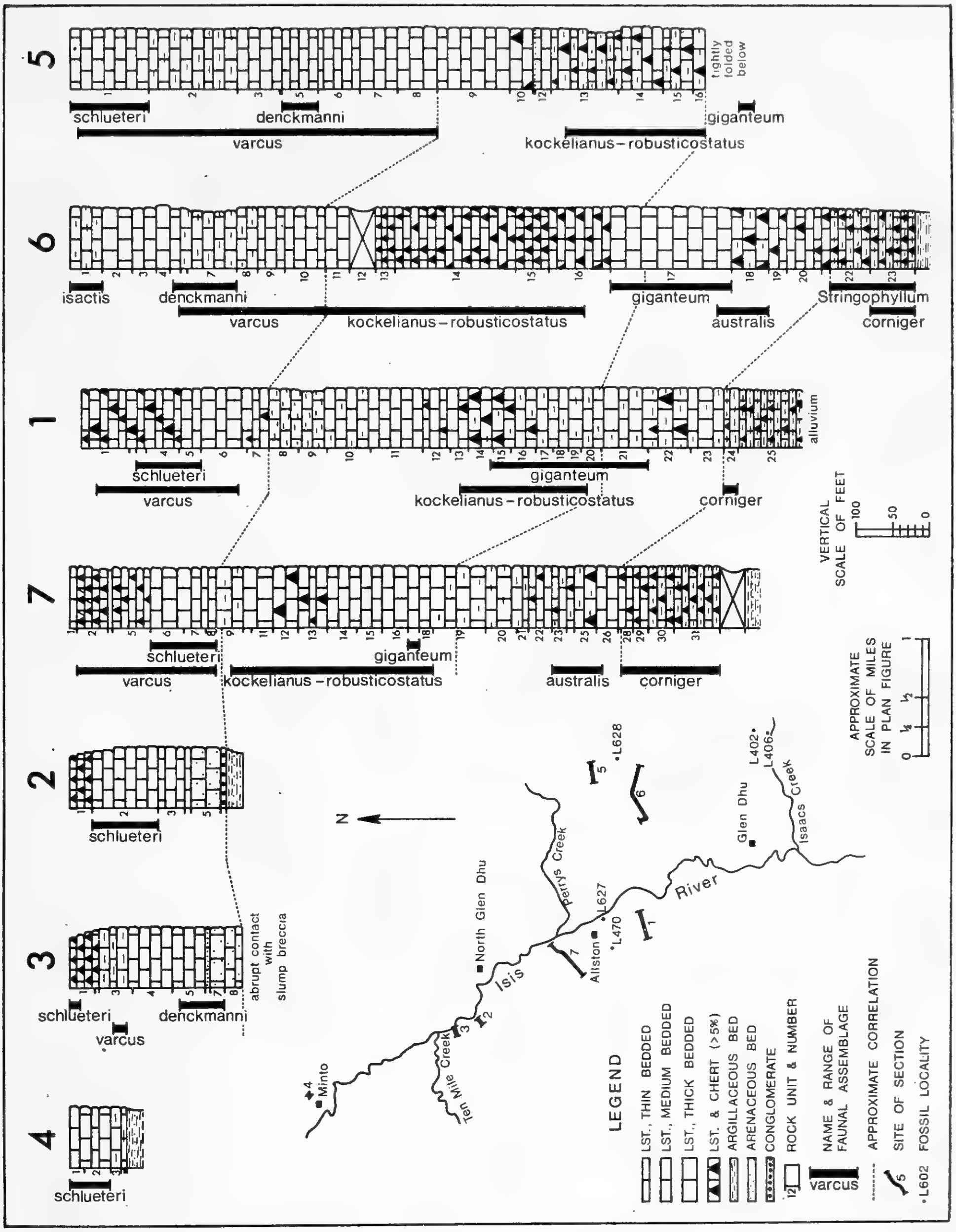


Fig. 2. Distribution of faunal assemblages in measured sections of the Timor Limestone with implied correlations. Plan inset shows fossil and measured section localities relative to main streams and homesteads.

Stratigraphy: The greatest obtainable stratigraphic thickness of limestone is 1150 feet in section 6 (Text-fig. 2). As this section is on the eastern flank of the anticlinorium there is no information regarding the thickness of the limestone further to the east; nor, because of folding and alluvial cover, is there much indication of its thickness to the south. There are however clear indications that it thins in places markedly, to the west, north-west and north.

At section 1, which is about one mile west of section 6, the limestone is 982 feet thick and although the base is not exposed, it is probably very nearly a complete section (unless limestone sedimentation began here earlier than elsewhere) since *Icriodus corniger* occurs almost 100 feet above the exposed base. At Section 7, which is three quarters of a mile north-west of section 1, there are between 890 and 921 feet of Timor Limestone. In less than one mile north-west of section 7, at section 2, the total thickness of the limestone diminishes to 212 feet and at section 4, one and three quarter miles further north-west again, it is only 77 feet. The limestone finally lenses out just under one half mile north of "Minto" Homestead.

Although in general contacts between the Timor Limestone and adjacent sediments are poorly exposed, there is no evidence of unconformity at either the top or the base of the limestone. Locally, as in sections 2 and 3, a basal conglomeratic unit disconformably overlies finely laminated siltstones of the Yarrimie Formation and at section 4 there is an abrupt contact with large elongate stromatoporoid coenostia resting directly on Yarrimie argillite; however in other localities where it is exposed, the contact is gradational in thin alternating beds of dark grey limestone and fine arenites and mudstones. The upper contact is similarly transitional in some places, and abrupt in others.

Since a type section has not been proposed previously we now designate section 6 of this work (Text-fig. 2, Pl. A) as the type Timor Limestone section. It is the thickest of the measurable sections and has reasonably well exposed upper and lower contacts. Beds within it are well exposed and can be traced laterally for some distance, furthermore they show variations of lithology that are almost as great as the total variation of the limestone and all eight of the conodont and tetracoral assemblages recognized in the Timor Limestone are well represented in it.

IV. Microscopic Petrography of the Type Timor Limestone Section

This preliminary description (by D.W.E.) is based on randomly orientated thin sections and supplementary acetate peels of 53 specimens from section 6 (type section). The terminology and grain size scale for the carbonate fragments employed here are essentially those of Folk (1959), with clastic particles classed according to the Wentworth (1922) grade scale. Descriptive phrases are used in preference to Folk's (1959, p. 17) composite-word nomenclature.

Units 23–20 (975·6′–1150·0′ from top): Coarse calcilutite to fine calcarenite with up to 25% medium to coarse sand size organic debris. Iron-stained argillaceous material is concentrated along the sutures of numerous microstylolites. Argillaceous microlaminae are moderately common. Disseminated silica is particularly profuse in unit 23 and the lower part of 22. Organic debris consists primarily of whole and broken crinoid plates and ossicles, ostracods, silicified corals and algal (?) strands lying parallel to the bedding planes; calcispheres occur in some sections. Intraclasts are common only near the top of unit 20. Pyrite is present principally as local concentrations along the questionable algal strands in the middle of unit 22.

Units 19–18 (899·8′–975·6′ from top): Biogenic, fine to medium calcarenite, consisting chiefly of broken and abraded crinoid debris cemented by a medium crystalline sparry calcite. Subrounded to subangular fine sand size detrital quartz and iron stained argillaceous material are concentrated along microstylolites. Minor amounts of disseminated silica are also present. Syntaxial overgrowths commonly obscure the original shape of the crinoid fragments and much void-filling spar occurs throughout these units.

Unit 17 (735·7′–899·8′ from top): Coarse calcilutite to fine calcarenite with a 10% to 20% coarse sand size or larger organic debris content. Minor amounts of subangular, fine sand size, detrital quartz grains occur near the top of the unit. Small, clear, variable patches of medium to coarsely crystalline sparry calcite are present. Well rounded, spheroidal intraclasts of dark grey crypto- to microcrystalline calcite ooze, mostly 0·13 to 0·20 mm. in diameter, constitute a major fragmental type. Organic debris includes broken and abraded crinoid fragments, commonly with optically continuous calcite overgrowths, and minor amounts of stromatoporoidal, coralline and algal material. Faecal pellets are also present.

Units 16–13 (416·2′–735·7′ from top): Very fine calcarenite with some interspersed fine sand size skeletal debris. The matrix consists of a dark brown to grey, finely crystalline calcite ooze, stained by organic matter and inclusions of ferruginous clay particles which usually occur as streaks. Recognizable organic debris is absent or rare in the lower units, but higher in units 14 and 13 broken and corroded crinoid fragments, entire ostracods, gastropods and especially algal fragments are abundant. Calcispheres and abraded brachiopod fragments are also present although they are not common. Pellets and coarse silt size intraclasts are scattered throughout, but are most prevalent in unit 16.

Units 11–9 (254·3′–380·2′ from top): Intraclastic, biogenic calcarenite with a clear medium crystalline sparry calcite cement. Well rounded elongate intraclasts with an average diameter of 0·20 mm. constitute about 35% of the rock volume. Up to 30% of the remainder comprises crinoid stems, coralline and stromatoporoidal fragments and questionable algal balls. Subangular, coarse silt size detrital quartz grains are a very minor constituent of this interval.

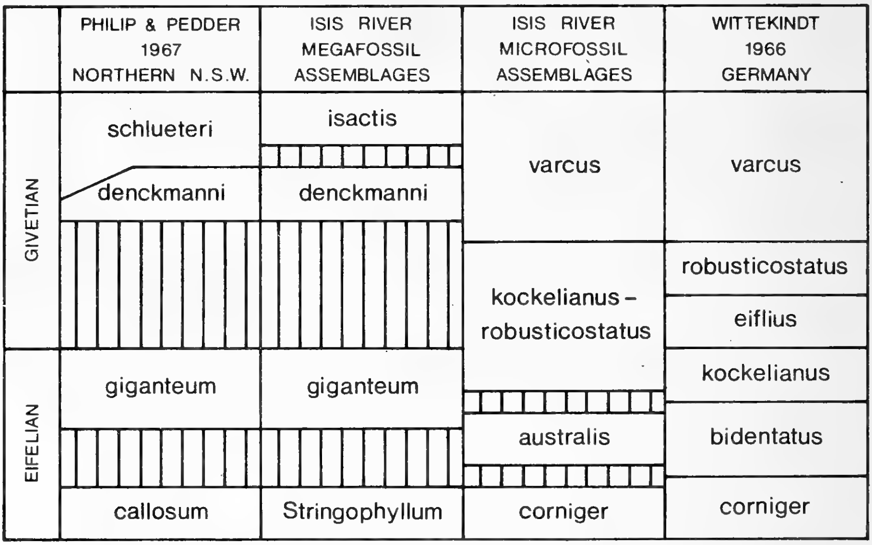
Units 8–4 (117·0′–254·3′ from top): Intraclastic calcarenite with a medium crystalline sparry calcite cement. A distinct brownish cast which pervades the groundmass appears to be due to concentrations of argillaceous and organic detritus associated with intraclasts are crinoid fragments which diameter 0·50 mm.) of microcrystalline calcite, some showing recrystallization textures, dominate the allochemical constituents of the interval. Fossil fragments, principally crinoid ossicles, are rare. Subangular, very fine sand size detrital quartz occurs throughout. The top of the unit 7 is relatively rich in pyrite.

Units 3–2 (43·4′–117·0′ from top): Intraclastic calcarenite with a medium to very coarsely crystalline sparry calcite cement. Well rounded intraclasts of extremely variable size and shape constitute up to 70% of the total rock. Mostly they seem to consist of silt size carbonate particles, but some contain crinoid and algal fragments and also detrital quartz. The most important organic detritus associated with the intraclasts are crinoid fragments which have been severely abraded and in places show signs of corrosion; many are optically continuous with the sparry calcite cement. Subrounded, fine to medium sand size detrital quartz fragments are liberally scattered throughout the interval. Very minor amounts of pyrite and haematite coat the surface of some intraclasts.

Unit 1 (uppermost 43·4′): Biogenic, pelletoidal calcarenite with a fine to medium crystalline sparry calcite cement. Fine sand size organic debris of crinoidal, coralline, ostracodal and algal (?) fragments, together with some calcispheres constitute up to 50% of the rock. Dark brown to opaque, spheroidal to oblate pellets of microcrystalline calcite make up 25% of the remainder. A brownish cast in the sparry calcite of the cement is apparently due to organic or argillaceous inclusions. Angular, silt size, detrital quartz is present in minor quantities.

V. Faunas and Age of the Timor Limestone

Four megafossil assemblages, believed to range in age from early Eifelian to late Givetian, have previously been recognized in the Timor Limestone (Pedder, 1968, pp. 139, 140; Philip and Pedder, 1967, pp. 236, 237). Further field and laboratory studies now allow one of us (J.H.J.) to suggest a provisional scheme of microfossil zonation. Known occurrences of mega- and microfossil assemblages in measured sections are indicated in Text-fig. 2; their approximate relationships and correlation with Wittekindt's (1966) German conodont zones are expressed in Text-fig. 3.



	PHILIP & PEDDER 1967 NORTHERN N.S.W.	ISIS RIVER MEGAFOSSIL ASSEMBLAGES	ISIS RIVER MICROFOSSIL ASSEMBLAGES	WITTEKINDT 1966 GERMANY
GIVETIAN	schlueteri	isactis	varcus	varcus
		▨		
	denckmanni	denckmanni		
	▨	▨	kockelianus – robusticostatus	robusticostatus
				eiflius
EIFELIAN	giganteum	giganteum		kockelianus
			▨	
			australis	bidentatus
	▨	▨		
			▨	corniger
	callosum	Stringophyllum	corniger	

Fig. 3. Table indicating the approximate relationships of the mega- and microfossil assemblages of the Timor Limestone and conodont zones currently recognized in Germany.

Icriodus corniger and *Stringophyllum** assemblages.—*Icriodus corniger* occurs at or near the base of the limestone in sections 1, 6 and 7. In section 6 it is accompanied by *Polygnathus linguiformis linguiformis* and *P. webbi.* This assemblage is known overseas in the late Emsian Heisdorfer Schichten of the Eifel, the early Eifelian Ballersbacher Kalk of the Rhenish Massif, the upper three members of the Onondaga Limestone of New York (Klapper and Ziegler, 1967, p. 78) and in the Jeffersonville Limestone of Indiana (Orr *in* Collinson *et al.*, 1968, p. 955). *I. corniger* itself occurs with *Paraspirifer cultrijugatus* in the upper beds of the Santa Lucía Limestone of northern Spain, where it is considered to be of early Eifelian age (Van Adrichem

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* A new large (maximum diameter 55 mm.) solitary species with up to 64 major septa.

Boogaert, 1967, enclosure 1; Brouwer, 1968, p. 41), but in Indiana it is reported to range as high as the North Vernon Limestone of probable Givetian age (Orr, *op. cit.*, p. 955). The Timor assemblages are believed to be early Eifelian as at the moment in Australia *Stringophyllum* and *Calceola sandalina* (*s.s.*) are presently unknown in definitely pre-Eifelian beds. Moreover they underlie the *Xystriphyllum* (?) *giganteum* megafauna, which on independent grounds is believed to be late Eifelian.

Polygnathus kockelianus australis assemblage: This includes *Polygnathus kockelianus australis* subsp. nov., *P. angustipennatus*; *P. pseudofoliatus*, *P. robusticostatus* (*s.1.*) and a few *Spathognathodus bidentatus bidentatus* and *S. b. transitans.* Although in the Belgium succession (Bultynck 1966; 1968, p. 427) *S. b. transitans* is not known before Co_2 and *S. obliquus* has not been identified at Timor, this assemblage appears to be an approximate correlative of Wittekindt's *bidentatus* Zone, that is the lower Günteröder Kalk of Germany. The assemblage index is presently known only from the Timor Limestone.

Xystriphyllum (?) *giganteum* assemblage: Among others this comprises *Dendrostella* sp. cf. *D. rhenana* of Hill, 1942*b*, *Xystriphyllum* (?) *giganteum*, *X.* sp. nov., *Sociophyllum densum*, *Sanidophyllum davidi*, *S. colligatum* and probably *Bornhardtina coulteri*, all of which are also known in the Moore Creek Limestone. The Moore Creek megafauna is not easily correlated with overseas faunas, but *X.* (?) *giganteum*, *"Campophyllum"* sp. cf. *"C." lindstroemi* and *Mesophyllum cornubovis* closely resemble *"Spongophyllum" varians* (see Birenheide, 1962, pp. 80, 81), *"Cyathophyllum" lindstroemi* (Frech, 1886, p. 183 (69)) and *M. cristatum* (see Birenheide, 1964, pp. 41, 42), which in Germany overlap in beds of late Eifelian age.

Polygnathus kockelianus—P. robusticostatus assemblage: The assemblage is heralded by the incoming of *P. kockelianus kockelianus* and *P. trigonicus*, which are also known to occur together in the latest Eifelian (Wittekindt, 1966) Kalkgie Zwischenschichten (Bischoff and Ziegler, 1957) of Germany and in strata regarded as Co_{2c} at the southern end of the Dinant Basin (Bultynck, 1966, pp. 195, 197). In the Timor sequence however, these, together with *P. eiflius* and *P. robusticostatus* (*s.l.*), almost range up to the entry of *P. varcus.* Thus it appears that this assemblage approximates to the combined *kockelianus*, *eiflius* and *robusticostatus* Zones of Wittekindt and that the Eifelian/Givetian boundary falls within it.

Polygnathus varcus assemblage: *Polygnathus varcus*, *Spathognathodus brevis* and other longer ranging conodonts characterize this assemblage. Abroad, *P. varcus* is recorded from the late Givetian of Germany (Bischoff and Ziegler, 1957, pp. 98, 99; Bartenstein and Bischoff, 1962, p. 50; Wittekindt, 1966, p. 627), the Kanzel-Kalk of Austria (Flajs, 1966, Pl. 25, Fig. 6), the basal Portilla, upper Gustalapiedra and lower Gardaño Formations of northern Spain (Van Adrichem Boogaert, 1967, enclosures 1, 3, 4) and the Tichenor, Kashong, Tully, Silica, Lingle, North Vernon and Cedar Valley (Solon Member) Formations of North America (Klapper and Ziegler, 1967, pp. 79, 80; Orr, *op cit.*, pp. 955, 956). The base of the Givetian is not yet established with certainty in North American sequences, but of these occurrences, all the European and at least several of the North American are middle to late Givetian in age. The appearance of *Ancyrognathus walliseri* in unit 5 of section 7 is interesting in that it may indicate correlation with the *walliseri* horizon of the middle *varcus* Zone (Wittekindt, 1966, pp. 628, 629). The presence of forms approaching *Polygnathus linguiformis transversus* and the absence of any evidence of the *hermanni-cristatus* Zone in the topmost Timor Limestone, suggest that it is of late, but not latest Givetian age.

Grypophyllum cf. *G. denckmanni* assemblage: This is best developed along the north-eastern flank of the Timor Anticlinorium, where it includes *Heliolites* sp., cf. *Placophyllum* sp., *Grypophyllum* sp. cf. *G. denckmanni, Dohmophyllum* sp., *Stringophyllum quasinormale* var., *S.* sp. nov., *Sociophyllum* sp. nov., *Amaraphyllum amoenum* gen. et sp. nov., cf. *Sinospongophyllum* sp. nov., *Endophyllum* sp., *Sanidophyllum etheridgei* sp. nov., *Blysmatophyllum isisense* gen. et sp. nov., *Plasmophyllum* sp., *Calceola sandalina,* together with some gastropods and brachiopods. *Grypophyllum*


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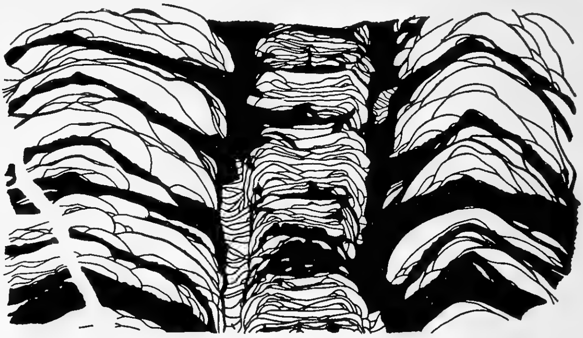
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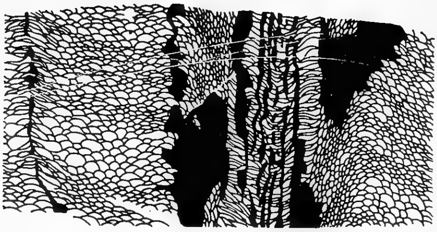
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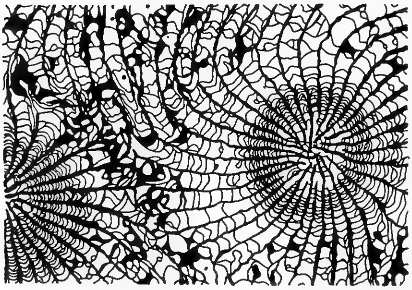
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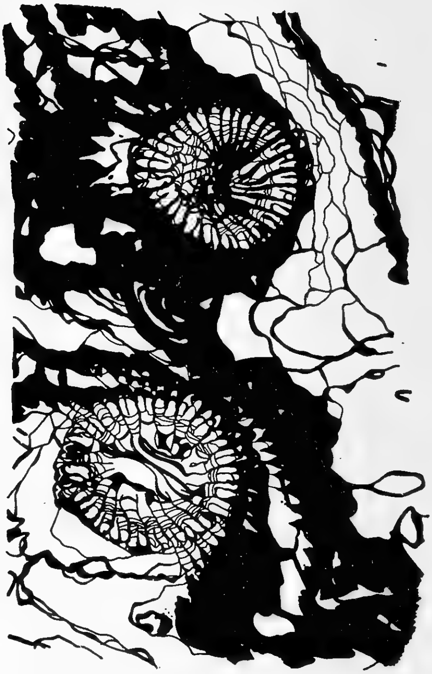
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Figs 4–9. Tetracorals of the *Stringophyllum* cf. *S. isactis* fauna of the Timor Limestone (Givetian part). All × 2. 4, 5, *Stringophyllum* sp. cf. *S. isactis* (Frech), UNE F10412, unit 1, section 6; 6, 9, "*Endophyllum*" *schlueteri* (Etheridge), UNE F8579, old collection labelled "Timor Limestone, Isis River"; 7, 8, *Taimyrophyllum* sp., UNE F10411, UNE Locality 470.

denckmanni is an early Givetian species in southern England (Engel and Schouppé, 1958, pp. 103–107; Scrutton, 1966, p. 186) and an early to late Givetian species in Germany (Engel and Schouppé, *loc. cit.;* Jux, 1964, for the age of the "Oberhonseler Schichten"). *Stringophyllum quasinormale* was originally described (Hill, 1942*a*, pp. 258–261, Pl. 10, Figs 5*a*–14*b*) from the early (?) Givetian Burdekin Downs Limestone of northern Queensland and corals akin to the form identified as cf. *Sinospongophyllum* sp. nov. are apparently abundant in the Eifelian and Givetian of Yunnan (Wang, 1948, Pl. 5, Figs 1–6; Ku 1950; Fontaine, 1966). We conclude that this fauna is Givetian and that it probably represents an early rather than late part of the stage. Much of it is endemic.

Stringophyllum cf. *S. isactis* assemblage: This corresponds closely with the *schlueteri* fauna of Philip and Pedder, 1967. In most places *"Endophyllum". schlueteri* is clearly younger than the *Grypophyllum* cf. *G. denckmanni* assemblage, but in one instance (section 7 which was measured after Philip and Pedder went to press) it first appears only 40 feet above the last occurrence of the *Polygnathus kokelianus—P. robusticostatus* assemblage, which is almost certainly within the range of *G.* cf. *denckmanni.* In view of this it is now proposed that the uppermost Timor megafauna be known as the *Stringophyllum* cf. *S. isactis* assemblage. Apart from the new index fossil the main components of this assemblage are *Taimyrophyllum* sp., *"Endophyllum" schlueteri* and *Plasmophyllum* sp. *Stringophyllum isactis* is a widely distributed Givetian species, known from Germany (Engel and Schouppé, 1958, pp. 90–93), Czechoslovakia (Kettnerová 1932, pp. 47, 48), the Russian Platform (Soshkina, 1954, p. 48), the Urals (Soshkina, 1949, pp. 136–138), Armenia (Soshkina, 1952, p. 96), Tian Shan (Frech *in* Suess, 1894, p. 442; Frech, 1897, pp. 246, 247; Brezhnev *et al.,* 1968, p. 446), Nepal (Flügel, 1966, pp. 103, 104), eastern Yunnan (Wang, 1948, p. 21) and Queensland (Hill, 1942*a*, pp. 262, 263). Timor specimens most resemble the small form figured by Frech from Tian Shan.

SYSTEMATIC PALAEONTOLOGY

The names of institutions responsible for the material referred to are abbreviated as follows:

AM: Australian Museum, Sydney, New South Wales.
GSNSW: Geological Survey of New South Wales, Sydney.
UNE: University of New England, Armidale, New South Wales.

The University of New England fossil localities are shown in Text-Fig. 2.

New morphological term: The term sanidophylloid is introduced for tetracoral coralla that are mostly phaceloid, but by periodic expansions of the calices are cerioid at certain levels. Sanidophylloid coralla are characteristic of the genera *Sanidophyllum, Blysmatophyllum* (see below) and *Strombodes.*

CONODONTA

POLYGNATHUS KOCKELIANUS Bischoff and Ziegler, 1957. *Polygnathus kockeliana* Bischoff and Ziegler, p. 91, Pl. 2, Figs 1–12. *non,* 1957. *Polygnathus* cf. *P. kockeliana* juv. Bischoff and Ziegler, pp. 91, 92, Pl. 2, Figs 13–15 (= *Spathognathodus* sp. nov.).

POLYGNATHUS KOCKELIANUS AUSTRALIS Jackson, subsp. nov.
(Pl. B, Figs 22, 25)

Name derivation: Latin, *australis* = southern.

Type series: Holotype and paratype 1, UNE F10434, F10435 respectively, 44 feet below the top of unit 18, section 6 (993 feet below the top of the Timor

Limestone); Paratypes 2, 3, UNE F10436, F10437, top of unit 26, section 7 (745 feet below the top of the Timor Limestone). Collected by J. H. Jackson All are believed to be Eifelian.

Diagnosis: A subspecies of *Polygnathus kockelianus* in which the platform is extremely narrow, has characteristically well developed denticles extending to its posterior tip, and is bent sharply inwards. Denticles above the platform are generally broader and thicker than those on the free blade.

Description: Apart from the posterior end, which may be flexed slightly upwards, the unit is straight in lateral view. In oral view it is straight from the anterior end to a point just posterior of the basal cavity where it is deflected sharply inwards. The platform is extremely narrow; it commonly has rounded margins or edges and is generally restricted to the inner side of the unit, although a small anterior outer platform may be present. It is usually broadest above the basal cavity and tapers gradually towards its posterior extremity. There is no ornament on the platform. The blade above the platform consists of laterally compressed and fused denticles. These are outwardly directed and are usually broader and thicker posterior of the point of curvature. The free anterior blade deepens and thins anteriorly; its slender denticles are fused and have rounded tips. A slight anterior ridge extends from the platform, below the base of the denticles along the inner face. A very slight posterior ridge may also be developed on the outer lateral face. Both of the anterior lateral faces of the free blade are flat to slightly convex. On the underside of the unit a shallow basal cavity with prominent lips is situated at the anterior end of the platform. In some specimens the cavity tapers to a point at the posterior end, but in others it is shorter and is replaced posteriorly by a keel. The centre of the cavity bears a median slit which extends for a short distance along the free blade.

Remarks: Mature specimens of the new subspecies are distinguished from those of the nominate subspecies by the restricted platform and by the nature of the denticles above the platform. Juveniles of these subspecies are not easily distinguished. Thus it is difficult to assign the specimens illustrated by Bischoff and Ziegler (1957) in Figure 12 of their Plate 2, or the specimen here illustrated in Plate B, Fig. 21, to either subspecies, although they compare closely with *P. kockelianus australis* subsp. nov. *Spathognathodus bidentatus transitans* Bultynck is much less bent at the posterior end and completely lacks a platform.

COELENTERATA

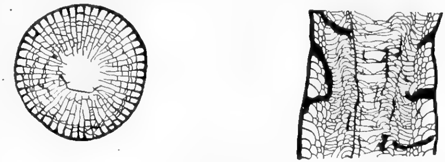
Family CYATHOPHYLLIDAE Dana, 1846
Subfamily DISPHYLLINAE Hill, 1939
Genus AMARAPHYLLUM Pedder, nov.

Name derivation: Greek, αμαρα = trench, and φυλλον = leaf.

Type species: *Amaraphyllum amoenum* Pedder, sp. nov., see below.

Diagnosis: Corallum fasciculate; budding peripheral and paricidal. Septa radially arranged, either thin and smooth with parallel fibres and no discernible trabeculae, or somewhat dilated, carinate and constituted of disphyllinoid trabeculae. Dissepiments small, forming a narrow dissepimentarium. Tabularium markedly triseriate with a peripheral series of flat plates, a periaxial series of highly arched vesicles and an axial series of flat or sloping plates.

Remarks: The type and at present only species is apparently a disphyllinoid homeomorph of the Silurian genus *Entelophyllum*. It is distinguished from typical species of *Entelophyllum* (e.g. *E. articulatum* (Wahlenberg), Lang and Smith, 1927, Figs 13, 14; Smith and Tremberth, 1929, Text-figs 1, 2, Pl. 7, Figs 1–6; *E. strictum* (M. Edwards and Haime), Stumm 1964, p. 32, Pl. 22, Figs 15–21; *E. latum* Hill, 1940, pp. 413, 414, Pl. 13, Figs 8–10) by its narrower dissepimentarium and more highly inflated periaxial tabularial elements. *E. parvum* Stumm (1962, pp. 2, 3, Pl. 2, Figs 9–11) and *E.* (?) *angulare* (Amsden, 1949, pp. 109, 110, Pl. 28, Figs 9–15) have narrow dissepimentaria but lack distinctly triseriate tabularia. Lateral processes and zigzag carinae which characterize some species of *Entelophyllum* are unknown in *Amaraphyllum amoenum*. The tabularium in many specimens of *Disphyllum* tends to be downturned near the margin and in rare cases is locally triseriate, but to my knowledge it is never consistently so as in *Amaraphyllum amoenum*. Compare for instance the figure of *Disphyllum lazutkini* (Bulvanker) given by Bulvanker (1958, Pl. 52, Fig. 1*b*) with that given by Ivaniya (1953, Pl. 5, Fig. 22; 1965, Pl. 97, Fig. 412).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Figs 10, 11. *Amaraphyllum amoenum* Pedder, gen. et sp. nov., × 2; holotype, UNE F10390, Timor Limestone (Givetian part), unit 5, section 3.

AMARAPHYLLUM AMOENUM Pedder, gen. et sp. nov.

(Pl. D, Figs 3–7; Text-figs 10, 11)

Name derivation: Latin, *amoenus* = pleasant.

Type series: Holotype, UNE F10390, 26 feet below the top of unit 5, section 3 (202 feet below the top of the Timor Limestone). Paratypes 1–12, UNE F10391–10402, 38 to 52 feet below the top of unit 7, section 6 (196 to 210 feet below the top of the Timor Limestone). Paratypes 13, 14, UNE F10403, F 10404, 23 to 33 feet below the top of unit 7, section 6 (181 to 189 feet below the top of unit 5, section 6 (142 feet below the top of the Timor Limestone). Paratypes 16, 17, UNE F10406, F10407, 3 feet below the top of unit 5, section 6 (139 feet below the top of the Timor Limestone). Paratype 18, UNE F10408, unit 5, section 5 (287 to 334 feet below the top of the Timor Limestone). Paratypes 19, 20, UNE F10409, F10410, Timor Limestone at UNE Locality 402. Collected by A. E. H. Pedder. All are from the Givetian part of the limestone.

Diagnosis: Corallum dendroid, increase paricidal, peripheral and probably also lateral. Adult corallite diameter 8 to 14 mm. Septa smooth to very weakly carinate, radially arranged, 22 × 2 to 28 × 2 per adult corallite; major septa extend to within 1·0 to 2·5 mm. of the axis; minor septa only slightly shorter than the major. Dissepiments small, steeply inclined in 2 to 5 rows. Tabularium triseriate with a marginal series of flat tabellae, a periaxial series of highly arched tabellae and an axial series of flat to nearly flat tabulae.

Description: The corallum is fasciculate and almost invariably dendroid. Several specimens including the holotype measured more than 40 cm. across before cutting. There is definite evidence of paricidal, peripheral and less conclusive evidence of lateral increase in the type series. Adjacent corallites are generally less than 15 mm. apart and may be contiguous, although the corallum is not known to be ever cerioid or even subcerioid. Mature corallites typically have diameters of 8·0 to 12·0 mm.; the largest known are 14·0 mm. in diameter (paratypes 1 and 2). Fine growth ridges and in places weak interseptal ridges mark the exterior of the corallites. The fine dark axial plate and lighter and much thicker fibrous layer of the wall are well preserved in much of the material; between septal bases their combined thickness is usually 0·2 to 0·3 mm., but may be as little as 0·15 or as much as 0·5 mm. The septa which are embedded in the wall are radially arranged and poorly differentiated into two orders. They may be thin and smooth and constituted of fine fibres directed inwards at 40° to 45°, or they may be thicker and lightly carinate and incorporate disphylloid trabeculae of similar inclination. In either case their point of greatest thickness is at, or very close to, the inner margin of the wall; outwards from this point, that is within the wall, they taper abruptly and do not usually touch the axial plate; inwards from this point they at first taper moderately and then, apart from any carinae, taper very gently to their axial extremity. Major septa which are only a little longer than the minor normally extend to within 1·0 to 2·5 mm. of the axis. Random septal counts at corallite diameters expressed in mm. are as follows:

19 × 2	at	6·0	paratype 19	23 × 2	at	13·0	paratype 18
19 × 2	at	7·0	paratype 19	24 × 2	at	13·8	paratype 1
21 × 2	at	9·4	paratype 16	24 × 2	at	14·0	paratype 2
22 × 2	at	7·0	holotype	26 × 2	at	9·5	paratype 20
22 × 2	at	8·6	paratype 11	26 × 2	at	12·0	holotype
22 × 2	at	11·5	paratype 19	27 × 2	at	8·4	paratype 11
23 × 2	at	9·0	holotype	27 × 2	at	11·0	paratype 20
23 × 2	at	10·0	paratype 15	27 × 2	at	12·8	paratype 20
23 × 2	at	10·3	paratype 11	28 × 2	at	12·0	paratype 20

Dissepiments are small, steeply inclined and in two to five rows. Adaxially they generally decrease in size and increase in inclination. Some carry a thin sclerenchymal investment. A few of the most peripherally situated ones cross the interseptal loculus obliquely in transverse section. The tabularium is about one half of the total width of the corallite and is distinctly triseriate. The outermost part consists of a narrow zone of predominantly flat or gently concave tabellae. Inside these the tabularium is markedly elevated and is largely composed of highly inflated vesicles. The innermost region consists of broad, flat or almost flat tabulae. Locally vesicles of the periaxial region may be continuous with either the flat outer tabellae or the inner tabulae of the dissepimentarium.

Remarks: The highly distinctive tabularium and to a lesser extent the septa distinguish this species from any other disphyllinid known to the writer. The Timor Limestone specimen catalogued as AM 49925 is probably another example of this species.

Family Endophyllidae Torley, 1933

Sanidophyllum etheridgei Pedder, sp. nov.

(Pl. F, Fig. 2; Pl. G, Fig. 3; Text-figs 12, 13)

1922. *Endophyllum* ? sp. indet.; Benson (*partim*), p. 150 (68).

Name derivation: Patronym in honour of Robert Etheridge (*fil.*), author of the genus *Sanidophyllum* and the first to describe fossils from the Timor Limestone.

Type series: Holotype and paratypes 1–6, UNE F10374–10380 respectively, unit 5, section 5 (287 to 334 feet below the top of the Timor Limestone). Paratypes 7–9, UNE F10381–F10383, 20 to 25 feet below the top of unit 7, section 6 (178 to 183 feet below the top of the Timor Limestone). Paratype 10, UNE F10384, Timor Limestone at UNE Locality 628. Paratype 11, GSNSW F3890, labelled "Isis River". The holotype and paratypes 1–10 were collected by A. E. H. Pedder; all are from the Givetian part of the limestone. Paratype 11 was collected by G. Kershaw sometime before 16:4:1904; its matrix is identical with that of the other material and is presumably also Givetian.

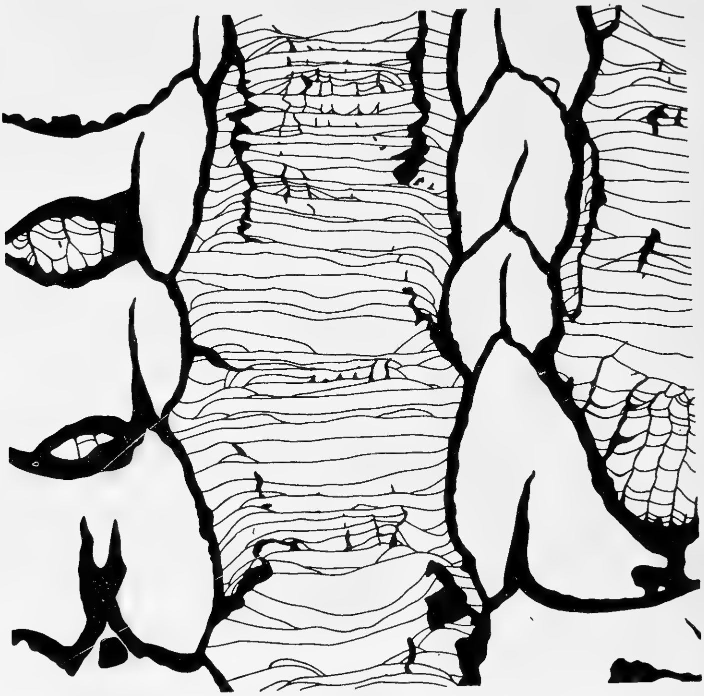
Diagnosis: Corallum sanidophylloid; corallites closely spaced, locally contiguous, 13 to 27 mm. in diameter at maturity. Calical expansions markedly upturned peripherally. Major septa 20 to 32 in number per adult corallite; minor septa very short or even entirely suppressed. Tabulae broad, commonly downturned at the periphery. Dissepiments absent.

Description: The sanidophylloid corallum is generally large and may exceed 40 cm. in diameter and 20 cm. in height. Corallites tend to be divergent initially but subsequently usually become more or less parallel; their adult diameter is typically within the range 13 to 18 mm., the largest seen attained an exceptional diameter of 27 mm. The calical expansions are generally less than 10 mm. broad and at the margin are strongly upwardly deflected forming walls that may be more than 8 mm. high. The under surfaces of the calical expansions merge gradually with the epithecas of the unexpanded parts of the corallites, moreover they are marked by similar growth annulations. The upper surface on the other hand, is quite distinct, for whereas the distal region of the calice bears short lamellae representing septa of both orders, the expanded part bears low and broad elevations corresponding to only one order of septa. New corallites first appear just inside the periphery of a calical expansion; if the expansion is broad there is no connection between the bud and the parent tabularium. Major septa normally extend approximately one half of the distance to the axis, but periodically lengthen so as to extend approximately two thirds of this distance. Minor septa are usually less than 0·5 mm. in length and may be entirely suppressed, thus there is a high degree of septal differentiation. Peripheral withdrawal of the septa is not common and where it is present is due to the insertion of a sloping marginal tabula rather than a lonsdaleoid dissepiment. Apart from minor dilations, septa of both orders are thin and smooth. Random counts of major septa at corallite diameters expressed in mm. are as follows:

1	at	4·5	holotype
14	at	5·0	paratype 1
20	at	6·0	holotype
20	at	8·5	holotype
20	at	13·5	holotype
21	at	11·5	paratype 10
21	at	15·0	paratype 10
22	at	16·0	holotype
24	at	9·0	paratype 11
29	at	17·0	paratype 11
29	at	19·0	paratype 11
32	at	27·0	paratype 1

The tabulae are broad and characteristically downturned at the margin; adaxially sloping tabulae may supplement the tabularium peripherally, but no true dissepiment has been seen.

Remarks: *Sanidophyllum davidi* Etheridge (spelling of trivial name amended as directed by I.C.Z.N. Article 32(c)) normally has a much larger corallum with more widely spaced and commonly larger corallites, but it is a variable species and may approach the morphology of *S. etheredgei*. In this case the calical expansions, which generally develop a much more pronounced wall between the individual corallites in *S. etheridgei*, serve to distinguish the two species. *S. colligatum* Hill is a larger species with more numerous septa and a moderately well developed septal stereozone; it also has relatively less developed walls where adjacent calical expansions meet.



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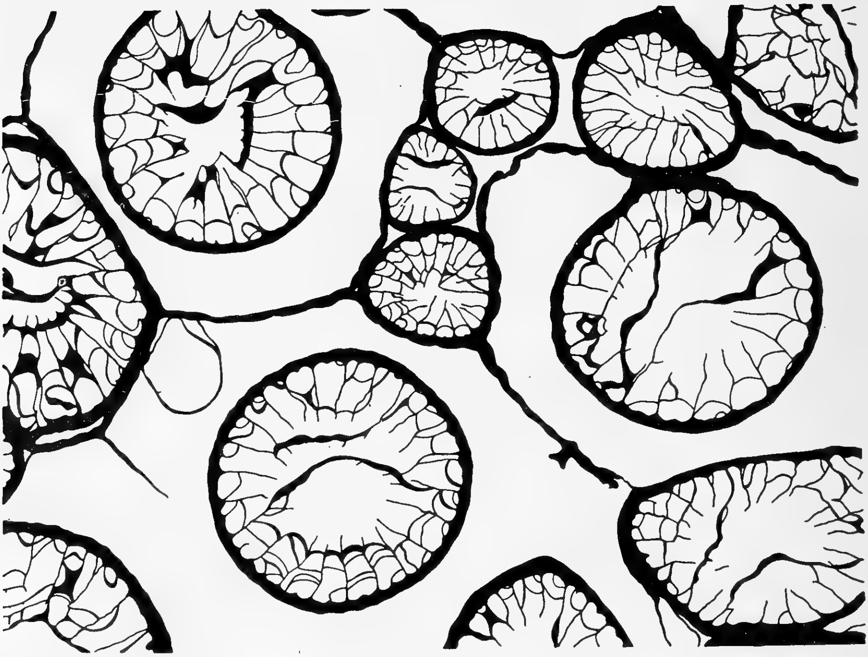

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Figs 12, 13. *Sanidophyllum etheridgei* Pedder, sp. nov., × 2; holotype, UNE F10374, Timor Limestone (Givetian part), unit 5, section 5.

Genus Blysmatophyllum Pedder, nov.

Name derivation: Greek, βλυσμα = bubbling, and φυλλον = leaf.

Type species: *Blysmatophyllum isisense* Pedder, sp. nov., see below.

Diagnosis: Corallum sanidophylloid. Septa radially arranged with an endophylloid microstructure and commonly withdrawn from the periphery. Dissepimentarium well developed, normally extending on to the calical

14

15

Figs 14, 15. *Blysmatophyllum isisense* Pedder, gen. et sp. nov., × 2; paratype 4, UNE F10389, Timor Limestone (Givetian part), UNE Locality 402.

expansions. Tabularium tending towards biseriate with a narrow outer series of flat to weakly concave tabellae and an inner series of peripherally down-turned and peripherally elevated tabulae.

Remarks: The new genus is closely related to *Sanidophyllum* and *Endophyllum,* and also resembles *Iowaphyllum.* From the first it is distinguished by its well developed dissepimentarium and from the others by its sanidophylloid form. To some extent *Blysmatophyllum* is homeomorphic with the Silurian genus *Strombodes,* however they may be distinguished by their dissepimentaria which in *Strombodes* is periodically rejuvenated and is generally far less lonsdaleoid. At the present time the type species only is included in the genus.

BLYSMATOPHYLLUM ISISENSE Pedder, gen. et sp. nov.

(Pl. E, only Fig.; Pl. F, Fig. 1; Text-figs 14, 15)

Name derivation: Isis River, Upper Hunter Valley, New South Wales.

Type series: Holotype and paratypes 1, 2, UNE F10385–F10387 respectively, unit 5, section 5 (287 to 334 feet below the top of the Timor Limestone). Paratype 3, UNE F10388, Timor Limestone at UNE Locality 406. Paratype 4, UNE F10389, Timor Limestone at UNE Locality 402. Collected by A. E. H. Pedder. All are from the Givetian part of the limestone.

Diagnosis: Corallum large, sanidophylloid. Mature corallites 16 to 29 mm. in diameter and 5 to 26 mm. apart at levels between calical expansions. Septa radially arranged, well differentiated, zigzagly carinate in the dissepimentarium, commonly peripherally withdrawn, and numbering 28 × 2 to 31 × 2 in adult corallites; both orders represented by ridges on the upper surfaces of the calical expansions. Calical expansions usually markedly upturned peripherally. Tabularium endophylloid, biseriate to triseriate. Dissepiments elongate, commonly lonsdaleoid, in 1 to 4 rows and locally extending out on to the calical expansions.

Description: Except in very rare situations where there was inadequate space for the development of calical expansions the corallum is sanidophylloid. The largest known, which is paratype 4, was at least 70 cm in diameter and 40 cm. in height at the time of collecting. Unexpanded adult corallites of the holotype and paratypes 1 and 2 are mostly 23 to 25 mm. in diameter and 5 to 15 mm. apart, but in paratypes 3 and 4 they are generally only 16 to 18 mm. in diameter and 5 to 13 mm. apart. The largest corallite seen has a diameter of 29 mm. and the greatest distance observed between adjacent corallites is 26 mm. Calical expansions are given out every 7 to 20 mm., the typical interval being about 10 mm. In some cases rates of growth of adjacent corallites was markedly discrepant (see Text-fig. 15). The wall at unexpanded levels of the corallites is usually 0·3 to 0·4 mm. thick and consists of a thin axial plate and what appears to be lamellar skeletal tissue. The axial plate extends uninterruptedly over the lower surface of the calical expansions and is clearly visible between contiguous calical expansions. The septa are radially arranged, thin and in the unexpanded parts of the corallites well differentiated into two orders. They generally develop weak to moderate zigzag carinae in the dissepimentarium. Major septa may terminate as much as 5 mm. from the axis or they may be longer and even weakly rotated in the axial region. In some corallites lengthening and shortening of the septa was apparently periodic. Minor septa are commonly 0·5 to 3·0 mm. in length. Both orders of septa tend to be discontinuous towards the axis and withdrawn from the periphery. Major and minor septa are equally developed as low but distinct ridges on the upper surfaces of the calical expansions. Typically the thickness of the calical expansions measured through the thickest part of one of these ridges is 0·8 to 1·0 mm. Calical expansions are upturned peripherally, producing a partition usually 3 to 7 mm. high, but in the absence of dissepiments it may be lower. The fine septal structure is not sufficiently preserved for detailed description, however slender rod-like trabeculae of the type seen in other endophyllids are visible in several of the thin sections. Various septal counts at diameters expressed in mm. are as follows:

30 (undiff.)	at	10·0	paratype 4
25 × 2	at	12·0	paratype 3
25 × 2	at	12·5	holotype
25 × 2	at	14·0	paratype 3
25 × 2	at	18·5	holotype
27 × 2	at	11·0	paratype 4
27 × 2	at	24·0	holotype
28 × 2	at	16·0	paratype 3
28 × 2	at	23·5	paratype 2
29 × 2	at	27·0	paratype 1
30 × 2	at	16·5	paratype 4
30 × 2	at	24·0	holotype
31 × 2	at	16·0	paratype 4
31 × 2	at	17·5	paratype 3

The dissepimentarium comprises large, elongate and commonly lonsdaleoid dissepiments arranged in 1 to 3, locally 4 rows; it may or may not extend on to the calical expansions. Sclerenchymal deposits may coat parts of the dissepimentarium. Generally the tabularium consists of a narrow outer zone of flat to gently concave tabellae and an inner broader zone of peripherally downturned tabulae. These tend to be elevated just inside the downward deflection and the elevation may be accentuated by vesicular tabellae so that in places the tabularium is tri- rather than biseriate. Some of the central tabulae flatten again beyond their downward deflection and then penetrate and form part of the outer flat zone.

Remarks: This is such a distinctive species that comparison with any other described to date would be superflous.

MEASURED SECTIONS

As the upper contact of the Timor Limestone is generally better exposed and less diachronous than the lower contact we have numbered the lithologic units downwards.

SECTION 1

The section is located in a normally dry valley centered approximately one half mile south of "Allston" Homestead on the west side of the Isis River (Portions 99 and 81, Parish of Lincoln, County of Brisbane). Measurement begins between 0 and 27 feet below the top of the Timor Limestone and ends where the limestone passes beneath alluvium of the Isis River Valley. Section initially measured with tape and compass by A. E. H. Pedder and J. H. Jackson, April 1964, with subsequent revisions completed by J. H. Jackson and D. W. Ellenor, March 1968.

		Thickness in feet	
Unit No.		Unit	Total from top
1.	Limestone, medium grey to black, fine to medium grained, dense, interbedded with irregular chert beds and nodules ranging from 1″ to 9″ in thickness and forming 15 to 30% of the total volume; thin to medium bedded. Megafossils sparse. *Polygnathus linguiformis* forma nova, *P. varcus*, *P.* (?) *variabilis*, *Spathognathodus brevis* and *S. planus* recovered from 20′ below the top of the unit.	60·9	60·9
2.	Limestone and chert, as above but principally dark grey and very fine grained to microcrystalline	10·0	74·5
3.	Limestone and chert as in unit 1. *Polygnathus varcus*, "*Endophyllum*" *schlueteri* and cystimorph tetracorals present	14·0	88·5

4.	Limestone, light to medium grey, fine grained, dense with dark, highly irregular chert lenses and nodules forming 30 to 40% of the total unit; thin to medium bedded. An abundant silicified fauna is present	43·5	132·0
5.	Limestone, essentially as above but no chert. *"Endophyllum" schlueteri* and digitate tabulate corals present	30·0	162·0
6.	Limestone, dark grey, fine to medium grained, dense; medium to massive bedded. Abundant pentamerid brachiopod fragments occur near the top of the unit. *Spathognathodus brevis* occurs 46′ from the top of the unit	62·9	224·9
7.	Limestone, light to medium grey, very fine grained to microcrystalline, small irregular light grey-brown chert nodules constitute approximately 10% of the unit; thin to medium bedded	30·0	254·9
8.	Limestone, light grey, cryptocrystalline, abundant ferruginous shale partings causing some brecciation, dense; medium bedded	40·2	295·1
9.	Limestone, essentially as above; poorly exposed	38·5	333·6
10.	Limestone, light to medium grey, fine grained, dense with a few shale stringers running randomly throughout; medium bedded. Some silicified fossils, including brachiopods	58·5	392·1
11.	Limestone, dark grey, fine to very fine grained, dense; medium bedded. Neither chert nor fossils evident	71·7	463·8
12.	Limestone, medium to dark grey, fine to very fine grained, non-biogenic, stylolitic with ferruginous material concentrated along the sutures, thin light grey chert lenses 1″ to 4″ total 8 to 10% of the unit's volume, dense; bedding thin to medium, well developed	36·5	500·3
13.	Limestone and chert, as above but chert content 15%. *Polygnathus kockelianus kockelianus*, *P. robusticostatus* (*s.l.*), *P. trigonicus* and *Spathognathodus bidentus bidentus* occur in lower 14′	27.0	527·3
14.	Limestone, light grey, fine to medium grained, some ferruginous staining along shale partings, light grey chert bands up to 4″ thick compromise 35% of the unit's volume, chert/limestone contacts very irregular, but are roughly parallel to the bedding, dense; bedding medium, well developed. *Polygnathus kockelianus kockelianus*, *and P. robusticostatus* (*s.l.*) from the top of unit. *Xystriphyllum* (?) *giganteum* approximately 30′ below the top	34·0	561·3
15.	Limestone and chert, as above but chert content 25% of the total rock	23·0	584·3
16.	Limestone and chert, as above but chert approximately 15–20% of the total rock	35·5	619·8
17.	Limestone as above but no chert present	23·0	642·8
18.	Limestone, essentially as above, but is profusely stylolitized resulting in apparent brecciation. A few corals are present including *Xystriphyllum* (?) *giganteum*, *Sociophyllum densum*, and *Sanidophyllum davidi*. *Polygnathus kockelianus kockelianus*, and *P. robusticostatus* (*s.l.*) occur 10′ below the top of the unit	19·0	661·8
19.	Limestone, light to medium grey, fine to very fine grained, heavily stylolitized, shale partings numerous, dense; thick to massive bedded	18·0	679·8
20.	Limestone, light grey, fine grained, essentially as above; medium bedded. *Polygnathus kockelianus kockelianus* and *P. robusticostatus* (*s.l.*) occur 8′ from the top of the unit	28·2	708·0
21.	Limestone, as above, some brecciated by stylolitization; medium to massive bedded. Corals include *Dendrostella* sp. cf. *D. rhenana* and *Sociophyllum densum*	64·5	772·5
22.	Limestone, light grey, microcrystalline, stylolitic, numerous red shale partings, concentrations on stylolite surfaces give rise to a red mottled appearance, irregular chert nodules and blebs constitute 20 and locally up to 40% of the total rock; massive bedded. Some corals present	57·5	830·0

23.	Limestone, light grey, fine grained, some chert, less than 5%, red argillaceous material coating stylolite faces; medium to thick bedded.	44·0	874·0
24.	Limestone, medium to dark grey, fine to medium grained, biogenic, siliceous argillaceous stringers (3″–5″ thick) running parallel to the bedding give the unit a characteristic "stepped" outcrop pattern; thin to medium bedded. *Icriodus corniger* occurs at the top of the unit	20·0	894·0
25.	Limestone, dark grey, fine to very fine grained, biogenic, siliceous argillaceous partings as above; thin bedded, lower part poorly exposed	87·5	981·5
	Total Timor Limestone exposed		981·5′

SECTION 2

The section is located on the western limb of the Timor Anticlinorium, one and one half miles north-west of "Allston" Homestead (Portion 78, Parish of Lincoln, County of Brisbane). The upper contact of the Timor Limestone is poorly exposed; the lower contact is well exposed and apparently disconformable above interbedded siliceous siltstones and mudstones of the Yarrimie Formation. Section initially measured with tape and compass by A. E. H. Pedder and J. H. Jackson, April 1964; subsequently revised by D. W. Ellenor, January 1968.

Unit No.		Thickness in feet	
		Unit	Total from top
1.	Poorly exposed, limestone rare, chert main rock type visible, cream to deep red. Relict corals present	31·5	31·5
2.	Limestone, dark grey to black, fine to medium grained, slightly biogenic, small chert nodules, comprising less than 5% of the units volume, dense; upper 15′ poorly exposed, otherwise medium bedded. *"Endophyllum" schlueteri* present	89·7	121·2
3.	Limestone, medium to dark grey, fine to very fine grained, biogenic, dense; thin to medium bedded. Some silicified faunal debris	35·0	156·2
4.	Limestone, medium grey, medium to coarse grained, slightly biogenic; medium bedded. Rhynchonellid brachiopods present	9·0	165·2
5.	Limestone, medium grey, medium to coarse grained, sand size detrital quartz and lithic fragments common; poorly developed cross-bedding; thick to massive bedded	40·0	205·2
6.	Conglomerate, oligomictic with round chert pebbles (⅛″ to ½″ in diameter), matrix mainly lithic fragments, cement calcareous; thick bedded	6·5	211·7
	Total thickness of the Timor Limestone		211·7′

SECTION 3

The section is located on the western limb of the Timor Anticlinorium between section 2 and Ten Mile Creek, approximately one and three quarter miles north-west of "Allston" Homestead (Portion 78, Parish of Lincoln, County of Brisbane). The upper contact is not well exposed but appears conformable. The lowest unit of the section is in sharp contact with a rock unit interpreted as a slump breccia. Section initially measured by A. E. H. Pedder and J. H. Jackson, April 1964, and subsequently revised by D. W. Ellenor, January, 1968.

Unit No.		Thickness in feet	
		Unit	Total from top
1.	Limestone, light to medium grey, very poorly exposed, black chert as large irregular masses comprises the bulk of the unit. Silicified corals, including *"Endophyllum" schlueteri* at the top, common	35·0	35·0

2.	Limestone, light grey, medium grained, biogenic, irregular dark chert nodules abundant, dense; thin bedded poorly exposed	5·0	40·0
3.	Limestone, medium to dark grey, fine to medium grained, biogenic, dense, small dark chert nodules forming less than 5% of the total rock, some ferruginous shale laminae interspersed throughout; thin to medium bedded. Some silicified tabulate corals. *Spathognathodus bipennatus*, and *S. brevis* collected 25′ from the top	46·2	86·2
4.	Limestone, medium grey, fine grained, biogenic, dense, some very minor chert; medium bedded. Pentamerid brachiopods fragments common	54·1	140·3
5.	Limestone, medium grey, fine grained, biogenic, dense; medium bedded. *Heliolites* sp., *Amaraphyllum amoenum*, and rhynchonellid brachiopods present 10′ to 26′ below the top	43·2	183·5
6.	Limestone, medium grey-brown, medium to coarse grained; unit contains rounded biogenic detritus, subrounded sand size detrital quartz and some lithic fragments (detrital fragments constitute 40% of the total rock), interbeds 6″ to 10″ thick of non arenaceous limestone occur throughout; arenaceous units exhibit cross-bedding; medium bedded	7·0	190·5
7.	Limestone, grey-green, medium to coarse grained; arenaceous with some rounded green and red chert fragments (½″–1½″ in diameter), coarse biogenic detritus; medium to thick bedded. *Heliolites* sp., and *Endophyllum* sp. present	20·5	211·0
8.	Limestone, light grey, fine to medium grained; biogenic, interbedded within thin bedded calcareous arenite beds, containing rounded detrital quartz and lithic fragments, and some greenish chert pebbles up to 8″ in diameter.	22·0	233·0
	Total thickness of the Timor Limestone		233·0′

SECTION 4

The section is located on a hill slope some 220 yards north-east of "Minto" Homestead (Portion 7, Parish of Lincoln, County of Brisbane). Fine grained lithic arenites and argillites of the Yarrimie Formation are moderately well exposed both immediately above and below the limestone. Section initially measured with tape and compass by A. E. H. Pedder and J. H. Jackson, April 1964, with revisions by D. W. Ellenor, January, 1968.

		Thickness in feet	
Unit No.		Unit	Total from top
1.	Limestone, light to medium grey, fine to medium grained, stylolitic with red argillaceous material concentrated along the sutures, biogenic, some siliceous faunal debris, small chert nodules comprising less than 5% of unit's volume; medium bedded. "*Endophyllum*" *schlueteri* abundant throughout	20·0	20·0
2.	Limestone, light to medium grey, medium to coarse grained, coarsely and abundantly biogenic, characterized principally by large stromatoporoid and coral colonies, crinoidal debris very common; thin to medium bedded. "*Endophyllum*" *schlueteri* and *E.* sp. undet. are present	35·0	55·0
3.	Limestone, light grey, fine to medium grained, sparsely biogenic, some ferruginous shale partings, dense; medium bedded	15·0	70·0
4.	Limestone, grey white, medium to coarse grained, coarsely biogenic, abundant sand size detrital quartz grains and ferruginous shale stringers; medium bedded	5·0	75·0
5.	Limestone, light grey, abundant stromatoporoids resting directly on underlying siltstones	2·0	77·0
	Total thickness of the Timor Limestone		77·0′

Section 5

The section is located on the eastern limb of the Timor Anticlinorium, approximately one and three quarters miles east of "Allston" Homestead in the first main creek south of Perrys Creek (Portion 180, Parish of Crawney, County of Brisbane). Measurement starts at, or very close to, the upper contact of the Timor Limestone (overlying scree is exclusively of Yarrimie type argillites) and ends just east of a tightly folded zone within the limestone. Section measured with tape and compass by A. E. H. Pedder and J. H. Jackson, February, 1966; some revisions by D. W. Ellenor, January, 1968.

Unit No.		Thickness in feet	
		Unit	Total from top
1.	Limestone, medium grey, fine grained, locally coarsely biogenic, dense; poorly bedded. Silicified fauna including *"Endophyllum" schlueteri*, *Mesophyllum* sp. and digitate tabulate corals. *Spathognathodus brevis* isolated from 10′ below top	104·1	104·1
2.	Limestone, light to medium grey, microcrystalline to coarse grained, biogenic, iron stained shale partings, dense; poorly bedded. Fauna which is silicified in upper part includes stromatoporoids, *Heliolites* sp. and massive tabulate corals	123·5	227·6
3.	Limestone, medium to dark grey, coarsely biogenic, dense; poorly bedded, ridge forming. Megafossils scarce but include *Heliolites* sp., a cystimorph tetracoral and rhynchonellids; *Endophyllum* sp. was collected *ex situ*	57·6	285·2
4.	Limestone, light grey, red tinted, coarse grained, dense *Endophyllum* sp. present	2·0	287·2
5.	Limestone, dark grey, fine grained, biogenic, dense; thin bedded. Rich coral fauna, partly silicified, including cf. *Placophyllum* sp. nov., *Dohmophyllum* sp., *Grypophyllum* sp. cf. *G. denckmanni*, *Stringophyllum quasinormale* var. *Amaraphyllum amoenum*, *Sanidophyllum etheridgei*, *Blysmatophyllum isisense*, *Plasmophyllum* sp. and *Calceola sandalina*	46·8	334·0
6.	Limestone, mostly dark grey, fine grained, biogenic; thin to medium bedded. Silicified tabulate corals present, other megafossils rare	57·9	391·9
7.	Limestone, medium to dark grey, fine grained, dense; massive, poorly bedded. No megafossils seen, but fossils rare	51·5	443·4
8.	Limestone, light to medium grey, fine grained, dense; massive, poorly bedded. No megafossils seen, but *Spathognathodus bipennatus* has been isolated from the top.	55·1	498·5
9.	Limestone, as above but some thin ferruginous shale partings; medium to thick bedded. *Bryantodus* sp. cf. *B. pravus*, *Polygnathus pseudofoliatus*, *Spathognathodus bipennatus* and *S. brevis* occur at the top	99·3	597·8
10.	Limestone, dark grey, fine grained with minor chert nodules and nodular bands; medium bedded	31·7	629·5
11.	Limestone, medium grey, coarse grained with coarse biogenic fragments, arenaceous, common brown weathered feldspathic fragments impart a speckled appearance to the rock	2·0	631·5
12.	Limestone, dark grey, fine grained, biogenic, dense, includes a 9″ medium to coarse grained limestone layer; medium bedded	22·4	653·9
13.	Limestone, medium to dark grey, fine to medium grained, biogenic, argillaceous stringers of dark chert forming 20 to 30% of the total rock; medium to thick bedded, lower part poorly exposed. Some silicified fossils. *Spathognathodus bipennatus* and *S. obliquus* 20′ from top; *P. kockelianus kockelianus*, *P. robusticostatus* (*s. l.*) *P. trigonicus* and *Spathognathodus bidentatus bidentatus*, occur throughout the lower 70′	92·1	746·0

14.	Limestone, medium grey, fine to medium grained, biogenic, dense, argillaceous stringers and chert occurring as bedded lenticles and lenses comprise from 20 to 30% of the total rock. *P. kockelianus kockelianus*, *P. robusticostatus* (*s. l.*), *P. trigonicus* and *Spathognathodus bidentatus bidentatus* occur at the top	59·4	805·4
15.	Limestone, light to medium grey, very fine grained, dense, thinly interbedded with argillaceous stringers and light grey chert, forming approximately 30% of the total rock; thin to medium bedded. *Polygnathus augustipennatus*, *P. kockelianus kockelianus*, *P. robusticostatus* (s. *l.*) *P. trigonicus* and *Spathognathodus bidentatus bidentatus* occur 5′ from the top	43·4	848·8
16.	Limestone, light to medium grey locally red stained, very fine to fine grained, dense, thin chert and argillaceous bands similar to those above; medium to thick bedded. *Polygnathus angustipennatus*, *P. kockelianus kockelianus*, *P. robusticostatus* (*s. l.*), *P. trigonicus* and *Spathognathodus bidentatus bidentatus* present	15·0	863·8
	Total thickness of Timor Limestone measured		863·8′

Section 6 (Type Section)

The section is located on the eastern limb of the Timor Anticlinorium and is centred approximately one and one half miles east-south-east of "Allston" Homestead; it extends from the north-eastern part of Portion 141 to the north-western part of Portion 142, Parish of Crawney, County of Brisbane. Yarrimie argillites outcrop poorly both immediately above and below the measured beds which thus constitute an almost complete section of the Timor Limestone. Section measured by A. E. H. Pedder and J. H. Jackson, June 1966.

Unit No.		Thickness in feet Unit	Thickness in feet Total from top
1.	Limestone, dark grey, medium to coarse grained, argillaceous, stylolitic, dense; medium bedded. Abundant silicified fauna including *Stringophyllum* sp. cf. *S. isactis*, "*Endophyllum*" *schlueteri*, *Mesophyllum* sp., and an undetermined atrypid brachiopod	43·4	43·4
2.	Limestone, light grey, locally pink, coarse grained, biogenic, styolitic, dense; medium to massive bedded	39·8	83·2
3.	Limestone, light grey to pink, medium to coarse grained, biogenic with scattered detrital quartz grains and three 2′ to 3′ pentamerid coquina beds; medium to massive bedded	33·8	117·0
4.	Limestone, medium to dark grey, fine to medium grained, biogenic, dense; massive, cliff forming	18·1	135·1
5.	Limestone, as above but thin rubbly weathered. *Amaraphyllum amoenum* 3′ and 7′ from top, and *Spathognathodus brevis* at base	15·0	150·1
6.	Limestone, dark grey, in part very slightly argillaceous, fine to medium grained, biogenic, minor detrital quartz grains, dense; medium bedded	8·0	158·1
7.	Limestone, as above but rubbly weathered. *Heliolites* sp., *Dohmophyllum* sp., *Stringophyllum quasinormale* var., *S.* sp. nov., *Amaraphyllum amoenum*, *Sanidophyllum etheridgei*, cf. *Placophyllum* sp. nov., *Calceola sandalina*, *Spathognathodus bipennatus* and *S. brevis* present	62·5	222·6
8.	Limestone, as above but massive to rubbly weathered. Sparsely fossiliferous. *Polygnathus* sp. cf. *P. webbi* present	33·7	254·3
9.	Limestone, medium grey, microcrystalline to fine grained, biogenic, dense; thin, partly rubbly to medium bedded. Few silicified fossils	37·9	292·2

10.	Limestone, medium grey, fine to medium grained, biogenic, dense; medium bedded except for one 5′ massive bed 23′ to 28′ above base. Few stromatoporoids and corals; *Polygnathus eiflius*, *P. varcus*, *Spathognathodus bipennatus* and *S. brevis* 28′ from top; *P. robusticostatus* (*s. l.*) at base	56·4	348·6
11.	Limestone, medium grey, fine to coarse grained, biogenic, dense; medium bedded but poorly exposed. Few silicified stromatoporoids and corals; *Polygnathus eiflius* at top; *Ozarkodina kutscheri*, *P. angustipennatus*, *P. eiflius*, *P. kockelianus kockelianus*, *P. robusticostatus* (*s. l.*), *P. trigonicus*, *Spathognathodus bidentatus bidentatus* and *S. bipennatus* at base	31·6	380·2
12.	Covered interval, evidently over cherty beds	36·0	416·2
13.	Limestone, dark grey, fine grained, biogenic, thinly interbedded with an approximately equal amount of dark grey chert. Comparatively rare silicified corals and brachiopods present throughout; *Polygnathus angustipennatus*, *P. kockelianus kockelianus*, *P. robusticostatus* (*s. l.*), *P. trigonicus*, *Spathognathodus bidentatus bidentatus* and *S. bipennatus* at top	25·7	441·9
14.	Limestone and chert, as above but chert approximately 30% of total rock. Some silicified atrypids throughout; *Ozarkodina kutscheri*, *Polygnathus eiflius*, *P. kockelianus kockelianus*, *P. robusticostatus*, (*s. l.*), *P. trigonicus*, *Spathognathodus bidentatus bidentatus* 70′ from top; *Lonchodina ramulata*, *Polygnathus kockelianus kockelianus* *P. robusticostatus* (*s. l.*), *P. trigonicus*, *Spathognathodus bidentatus bidentatus* 118′ from top; *Polygnathus kockelianus kockelianus* at base	163·2	605·1
15.	Limestone and chert, as above but chert approximately 60% of total rock. *Polygnathus angusticostatus*, *P. angustipennatus*, *P. kockelianus kockelianus*, *P. trigonicus*, *Spathognathodus bidentatus bidentatus*, *S. bidentatus transitans* and *S. obliquus* at base	45·8	650·9
16.	Limestone and chert, as above but chert approximately 40% of total rock. *Polygnathus eiflius*, *P. kockelianus kockelianus*, *P. robusticostatus* (*s. l*), *P. trigonicus*, *P.* sp. cf. *P. hulkus* and *Spathognathodus bidentatus transitans* 48′ from top	84·8	735·7
	Traverse of about 250 yards here.		
17.	Limestone, fawn, light grey to maroon, mostly crypto- to microcrystalline, highly stylolitic, dense; massive. *Dendrostella* sp. cf. *D. rhenana*, *Xystriphyllum* (?) *giganteum*, *Sociophyllum densum*, *Sanidophyllum colligatum* and *S. davidi* present at certain levels; *Polygnathus angustipennatus*, *P. kockelianus australis* *P. robusticostatus* (*s. l.*) and *P.* sp. cf. *P. trigonicus* 126′ from top	164·1	899·8
18.	Limestone, white to light grey, rose tinted, dense, argillaceous and up to 35% chert and jasper, stylolitic; medium bedded. Rare silicified corals; *Polygnathus angustipennatus*, *P. kockelianus australis*, *P. kockelianus* subsp. cf. *P. kockelianus australis*, *P.* cf. sp. *P. pseudofoliatus* *P. robusticostatus* (*s. l.*) and *Spathognathodus bidentatus bidentatus* 44′ from top	49·6	949·4
19.	Limestone, white to light grey or pink, coarsely crystalline, dense with approximately 5% chert; medium to thick bedded. No megafossils observed, but *Polygnathus robusticostatus* (*s. l.*) occurs at the base	26·2	975·6
20.	Limestone, siliceous, poorly exposed, rubbly, weathered, thin bedded where exposed	47·1	1022·7
21.	Limestone, medium to dark grey, microcrystalline to coarse grained, biogenic thinly interbedded with cherty bands forming approximately 35% of the total rock; thin bedded, poorly exposed	12·0	1034·7
22.	Limestone, as above but argillaceous and interbedded with chert forming 30% of the total rock. *Haplistian robustum*, *Favosites* sp. and *Stringophyllum* sp. nov. are present	54·1	1088·8

23.	Limestone, dark grey, microcrystalline to very fine grained, argillaceous, dense, thinly interbedded with an approximately equal amount of dark chert; ochrous weathered, poorly exposed. *Columellaespongia woolomelensis* and silicified corals, including *Stringophyllum* sp. nov., *Calceola sandalina* and *Plasmophyllum* sp.; *Polygnathus* sp. cf. *P. pseudofoliatus* 44′ from top; *Icriodus corniger* occurs throughout	61·2	1150·0
	Total Timor Limestone exposed		1150·0′

SECTION 7

The section is located in a normally dry valley centred about one quarter mile north-west of "Allston" Homestead on the western side of the Isis River(Portions 14 and 80, Parish of Lincoln, County of Brisbane). Contact with the overlying Yarrimie argillites is sharp and apparently conformable; the section ends on the bank of the Isis River but there is a covered interval of approximately 35 stratigraphic feet between the base of the section and the underlying arenites and siltstones of the Yarrimie Formation. Section measured with tape and compass by A. E. H. Pedder, J. H. Jackson and D. W. Ellenor, June and July 1967.

Unit No.		Thickness in feet	
		Unit	Total from top
1.	Limestone, light grey, coarse grained, biogenic; thin to medium bedded	9·0	9·0
2.	Limestone, medium grey, fine grained, dense; dark chert nodules constitute about 30% of the total rock; thin to medium bedded, poorly exposed in lower part. *Polygnathus linguiformis* forma nova, *P. varcus*, *P.* (?) *variabilis* at top; *Polygnathus linguiformis* forma nova, *P. pseudofoliatus*, *P. varcus* and *Spathognathodus brevis* 20′ from top; *Polygnathus linguiformis linguiformis* and *Spathognathodus brevis* at base	44·1	53·1
3.	Dolerite, altered; green weathered	1·0	54·1
4.	Covered interval	5·4	59·5
5.	Limestone, medium to dark grey, fine grained, dense; dark thin bedded chert forming 20 to 40% of the total rock; thin bedded. Fauna, including tabulate corals and brachiopods, partly silicified. *Polygnathus linguiformis* forma nova and *Spathognathodus brevis* at top; *Ancyrognathus walliseri*, *Polygnathus linguiformis linguiformis* and *P. linguiformis* forma nova 20′ from top	50·8	110·3
6.	Limestone, medium grey, finely biogenic, dense; medium to massive bedded. "*Endophyllum*" *schlueteri* and a large pentamerid brachiopod occur throughout; *Polygnathus varcus* occurs at top	42·7	153·0
7.	Limestone, as above but mostly medium bedded	31·7	184·7
8.	Limestone, dark grey, fine to medium grained, biogenic; mostly medium bedded. Fauna, including "*Endophyllum*" *schuleteri* and a pentamerid brachiopod, partly silicified; *Polygnathus varcus* and *Spathognathodus brevis* present near top	13·9	198·6
9.	Limestone, light grey, cryptocrystalline, dense; massive poorly bedded with some ferruginous staining. *Polygnathus eiflius*, *P. robusticostatus* (*s. l.*) and *Spathognathodus bidentatus bidentatus* occur near middle of unit	37·0	235·6
10.	Limestone, medium to dark grey, crypto- to microcrystalline, dense; massive. Poorly fossiliferous, *Polygnathus trigonicus* and *Spathognathodus bidentatus bidentatus* occur at top	12·0	247·6
11.	Limestone, as above but with chert nodules forming 3 to 5% of the total rock	28·5	276·1

12.	Limestone, light to dark grey, crypto- to microcrystalline, dense, light coloured chert nodules forming 10 to 15% of the total rock; massive. *Polygnathus kockelianus kockelianus* and *P. robusticostatus* (*s. l.*) 5′ from top	34·0	310.1
13.	Limestone, medium grey, microcrystalline, dense; thin to medium bedded; light coloured chert nodules forming 10 to 15% of the total rock. *Spathognathodus bidentatus bidentatus* occur at top	40·1	350·2
14.	Limestone, medium grey, very fine grained, dense; scattered chert nodules forming less than 5% of total rock; poorly bedded. *Polygnathus kockelianus kockelianus* at top	40·8	391·0
15.	Limestone, light grey, mostly medium grained, dense; chert nodules less than 3% of the total rock; poorly bedded	32·2	423·2
16.	Limestone, as above but mostly finely crystalline. *Polygnathus kockelianus kockelianus*, *P. robusticostatus* (*s. l.*) *Spathognathodus bidentatus bidentatus* and *S. bidentatus transitans* occur at top	35·3	458·5
17.	Limestone, light grey, fine to medium grained, dense, sporadic chert pods and lenses; medium to thick bedded, some iron staining. *Sanidophyllum colligatum* and *S. davidi* at base; *Polygnathus robusticostatus* (*s. l.*) at top ..	17·4	475·9
18.	Limestone, light grey, microcrystalline, dense, minor chert stringers; poorly medium bedded, grey-brown mottled weathering. *Polygnathus kockelianus kockelianus* and *P. robusticostatus* (*s. l.*) at top	17·6	493·5
19.	Limestone, light grey, crypto- to microcrystalline, dense; poorly bedded, red iron staining along stylolitic faces. *Polygnathus kockelianus kockelianus*, *P. robusticostatus* (*s. l.*) and *P. trigonicus* occur at top	72·4	565·9
20.	Limestone, medium grey to brown, crypto- to microcrystalline; medium to thick bedded, red iron staining along stylolitic faces	41·4	607·3
21.	Limestone, as above but partly brecciated and thin bedded towards the base	15·0	622·3
22.	Limestone, light grey, crypto- to microcrystalline in 2′ to 3·5′ bands alternating with 2″ to 6″ bands of chert; partly brecciated; iron stained and rubbly weathered. *Polygnathus robusticostatus* (*s. l.*) at top	32·8	655·1
23.	Limestone, reddish grey, very fine grained, interbedded with 1″ to 3″ chert layers forming approximately 10% of the total rock; iron staining along stylolites; rubbly to blocky weathered. *Polygnathus kockelianus* subsp. cf. *P. kockelianus australis* and *P.* sp. cf. *P. trigonicus* are present	19·7	674·8
24.	Limestone, grey to brown with red tint, cryptocrystalline to very fine grained, interbedded with 1″ to 3″ cherty layers forming approximately 10% of the total rock; iron staining along stylolites, medium to thick bedded; rubbly to blocky weathered	10·0	684·8
25.	Limestone, as above but chert in distinct 2″ to 6″ beds forming 25% of the total rock	31·1	715·9
26.	Limestone, grey to brown, medium to coarse clastic; thick to massive bedded; rubbly to blocky weathered. *Polygnathus kockelianus australis* at top	29·6	745·5
27.	Limestone, as above but with nodules and stringers of chert forming 15 to 20% of the total rock. *Polygnathus linguiformis linguiformis* and *P. webbi* at top	3·0	748·5
28.	Limestone, light to medium grey, medium to coarse clastic with chert as above; thin bedded. *Icriodus nodosus*, *I.* sp. nov. and *Spathognathodus obliquus* present	17·3	765·8
29.	Limestone, medium to dark grey, medium grained, crinoidal, with chert as above; thin to medium bedded ..	20·0	785·8
30.	Limestone, argillaceous, medium to dark grey, cryptocrystalline to fine grained, abundant stringers of chert forming 25 to 30% of the total rock; thin rubbly recessive weathering	35·8	821·6

31. Limestone, argillaceous, dark grey to black, fine grained, rhythmically interbedded, typically every 6″ to 8″ with irregular lenticular chert bands, usually 1″ to 4″ thick, chert comprises 30 to 40% of the total rock; top part exposed in road cut, lower beds rubbly weathered. *Isispongia paradoxa*, *Calceola sandalina*, *Icriodus corniger*, *Polygnathus webbi* and *Polygnathus linguiformis linguiformis* are present	65·6	887·2
Total Timor Limestone exposed, including 1′ to 6·4′ of dolerite		887·2′

Acknowledgements

We record with pleasure the hospitality extended to us while in the area by Mr. and Mrs. Michael Moore of "Glen Dhu." Pedder was supported in the field by grants first from the University of New England and later from the Australian Research Grants Committee. Jackson's and Ellenor's participation was made possible by an Australian Postgraduate Commonwealth Scholarship and a Commonwealth Scholarship and Fellowship Plan award. Professor G. M. Philip, Department of Geology of the University of New England, has facilitated our studies in a number of ways especially with discussions concerning conodont correlations. Mr. W. Manser, formerly of the same department, showed us his manuscript geological map of the area. Dr. J. W. Pickett of the Geological Survey of New South Wales kindly examined our sponges and is responsible for the determinations given in sections 6 and 7. Dr. E. O. Raynor, Mr. H. F. Whitworth of the New South Wales Department of Mines and Mr. H. O. Fletcher of the Australian Museum assisted by loaning specimens in their care. Mr. R. L. Sinclair, the Under Secretary of the New South Wales Department of Lands, has permitted us to reproduce parts of two aerial photographs.

References

Amsden, T. W., 1949.—Stratigraphy and paleontology of the Brownsport Formation (Silurian) of western Tennessee. *Bull. Peabody Mus. nat. Hist.*, 5.

Bartenstein, H., and Bischoff, G., 1962.—Paläozoikum, Ausgewählte Beispiele aus dem deutschen und mitteleuropäischen Paläozoikum *In*: Simon, W., and Bartenstein, H. (editors), "Leitfossilien der Mikropoläontologie", text and atlas: 35–65, Pls 1–6. Gebrüder Borntraeger, Berlin-Nikolassee.

Benson, W. N., 1913.—The geology and petrology of the Great Serpentine Belt of New South Wales. Part 1. Introduction. Proc. Linn. Soc. N.S.W., 38: 490–517, Pls 20, 21.

————, 1918.—*Ibid.* Part VIII. The extension of the Great Serpentine Belt from the Nundle district to the coast. *Ibid.*, 43: 593–599.

————, 1922.—Materials for the study of the Devonian palaeontology of Australia. *Rec. geol. Surv. N.S.W.*, 10: 83–204, Pls 13–14a. Issued separately with pagination 1–122.

Birenheide, R., 1962.—Revision der koloniebildenden Spongophyllidae und Stringophyllidae aus dem Devon. *Senckenbergiana leth.*, 43: 41–99.

————, 1964.—Die "Cystimorpha" (Rugosa) aus dem Eifeler Devon. *Abh. senckenb. naturf. Ges.*, 507.

Bischoff, G., and Ziegler, W., 1957.—Die Conodontenchronologie des Mitteldevons und des tiefsten Oberdevons. *Abh. hess. Landesamt. Bodenforsch.*, 22: 1–136, Pls 1–21.

Brezhnev, V. D., Gorianov, V. B., Klishevitch, V. L., Martyshev, V. R., Nasybulin, N. N., and Zubtsov, E. I., 1968.—Devonian of Tien Shan. *In*: Oswald, D. S. (editor), "Internat. Symp. Dev. System Calgary", 1: 433–450. Alta. Soc. Petrol. Geol., Calgary.

Brouwer, A., 1968.—Devonian of the Cantabrian Mountains, northwestern Spain. *Ibid.*, 2: 37–45.

Bultynck, P. L., 1966.—Répartition stratigraphique de quelques conodontes dans le Couvinien. *Annls Soc. géol. Belg.*, 89: 189–206, Pls 1, 2.

————, 1968.—Déscription revisée de la coupe type du Couvinien à Couvin. *In*: Oswald, D. S. (editor), "Internat. Symp. Dev. System Calgary", 2: 421–440. Alta. Soc. Petrol. Geol., Calgary.

Bulvanker, E. Z., 1958.—"Devonskie chetyrekhluchevye korally okrani Kuznetskogo basseyna", text and atlas. Vsegei, Leningrad.

Carne, J. E., and Jones, L. J., 1919.—The limestone deposits of New South Wales. *Miner. Resour. N.S.W.*, 25.

COLLINSON, C., (co-ordinator), 1968.—Devonian of the north-central region, United States. *In*: Oswald, D. S. (editor), "Internat. Symp. Dev. System Calgary", 1: 933–971. Alta. Soc. Petrol. Geol., Calgary.

CROOK, K. A. W., 1961.—Stratigraphy of the Tamworth Group (Lower and Middle Devonian), Tamworth-Nundle District, N.S.W. *J. roy. Soc. N.S.W.*, 94: 173–188, 1 Pl., 4 map sheets.

DAVID, T. W. E., "edited and much supplemented by" BROWNE W. R., 1950.—"The geology of the Commonwealth of Australia", 1. Edward Arnold & Co., London.

DUN, W. S., 1901.—Annual report of the Palaeontologist for 1900. *Rep. Dep. Min. N.S.W.*, 1900: 195, 196.

ENGEL, G., and VON SCHOUPPÉ, A., 1958.—Morphogenetisch-taxionomische Studie zu der devonischen Korallengruppe *Stringophyllum*, *Neospongophyllum* und *Grypophyllum*. *Paläont. Z.*, 32: 67–114, Pls 8, 9.

ETHERIDGE, R., (fil.), 1898.—On the occurrence of the genus *Endophyllum*, Ed. and H. (emend. Schlüter) in the Lower Palaeozoic rocks of N. S. Wales. *Rec. geol. Surv. N.S.W.*, 6: 43–46, Pls 4, 5.

————, 1902.—Additions to the Middle Devonian and Carboniferous corals in the Australian Museum. *Rec. Aust. Mus.*, 4: 253–262, Pls 37–40.

————, 1907.—A monograph of the Silurian and Devonian corals of New South Wales: with illustrations from other parts of Australia. Part II.—The genus *Tryplasma*. *Palaeont. Mem. geol. Surv. N.S.W.*, 13.

————, 1921.—Palaeontologia Novae Cambriae Meridionalis—Occasional descriptions of New South Wales fossils—No. 8. *Rec. geol. Surv. N.S.W.*, 10: 1–11, Pls 1–7.

FLAJS, G., 1966.—Die Mitteldevon/Oberdevon-Grenze im Paläozoikum von Graz. *Neues Jb. Geol. Paläont. Abh.*, 124: 221–240, Pls 23–26.

FLÜGEL H., 1966.—Paläozoische Korallen aus der tibetischen Zone von Dolpo (Nepal). *Jb. geol. Bundesanst. Wien*, 12: 101–119, Pls 1–4.

FOLK, R. L., 1959.—Practical petrographic classification of limestones. *Bull. Amer. Ass. Petrol. Geol.*, 43: 1–38.

FONTAINE, H., 1966.—Quelques Madréporaires Dévoniens du Musée du Service Géologique de Saigon (Collections du Yunnan). *Arch. géol. Viêt-Nam*, 9: 51–95, Pls 1–16.

FRECH, F., 1886.—Die Cyathophylliden und Zaphrentiden des deutschen Mitteldevon. *Palaeont. Abh.*, 3: 115–234, Pls 13–20. Issued separately with pagination 1–120 and Pls 1–8.

————, 1897.—"Lethaea geognostica oder Beschreibung und Abbildung der für die Gebirgs-Formationen bezeichnendsten Versteinerungen. 1. Theil. Lethaea palaeozoica. 2. Band 1. Lieferung". E. Schweizerbart'sche Verlagshandlung, Stuttgart.

HILL, D., 1940.—The Silurian Rugosa of the Yass-Bowning district, N.S.W. PROC. LINN. SOC. N.S.W., 65: 388–420, Pls 11–13.

————, 1942*a*.—The Middle Devonian rugose corals of Queensland, III. Burdekin Downs, Fanning R., and Reid Gap, North Queensland. *Proc. roy. Soc. Qd.*, 53: 229–268, Pls 5–11.

————, 1942*b*.—The Devonian rugose corals of the Tamworth district, N.S.W. *J. roy. Soc. N.S.W.*, 76: 142–164, Pls 2–4.

IVANIYA, V. A., 1953.—Materialy k izucheniyu nizhnefranskogo kompleksa korallov Rugosa Kuzbassa. *Trudy Tomsk. Ghosudarst. Univ.*, 124: 19–50, Pls 1–12.

————, 1965.—"Devonskie korally rugosa Sayano-Altayskoy gornoy oblasti". Izdatel'stvo Tomskogo Universiteta, Tomsk.

JONES, O. A., and HILL, D., 1940.—The Heliolitidae of Australia, with a discussion of the morphology and systematic position of the family. *Proc. roy. Soc. Qd.*, 51: 183–215, Pls 6–11.

JUX, U., 1964.—Zur stratigraphischen Gliederung des Devonprofils von Bergisch Gladbach (Rheinisches Schieferebirge). *Decheniana*, 117: 159–174.

KETTNEROVÁ, M., 1932.—"Paleontologické studie z čelechovického devonu, část IV. Rugosa". Práce geologicko-palaeontologického ústavu Karlovy university v Praze za rok 1932. Praha.

KLAPPER, G., and ZIEGLER, W., 1967.—Evolutionary development of the *Icriodus latericrescens* group (Conodonta) in the Devonian of Europe and North America. *Palaeontographica*, A127: 68–83, Pls 8–11.

KNIGHT, J. B., 1941.—Paleozoic gastropod genotypes. *Spec. Pap. geol. Soc. Amer.*, 32.

KU, C. W., 1950.—Devonian stratigraphy of the Poshi area with a special discussion on the stratigraphical position of the Devonian fish-bearing series of eastern Yunnan. *Bull. geol. Soc. China*, 29: 75–84.

LANG, W. D., and SMITH S., 1927.—A critical revision of the rugose corals described by W. Lonsdale in Murchinson's "Silurian System". *Quart. J. geol. Soc. Lond.*, 83: 448–490, Pls 34–37.

MANSER, W., 1968.—"Geological map of New England 1:100,000, Wingen Sheet (no. 359) with parts of nos. 350, 351, 360, with marginal text and 1: 50,000 map of thê Timor Anticline". The University of New England, Armidale.

PLATE XX

Figs 1, 2. *Grypophyllum* sp. cf. *G. denckmanni* Wittekindt, × 2; UNE F10414, Timor Limestone (Givetian part), unit 5, section 5.

Fig. 3. *Sanidophyllum etheridgei* Pedder, sp. nov., × 2; holotype, UNE F10374, Timor Limestone (Givetian part), unit 5, section 5.

PLATE XXI

Figs 1, 2. *Sanidophyllum colligatum* (Etheridge), × 2; UNE F10372, Timor Limestone (late Eifelian part), base of unit 17, section 7.

PLATE XXII

Figs 1, 2. *Sanidophyllum davidi* (Etheridge), × 2; UNE F10371, Timor Limestone (late Eifelian part), base of unit 17, section 7.

PLATE XXIII

Figs 1, 2. *Xystriphyllum* (?) *giganteum* (Etheridge), × 2; 1, UNE F10415, unit 18, section 1; 2, UNE F10416, 30 feet below the top of unit 14, section 1.

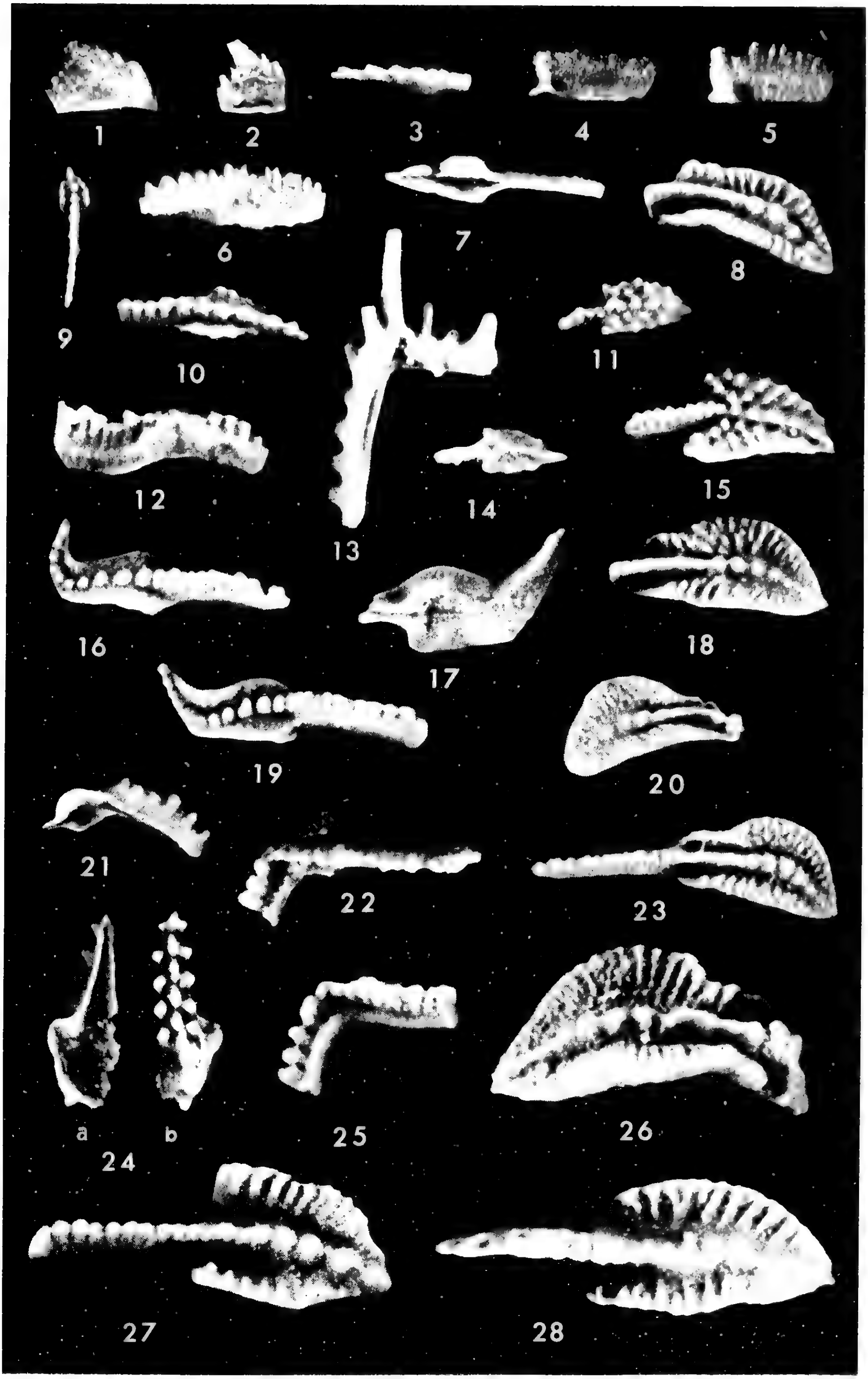
Figs 3–5. *Dendrostella* sp. cf. *D. rhenana* of Hill 1942*b*, × 3; UNE F10368, Timor Limestone (late Eifelian part), UNE Locality 627.

PLATE XXIV

Figs 1–3. *Sociophyllum densum* (Hill), × 3; UNE F10360, Timor Limestone (late Eifelian part), UNE Locality 627.

PLATE XIV

PLATE XV

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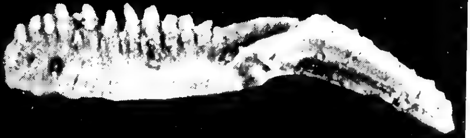
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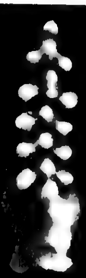
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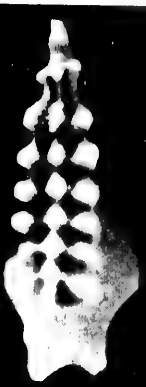
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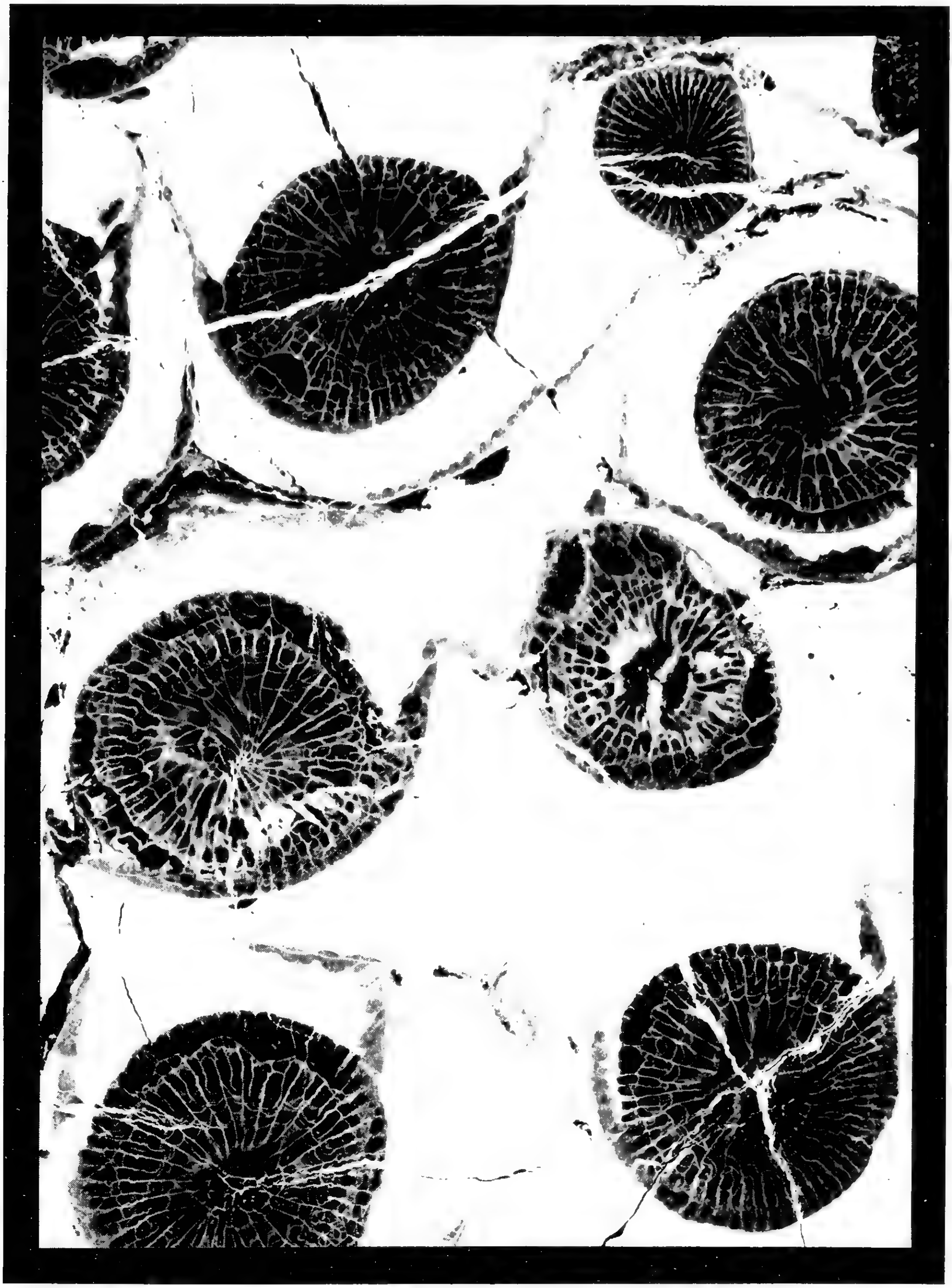

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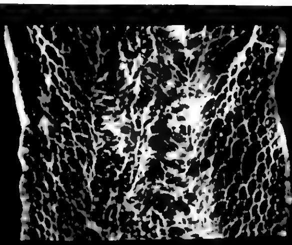

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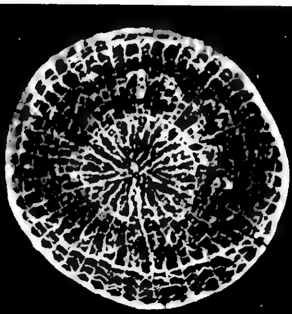

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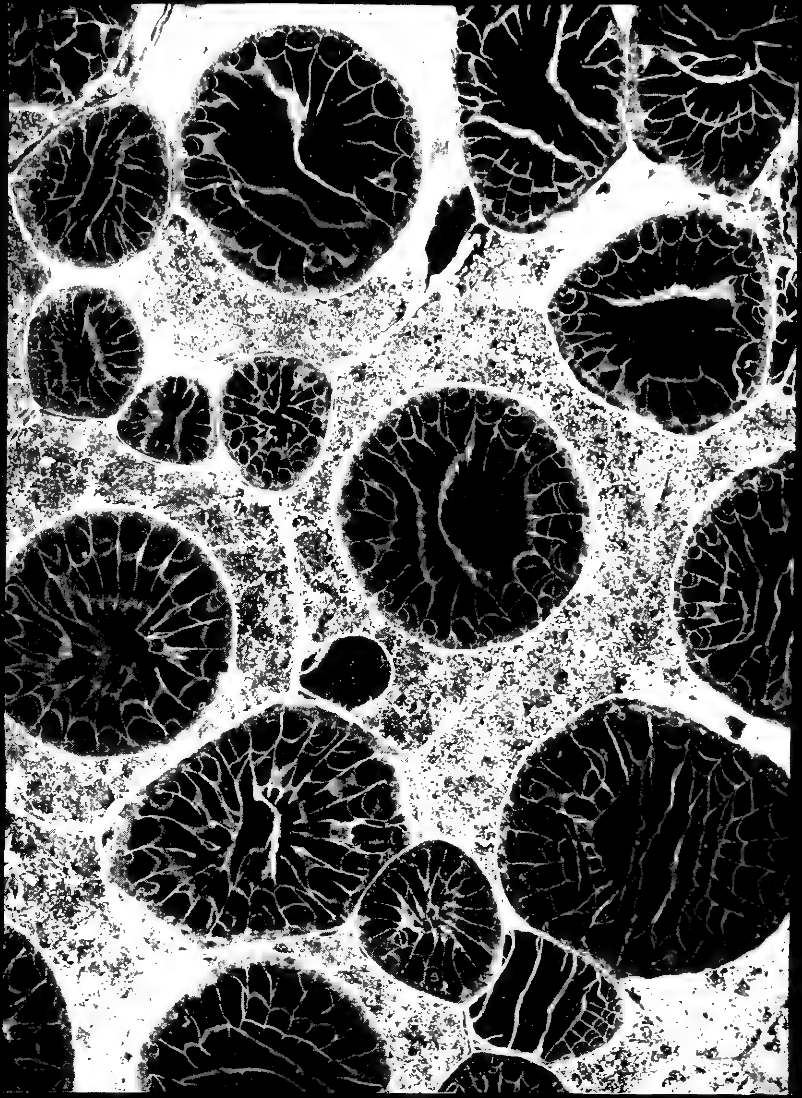

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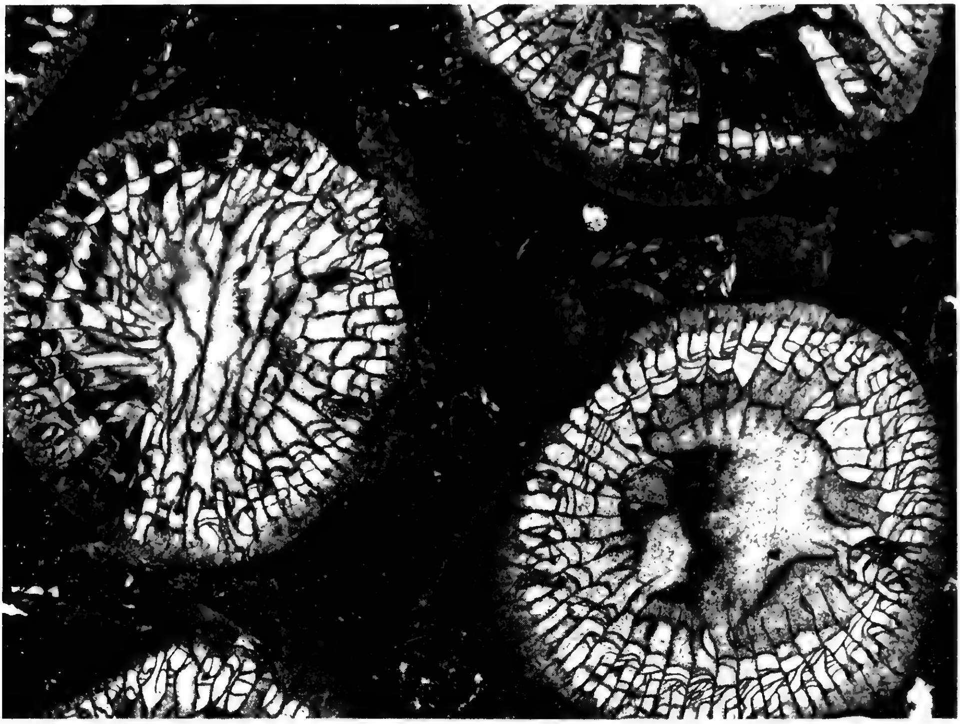

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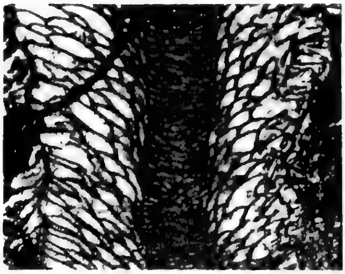

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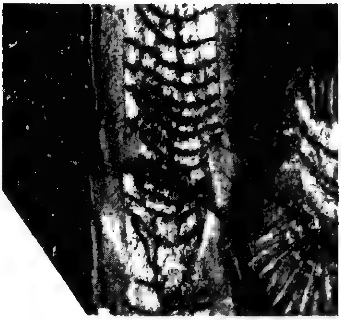

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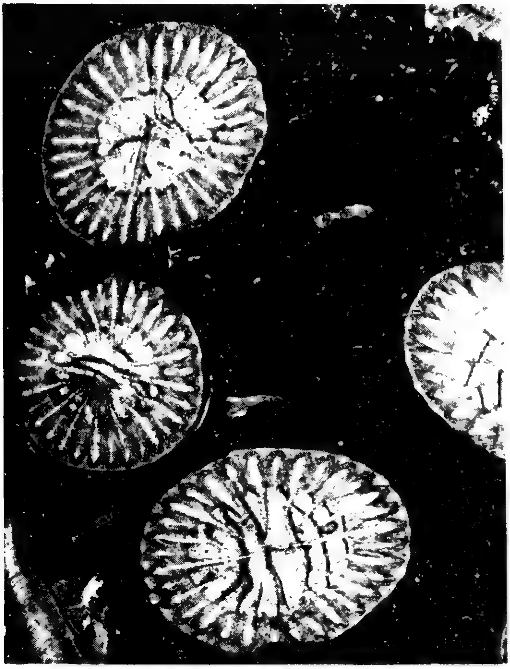

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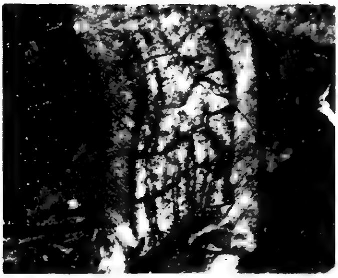

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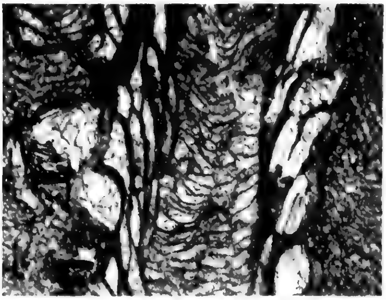

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THE MALE OF *NEOCHEYLETIELLA ARTAMI* DOMROW (ACARI: CHEYLETIDAE)

Robert Domrow
Queensland Institute of Medical Research, Brisbane

[Read 26th November, 1969]

Synopsis

The male of *Neocheyletiella artami*, a cheyletid mite parasitic on wood-swallows, is described; it exhibits a peculiar caudal process unknown in its congeners.

Of the eleven taxa originally assigned to *Neocheyletiella* Baker (see Baker, 1949; Lawrence, 1959), two (*pinguis* Berlese and *canadensis* Banks) have been transferred to *Ornithocheyletia* Volgin (1964), and seven (*chanayi* Berlese and Trouessart, *microrhyncha* Berlese and Trouessart, *heteropalpus* Mégnin, *macronycus* Mégnin, *subquadrata* Lawrence, *transvaalica* Lawrence, and *faini* Lawrence) to *Bakericheyla* Volgin (1966).

To the remaining two species (*rohweri* Baker, type-species, and *smallwoodae* Baker), Volgin (1966) added *Ornithocheyla megaphallos* Lawrence, while Domrow (1966) described the female of a fourth species, *N. artami*. Its male is now described, but as its peculiarities are only of a secondary sexual nature, no change in status is proposed.

The closely related *Cheyletiella parasitivorax* (Mégnin) causes a pruritic rash both in household animals (cats, dogs, rabbits) and man (Moxham, Goldfinch, and Heath, 1968; Thomsett, 1968).

NEOCHEYLETIELLA ARTAMI Domrow

Material examined: One paratype female from a dusky wood-swallow, *Artamus cyanopterus* (Latham) (Artamidae, Passeriformes), Exeter, Tas., 9.iv.1964, R. H. Green. One male, twelve females, and two nymphs from *A. cyanopterus*, Dunedoo, N.S.W., 4 and 6.vi.1968, Carolyn Nelson.

Male: Idiosoma 335μ long, ovate, with greatest width just in front of coxae III (Figs 1–2). Anterodorsal shield strongly tapered anteriorly, broadly rounded posterolaterally, and irregular in outline posteromedially; bearing four short, nude setae submarginally. Middorsal shield irregular in outline, bearing six minute setae at genital aperture and two long, ciliated setae posteriorly. Aedeagus sinuous, sharply pointed. Posterolateral shield elongate, parallel-sided, and with two triangular processes posteriorly; these latter protrude above caudal process, largely obscuring two stout setae in resultant cavity. Apex of opisthosoma flared, more darkly coloured than remainder of body, with irregular surface and outline except for median trilobe. Dorsal cuticle with 16 long, ciliated setae arranged 4.3+3.2.2.2; annulations largely parallel to lateral margins of shields.

Venter anteriorly as in female except that coxal apodemes I are fused medially. Coxal apodemes IV incorporated into broad shield covering remainder of venter in front of caudal process, which latter bears irregular anal sclerotization and two heavy, nude setae. Cuticular annulations on coxae I–II parallel to apodemes, but transverse between coxae III.

Legs and capitulum as in female except that inner claw on tarsi II is much larger than outer.

Female: Nothing need be added to the original description except that the palpal tibia and tarsus each have three nude setae, and the latter a sensory rod.

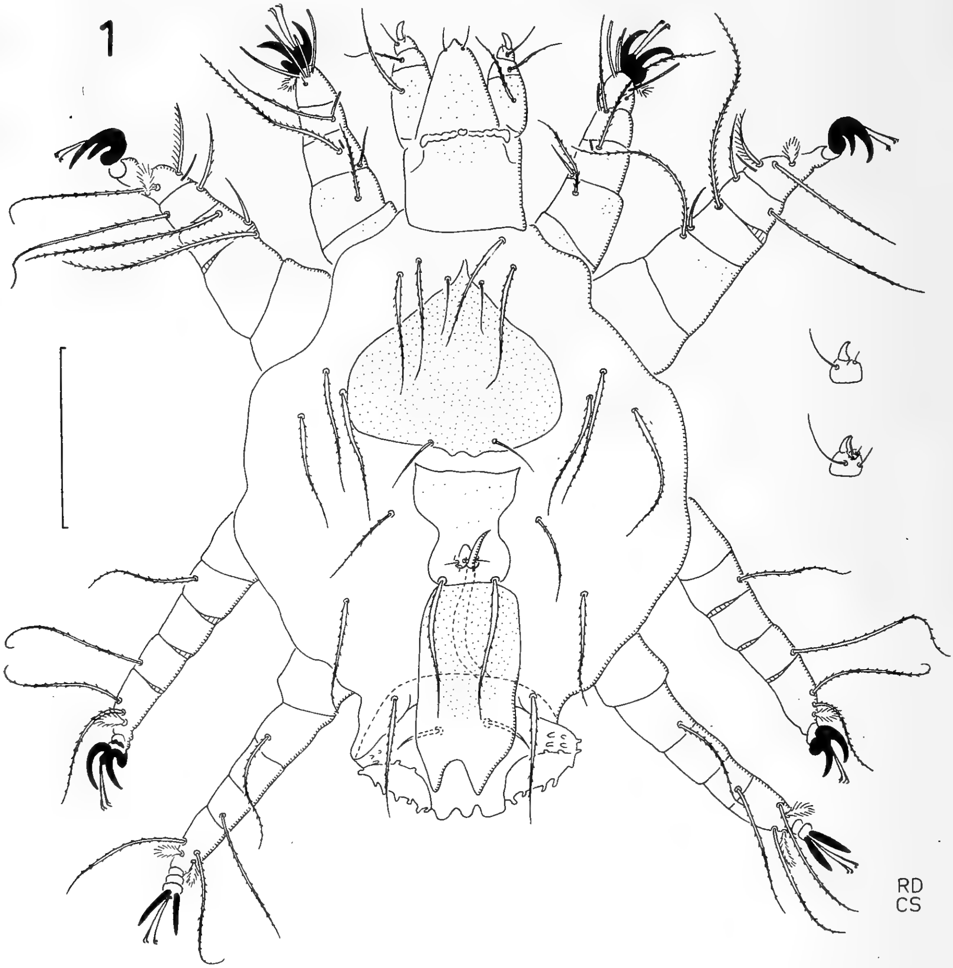


Fig. 1. *Neocheyletiella artami* Domrow.—Dorsum of male, with insets of palpal tibiotarsus of female. (All scales = 100μ).

Nymph: Similar to female except for transversely oval, sculptured, posterodorsal shield (which shows two slight posterolateral depressions suggestive of maleness), and absence of two adanal, and two anal, setae (Figs 3–4). Idiosoma 385–440μ long.

Acknowledgements

I thank Dr. B. C. Nelson, McMaster Laboratory, C.S.I.R.O., Sydney, for the opportunity to examine this interesting series, and Miss Carol Sayers for technical assistance.

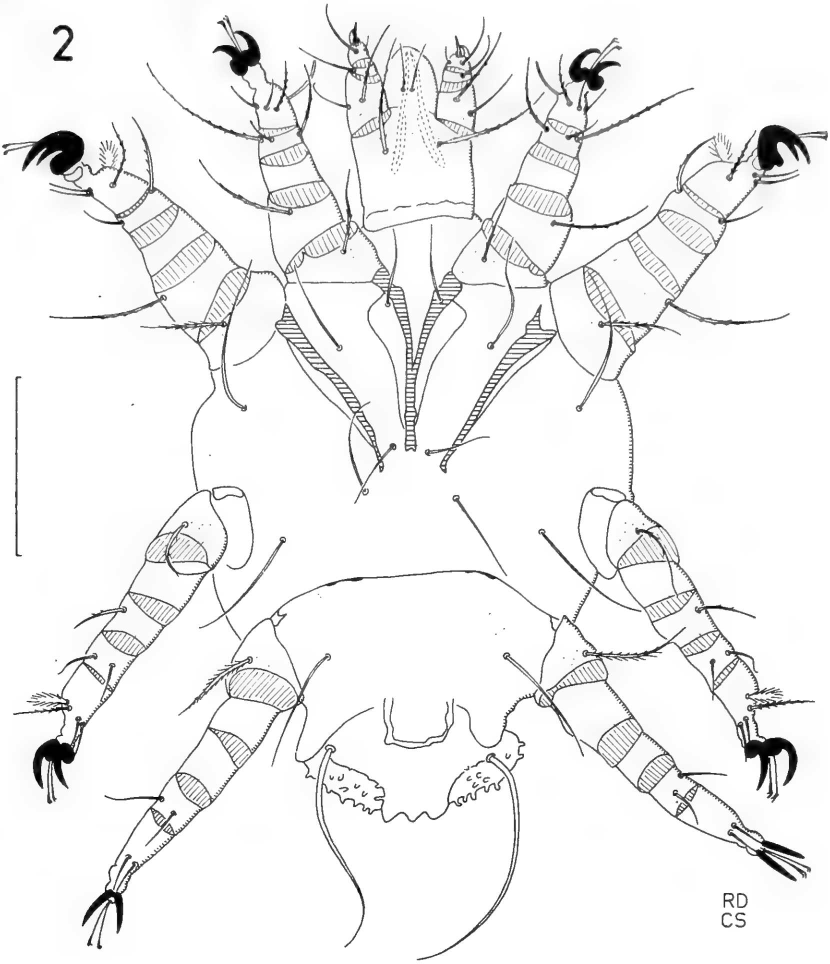
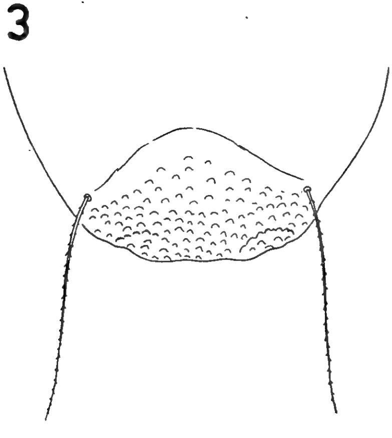
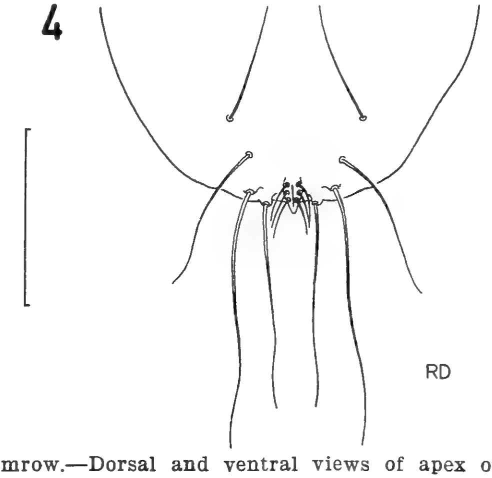


Fig. 2. *Neocheyletiella artami* Domrow.—Venter of male.





Figs 3–4. *Neocheyletiella artami* Domrow.—Dorsal and ventral views of apex of opisthosoma of nymph.

References

BAKER, E. W., 1949.—A review of the mites of the family Cheyletidae in the United States National Museum. *Proc. U.S. natn. Mus.*, 99: 267–320.

DOMROW, R., 1966.—Some mite parasites of Australian birds. PROC. LINN. SOC. N.S.W., 90: 190–217.

LAWRENCE, R. F., 1959.—New mite parasites of African birds (Myobiidae, Cheyletidae). *Parasitology*, 49: 416–438.

MOXHAM, J. W., GOLDFINCH, T. T., and HEATH, A. C. G., 1968.—*Cheyletiella parasitivorax* infestation of cats associated with skin lesions of man. *N.Z. vet. J.*, 16: 50–52.

THOMSETT, L. R., 1968.—Mite infestations of man contracted from dogs and cats *Br. med. J.*, 3: 93–95.

VOLGIN, V. I., 1964.—On the taxonomy of predatory mites of the family Cheyletidae. VI. The genus *Ornithocheyletia* Volgin gen. n. *Zool. Zh.*, 43: 28–36.

————, 1966.—Morphological peculiarities of the mites of the family Cheyletidae (Acarina, Trombidiformes) and their ontogenetical development. *Ent. Obozr.*, 45: 217–231.

PRAWN TAGGING EXPERIMENTS IN NEW SOUTH WALES

NICK V. RUELLO
N.S.W. State Fisheries Laboratories, Chief Secretary's Department, Sydney
(Communicated by Dr. A. A. Racek)

(Plate xxv and Text-figures 1–3)

[Read 26th November, 1969]

Synopsis

An account is given of five field experiments in estuarine and ocean waters of New South Wales, in which an Atkins type tag was attached to 3,358 penaeid prawns, which were subsequently released into their natural habitat. The methods used in these experiments, the percentage of prawns recaptured and the initial mortality due to tagging are described and discussed.

INTRODUCTION

Tagging and marking techniques have been established as important tools in the study of fish populations for nearly a century. Crustaceans, however, are difficult to tag or mark effectively because of the frequent shedding of the exoskeleton at ecdysis, and suitable methods have only been developed over the past fifty years. George (1965) recently described the techniques used in the marking and tagging of various decapod crustaceans. Penaeid prawns have been even more difficult to tag and mark because of their comparatively small size and frequent moulting. Lindner and Anderson (1956) tagged prawns as early as 1934 with Petersen disk tags, but considerable research is still being carried out to develop better tagging and marking techniques, since the Petersen tag is suspected of causing physical damage to the prawns as well as impairing their swimming ability (Dawson, 1957; Allen and Costello, 1963). Menzel (1955) successfully marked *Penaeus setiferus* by injection of a solution of Fast Green vital stain. Dawson (1957) developed this injection technique further, and Costello (1959), and Costello and Allen (1960), successfully demonstrated its use in field experiments.

The stain injection method of marking is rapid, and evidently has no adverse effect on the prawns marked (Klima, 1964), but it has the disadvantage that individuals cannot be distinguished, and for experiments designed to estimate growth all animals released must necessarily be of uniform size. Kourist, Mauch and Tiews (1964), and Tiews (1965), attached small plastic tags to *Crangon* by wrapping thin silver wire around the animal between the carapace and the first abdominal segment. This tagging technique, however, can only be used in short term studies since the majority of tagged animals do not survive for more than 1–2 ecdyses. Allen and Costello (1963) reported that an Atkins tag "may be particularly useful for tagging small-sized shrimp". This is a small plastic tag attached to the animal by a nylon line which is passed through the first abdominal somite with a needle. The Atkins tag is believed to cause less injury to prawns than the Petersen tag, attached to the animals with a nickel pin passing through the abdomen, but unfortunately it was never before used in field experiments. The Atkins tag appeared to be an improvement over the earlier techniques, and laboratory experiments were conducted by the author to test this tag on the King prawn (*Penaeus plebejus*) and the School prawn (*Metapenaeus macleayi*). These experiments showed sufficient promise to warrant evaluation of the Atkins tag in field experiments.

This paper deals with the procedures adopted in five tagging studies of growth and migrations of prawns in the Hunter and Clarence regions in New South Wales. Detailed information on the migrations between release and recapture, days of freedom and growth of tagged prawns will be given in a forthcoming paper (Ruello, M.S.).

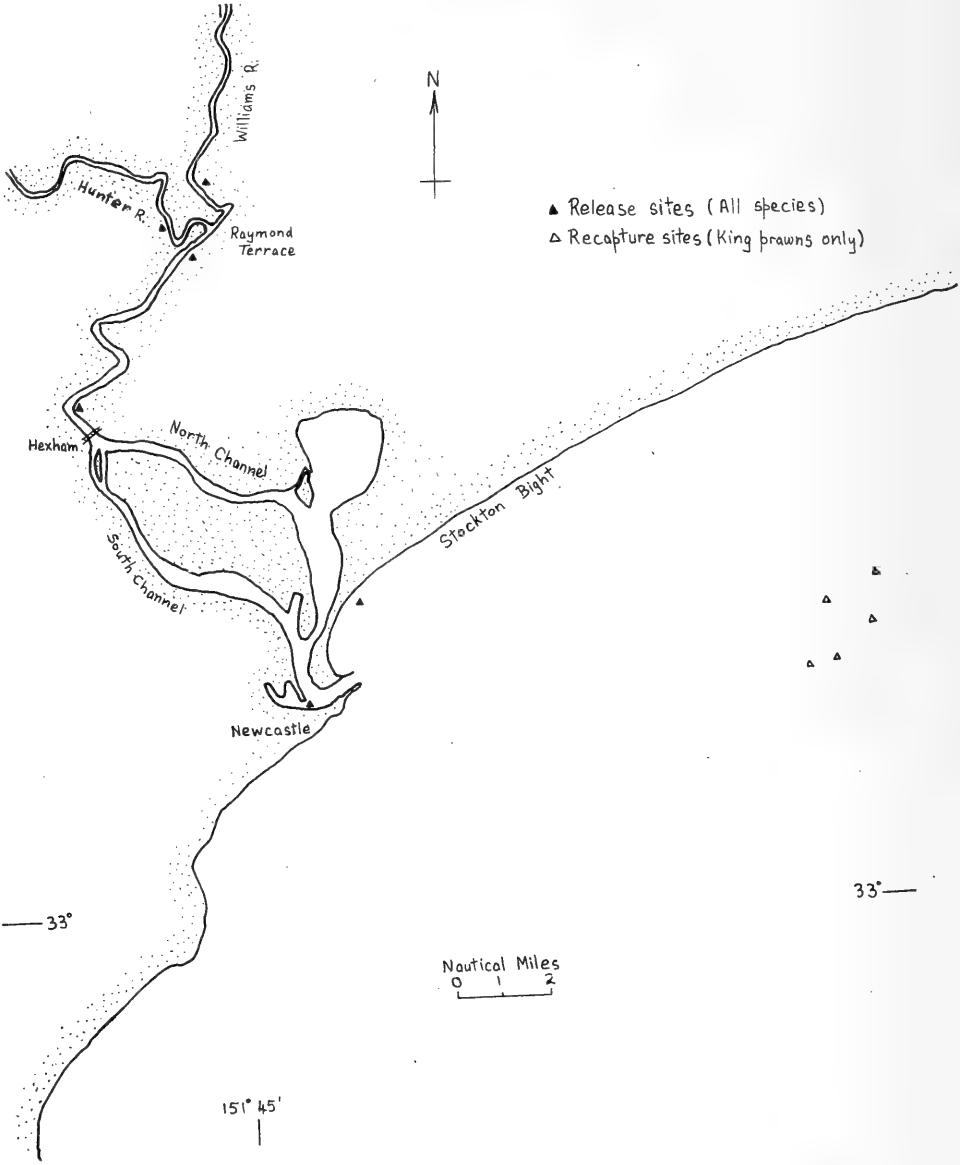


Fig. 1. Map of Hunter region showing the release sites of all species tagged in this area. The recapture sites of the king prawns caught in ocean waters are also marked.

Material and Methods

Atkins tags

These were manufactured from Astralon, a semi-rigid polyvinylchloride material, rectangular in shape, approximately 13·5 mm. long and 6·3 mm. wide and yellow in colour. The words "NSW Fish" were printed on one side and a serial number on the other. Monofilament nylon fishing line of 3 lb. breaking strain was tied to the punched end of the tag and a loop tied in the free end of the line. The average weight of the tag and line was 0·033 gm. The length of the nylon line will depend on the size of the prawns to be tagged, but a line about 40 mm. long plus a loop about 13 mm. "long" was found to be satisfactory for prawns with carapace lengths from 15 to 25 mm. The knot forming the loop must be pulled tight so that the line passes through the prawn's abdominal tissue with minimal resistance. The tied tags were fixed in plasticine in the numbered compartments of histological slide boxes. These boxes kept the tags safe and in numerical order even in windy conditions (see Plate xxv).

Tagging needles

Ordinary carbon steel nickel plated sewing needles, modified by cutting open the forward part of the eye on an electric grinding wheel, were used in these experiments.

Holding tanks and water pump

Prawns were held in rectangular polyethylene tanks 48″ × 24″ × 24″ and in plastic tanks 21″ × 14″ × 12″. The large tanks were filled and emptied with a Villiers powered 1″ Finsbury pump unit.

Underwater release box

A rectangular plywood box 21″ × 15″ × 10″ standing on 16″ legs with a weighted hinged door on the bottom and a small sliding door on top, was used to release prawns on the bottom. The box was weighted with lead and perforated with ¼″ holes so that it could sink.

Salinity and temperature measurements

Water temperature and salinity in the large holding tanks, and at the site of capture and release of prawns, was measured with an Electronic Switchgear S-T bridge type MC-5.

Length measurements

The length of prawns was determined by measuring the carapace, to the nearest ½ mm., with dial calipers. This procedure was adopted because it was quicker and more reliable than measuring total lengths of prawns.

Capture and selection of prawns

Prawns for tagging were especially caught by commercial fishermen, using trawl and pocket nets* measuring approximately 6 fathoms along the corkline. The duration of each individual fishing operation was restricted as much as possible to minimize injury to prawns after they had entered the net. Lively prawns, with a carapace length of about 15 mm. or greater, were quickly selected from the catch and dropped into the large tanks. These large tanks, containing a foot of water, were used to hold as many as 300 prawns before tagging. Prawns were periodically removed from the large tanks with dipnets and transferred to small plastic tanks on a table, ready for tagging.

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* Pocket nets are staked out at night across the stream and trap prawns moving with the tidal current and/or the wash produced by the propeller (and motor) of an anchored vessel.

Location and Date of Experiment

1. Stockton Bight—July 1968

Prawns were captured by trawling, midway along Stockton Bight at a depth of about 15 fathoms on the 3rd and 4th July. School and king prawns were tagged aboard a trawler and later released in Stockton Bight near the Stockton Hospital at a depth of about 7 fathoms (see Fig. 1).

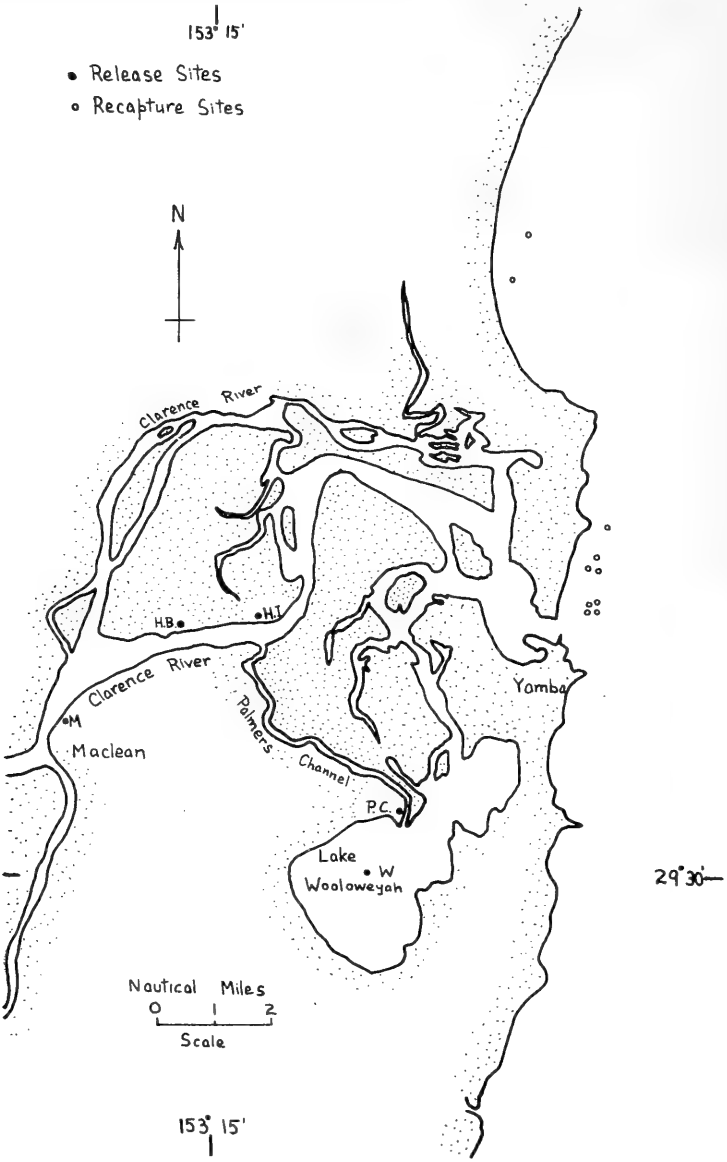

Fig. 2. Map of Clarence region showing the release sites of tagged prawns and the recapture sites of prawns caught in ocean waters.

2. Hunter River—October 1968

School prawns were caught by trawling in the river about 1 mile upstream of the Hexham Bridge on the 16th October. The prawns were tagged aboard a trawler and later released in the same area of the river. The Hunter River was closed to trawling at this time and commercial fishing did not commence until the 22nd November; three tagged prawns were recaptured in the closed season, however, during routine prawn sampling operations by the Fisheries Department.

3. Clarence River and Lake Wooloweyah—November 1968

A small number of school prawns were caught with pocket nets in the Clarence River on the 5th November; these prawns were tagged on shore and 93 were subsequently released in the river at Maclean. The majority of prawns for this experiment were obtained by trawling in Lake Wooloweyah on the Clarence River on the 6th November. These prawns were tagged on shore and 77 school and 1 king prawn were released in the centre of Lake Wooloweyah, 107 school prawns were released in the southern end of Palmers Palmers Channel. On the following day 127 trawled school prawns were Channel and 144 school prawns were released in the Clarence River near tagged and released in the Clarence River near the Harwood Bridge. The Clarence River was closed to prawn trawling at the time of this experiment and trawling did not commence in the river proper, until the 1st December, 1968 (prawn trawling was permitted in Lake Wooloweyah, and prawns could be caught in the river with pocket nets, in November). See Fig. 2.

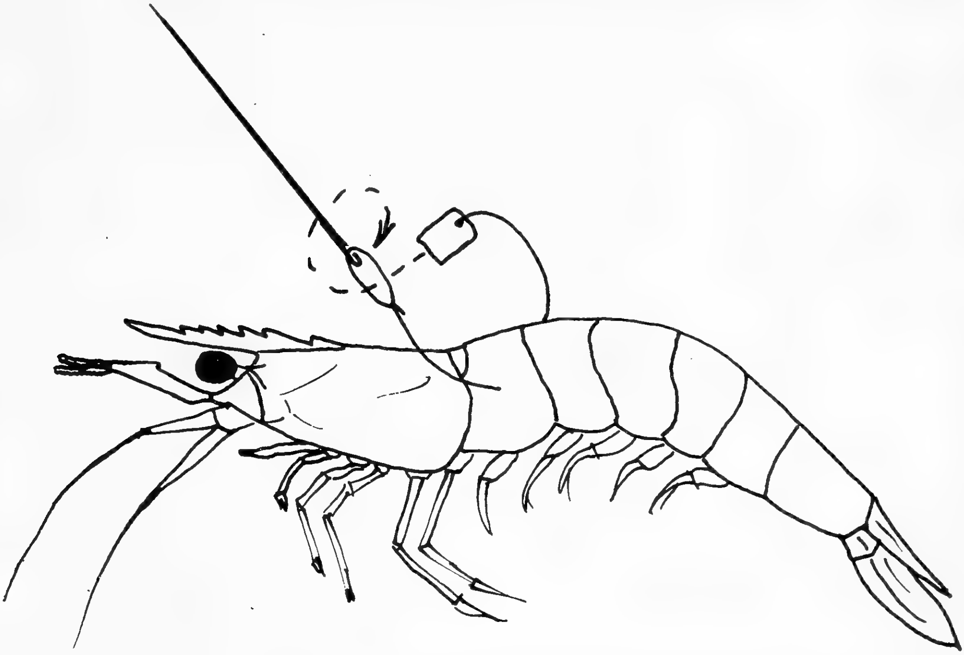

Fig. 3. Method of attachment of Atkins tag to the prawn: The nylon line is passed through the prawns abdomen with a needle, the tag is passed over the prawn and through the loop in the line, twice.

4. Hunter River—January 1969

Prawns were caught by trawling in Newcastle Harbour, tagged on shore, and subsequently released in the same area. A total of 791 king prawns, 97 school prawns and 2 greasyback prawns (*Metapenaeus bennettae*) were released on the 9th and 10th January; a total of 649 king prawns, 178 school prawns and 2 greasyback prawns were tagged and released on the 16th and 17th January.

5. Hunter and Williams Rivers—March 1969

School prawns were caught by trawling in the Hunter and Williams Rivers near Raymond Terrace. They were tagged on shore and 183 were released in the Williams River about 2 miles upstream of the Hunter River, 169 prawns were released in the Hunter River about 2 miles upstream of Raymond Terrace and 162 prawns were released in the Hunter River about 1 mile downstream of Raymond Terrace.

TAGGING AND RELEASE OPERATIONS

Atkins tags were attached to prawns in the manner described by Allen and Costello (1963). The loop on the end of the nylon line was hooked onto the eye of the needle and the needle passed laterally through the first abdominal somite (avoiding the gut) drawing the loop through the animal (see Fig. 3). The tag was passed over the abdomen and through the loop and then secured by passing it through the loop again. After tagging a prawn, its carapace was measured and sex determined by the presence or absence of a petasma. King prawns were not sexed because of the difficulties involved in rapid sex determination, particularly in smaller individuals of this species.

TABLE 1

*Comparison of Initial Tagging Mortality at Different Water Temperature and Salinity in Holding Tanks**

Locality and date of experiment	Species	Number tagged	Initial tagging mortality (%)	Water temperature (° C.)	Salinity (‰)
1. Stockton Bight	School	361	0	15–16	34
July, 1968	King	18	0	15–16	34
2. Hunter River October, 1968	School	193	3·1	20–21	7
3. Clarence region	School	592	3·5	24–25	23–28
November, 1968	King	2	50·0	24–25	23–28
4. Hunter River	School	293	6·1	23–24	33–35
January, 1969	King	1,472	2·0	23–24	33–35
	Greasyback ..	4	0	23–24	33–35
5. Hunter region March, 1969	School	548	6·2	24–25	8–9

* The difference in temperature between the water in the holding tanks and the river or sea-water where the prawns were caught and later released was never greater than 1° C.

Female school prawns were also examined for the presence of developing eggs in the ovaries (these are visible through the exoskeleton) and for the presence of spermatophores attached to the thelycum. Different prawn species were identified by the characteristic rostral tooth armature (Racek, 1955). Tagging was normally carried out by a group of three persons, one recording the information dictated by the two others tagging. Thus it was possible to tag an average of 120 prawns per hour. Tagged prawns were dropped into a large polyethylene tank containing about 18 inches of water, and held (in batches of 100) for 2 hours, at the end of which all dead or suspect prawns (those unable to move away when disturbed) were removed and marked off the tagging records. This holding procedure was adopted to provide an estimate of the initial mortality due to tagging. Surviving prawns were transferred from the holding tanks to the underwater release box with dip nets. The box was lowered to the sea bottom on a strong line and the prawns released by pulling on another line which released a sliding bolt lock and opened the bottom door on the box. Prawns were released on the bottom to prevent the undue losses due to predation by fishes and birds, had they been released at the surface.

RECOVERY PROCEDURE

Prawns in the release areas and anticipated areas of occurrence were captured almost exclusively by commercial fishermen. Publicity regarding the present tagging experiments was therefore directed more to commercial fishermen than to the general public. Notices outlining the objectives of the experiments and featuring illustrations of a tagged prawn were prominently displayed in Fishermen's Co-operatives and State Fisheries Inspectors' offices in New South Wales. These notices requested fishermen to record the tag number and other relevant information immediately after capture of tagged prawns and to return them to the nearest Fisheries office without delay.

TABLE 2

Summary of Release and Recapture Data from Prawn Tagging Experiments

Locality and date of experiment	Species	Number released	Percentage recaptured	Days freedom			Average increment in carapace length (mm.)
				Min.	Max.	Av.	
1. Stockton Bight July, 1968	School ..	361	8·3	0	163	25·8	0·42
	King ..	18	0	—	—	—	—
2. Hunter River October, 1968	School ..	187	6·4	16	69	37·9	3·75
3. Clarence region November, 1968	School ..	558	4·3	1	28	7·6	0·20
	King ..	1	0	—	—	—	—
4. Hunter River January, 1969	School ..	275	9·8	1	73	17·2	0·22
	King ..	1,440	2·4	1	52	15·8	0·68
	Greasyback	4	25·0	21	21	21·0	0
5. Hunter region March, 1969	School ..	514	31·7*	0	26	6·8	0·13

* This includes 1% verified recaptured but not returned.

Commercial fishermen in the Hunter and Clarence regions were also shown samples of tagged prawns and given copies of publicity notices before tagged prawns were released. A reward of 40 cents was offered for the return of each tagged prawn together with information on the time and place of capture. These experiments also received considerable publicity on television, radio and in the local press, so that it can be assumed that all commercial fishermen in the Hunter and Clarence regions were aware of the tagging experiments. The Fisheries Inspectors at Newcastle and Maclean received tagged prawns and preserved them in 5% neutral formalin and maintained records of the tag number, species, time and place of capture and other information given by fishermen. Tagged prawns were periodically collected by the author, examined, and checked against tagging records, to ensure that the tags had not been removed and replaced on another prawn. No attempts were made to substitute prawns in the present experiments though Lindner and Anderson (1956) reported that a few attempts were made to substitute animals in their experiments. Prawn fishermen in the Hunter region were approached personally or by mail, two months after the experiment in March 1969 and asked to report any tagged prawns recaptured but not returned to this Department. This approach was rewarded as 1 per cent of the prawns released were later reported to have been captured but not returned for various reasons: four tagged prawns were lost when one fishing vessel caught fire, one prawn was taken from a fishing vessel by a seagull, and one prawn fell victim to a cat.

MEASUREMENT OF RECAPTURED PRAWNS

Since all tagged prawns returned were subsequently measured by the author a test was conducted to see if there were differences in the carapace measurements obtained by the author and those obtained by others: Each person involved in the tagging operations measured 50 king prawns in the usual manner, and their measurements were compared with those of the author's but no significant differences were detected.

The following experiments were conducted to study the effects of the various handling procedures, normally adopted by commercial fishermen, on the carapace measurements of prawns: Fifty king prawns were tagged, kept in the shade for 2 hours before being cooked (by boiling) and then allowed to cool for 2 hours before they were put into 5% neutral formalin. Another 50 king prawns were cooked immediately after tagging, cooled for 2 hours then put into formalin. Carapace measurements of these prawns were taken after each step and after 3 weeks in formalin. This experiment revealed that there were no significant differences in the carapace lengths of the prawns at any stage in the handling procedure or after their submersion in formalin. It was assumed that the results of the above experiments were applicable to the other species tagged. The carapace length of all prawns returned was determined to the nearest ½ mm., but a positive or negative change of ½ mm. was considered insignificant because of the low precision involved in the carapace measurements, and was therefore treated as zero change for growth studies.

RESULTS AND DISCUSSION

A summary of the results of the five experiments is presented in Tables 1 and 2. Tagged prawns were recaptured by commercial fishermen in the Hunter and Clarence regions. Fishermen apparently had little difficulty in detecting tagged prawns because 95% of those returned were detected before the catch was cooked on board the vessel. Only 2 tagged prawns, representing less than 1 per cent of those returned, completely escaped detection by fishermen and were subsequently returned by a housewife and a fish merchant. Although a few of the tags returned were covered with mud, none were covered with fouling organisms.

The only apparent deleterious effect of the application of the Atkins tag was a small dark lesion in the exoskeleton and superficial abdominal muscles around the tagging puncture. Such injuries could possibly be reduced by treating the nylon line on the tag and the tagging needle with an antibiotic before use. Larger lesions are, however, occasionally found on prawns in natural populations.

Approximately a third of the 548 tagged school prawns released in the Hunter and the Williams rivers in March 1969 were recaptured further downstream in the Hunter River within 26 days of their release. Some of the tagged prawns presumably would have left the river on their spawning migration (Racek, 1959; Ruello, 1969) and others would have died from causes other than fishing. Costello and Allen (1968), in a study of the mortality rates of the pink shrimp *Penaeus duorarum* in Florida, estimated that the loss in the population over a two week period, due to all causes other than fishing, was 19·7 per cent on the Tortugas grounds and 14·8 per cent on the Sanibel grounds. Assuming that the mortality rates in the school prawn populations in the Hunter region are similar, the high recapture rate in experiment 5 suggests that the Atkins tag does not have much adverse effect on the survival of prawns released in their natural environment.

The initial tagging mortality* of zero in the Stockton Bight experiment was presumably due to the low temperature of the water in the holding tanks and the prevailing low sea temperature. Reference to Table 1 reveals that the initial tagging mortality of school prawns increases with water temperatures. The initial tagging mortality in school prawns was significantly higher than that in king prawns in the Hunter River experiment in January 1969. This difference in mortality rates was not due to a size difference in the prawns tagged, as might be expected, because the size range and average size of the school prawns tagged was higher than that for king prawns.

Initial tagging mortality could probably be reduced by circulating cooled water in the holding tanks during experiments. Neal (1968) has held shrimp for marking experiments, at a temperature 3 to 5°C. lower than the water from which they were taken, "thus reducing their metabolic rate and increasing survival". Water salinity had no apparent effect on the initial tagging mortality (Table 1). The school prawns tagged in these experiments had carapace lengths ranging from 14 to 31 mm., the smallest one recaptured had a carapace 16 mm. long when released. Tagged king prawns had carapace lengths from 13 to 35 mm., the smallest recaptured had a carapace length of $18\frac{1}{2}$ mm. when released. A chi-square test applied to the 2×2 contingency table comparing the recapture rates of large and small ($CL \geqslant 22$ mm. and $CL \leqslant 21$ mm. respectively) male and female school prawns in experiment 5 revealed no significant differences in the rate of recapture. A chi-square test indicated a significant difference in the recapture rates of large and small king prawns ($CL \geqslant 23$ mm. and $CL \leqslant 22$ mm. respectively, sexes combined) in experiment 4 but unfortunately this test remains inconclusive because of the small number of prawns recaptured. All the prawns in these experiments were of sufficient size to be retained by prawn fishing nets and mesh selectivity would not account for the higher recapture rate of the larger king prawns in experiment 4.

Lindner and Anderson (1956) and Iversen and Jones (1961) reported that the percentage of shrimp recovered was greater for the larger shrimp than for the smaller ones. A small number of school prawns in experiments 2, 3 and 4 left the Hunter and Clarence Rivers and were recaptured up to 7 miles north of the river mouth in depths to 8 fathoms. (The existing fishing grounds in the Hunter and Clarence regions are situated north of the river mouth.) The majority, however, were soon recaptured in the river a few miles downstream from the release point. The school prawns released in Stockton Bight were recaptured up to 163 days later, in Stockton Bight, north and south of the release point in depths to 17 fathoms. This record of 163 days of freedom by an adult male school prawn (20 mm. carapace length at release) was noteworthy because the average lifespan of this species is considered to be less than 1 year (Racek, 1959; Ruello, unpublished data). Nearly all of the king prawns released in Newcastle Harbour were recaptured in the river within a few weeks of being released. Five were recaptured east and north-east of Newcastle at depths ranging from 37 to 45 fathoms, at least a month after release. Experiment 2 in the Hunter River provided the highest growth estimates obtained in these studies, the average increase in carapace length (of school prawns) was 0·1 mm. per day. The largest individual growth was

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* This is the percentage of prawns found injured or dead in the two-hour holding period before release.

recorded from a female school prawn whose carapace length increased from 18½ to 28 mm. in 61 days. (This is equivalent to an increase in total length of approximately 38 mm.) These growth estimates compare favourably with those obtained from length frequency studies in the natural populations (Ruello, unpublished data).

Seven per cent of all tagged prawns returned showed negative changes in carapace length of 1 mm. or more. These decreases could be due to observational errors, but in most cases they would represent negative growth. Lindner and Anderson (1956) had 6·2 per cent of white shrimp returned from the north-central Gulf of Mexico with equivalent negative changes in total length (their table 5, pp. 564–565). In addition to evidence of growth and the characteristic inshore-offshore migration of penaeid prawns, a case was recorded where a tagged female school prawn had mated after release. Three school prawns also showed considerable development of the ovaries during their period of freedom. Valuable data was obtained from these tagging studies despite the small number of prawns released and the limited fishing effort expended in New South Wales, particularly in ocean waters.

Conclusion

Evidence has been presented which shows that penaeid prawns bearing Atkins tags can grow, mature, mate and carry out their characteristic inshore-offshore migration. Although the adverse effects of the application of an Atkins tag are not known this tag is nevertheless an obvious improvement over the Petersen disk tag, particularly for the smaller sized animals. The Atkins tag is extremely light, does not interfere with the movements of prawns, apparently inflicts little physical damage to the animal and can be effectively used in the recognition of individual prawns for population studies.

Addendum

A tagged male king prawn released in the Hunter River at Newcastle in January 1969 (Experiment 4) was recaptured 368 days later, approximately 400 nautical miles north of the release point, at a depth of 57 fathoms due east of Cape Moreton, Queensland. The prawn had increased 12½ mm in carapace length from 27 to 39½ mm. between the time of release and recapture. The recovery of this king prawn was the first evidence of extensive migration of penaeid prawns along the east coast of Australia and provided invaluable information on the age and growth of this species. Lindner and Anderson (1956) recorded a migration of 360 miles in a white shrimp (*Penaeus setiferus*) tagged with a Petersen disk tag and the longest time between release and recapture of another white shrimp as 257 days.

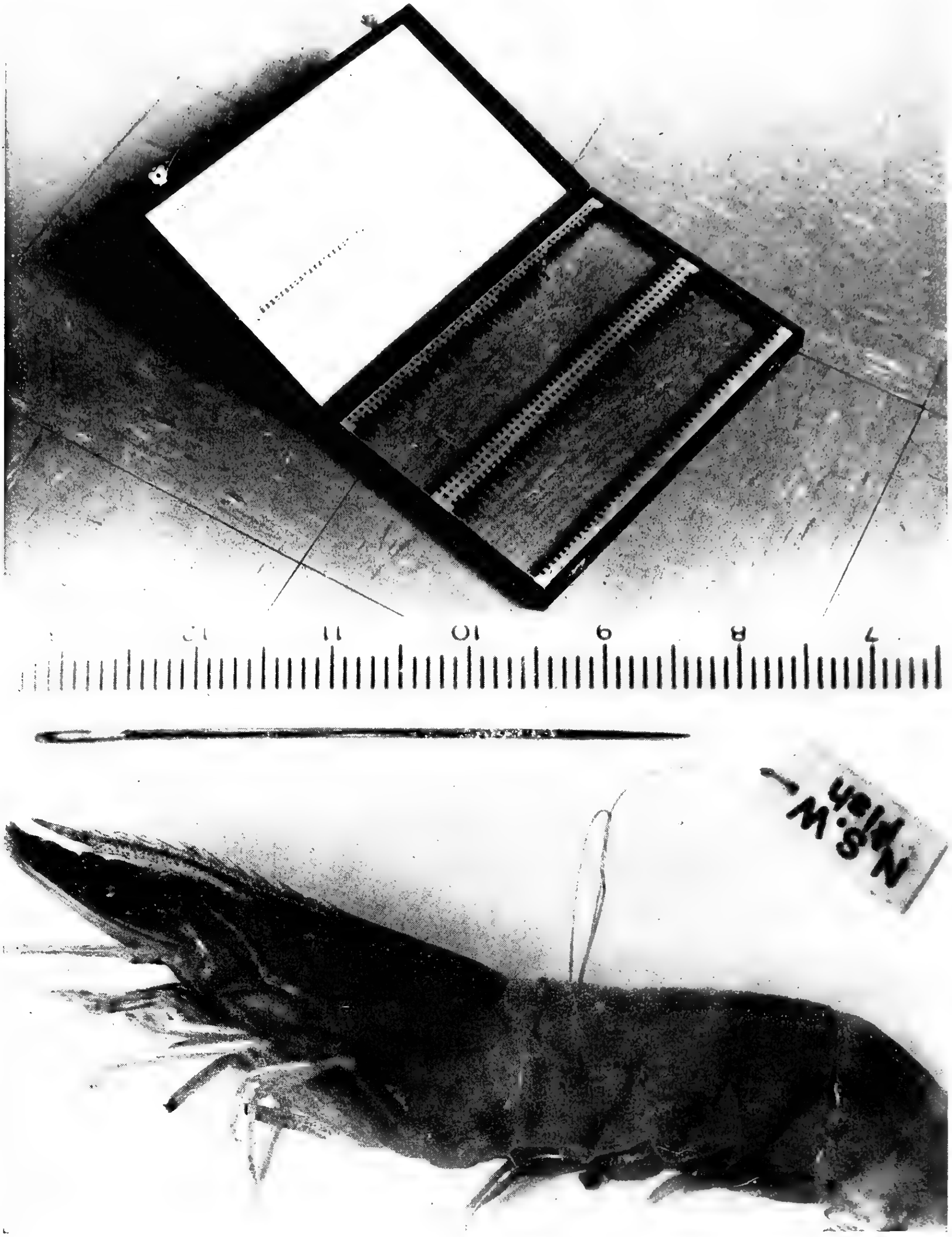
Acknowledgements

I wish to thank the fishermen and the Fisheries personnel who gave advice and help during the course of this work, in particular Mr. R. Symons for technical assistance and Mr. P. Wolf for the photographs for Plate xxv. Dr. A. A. Racek of the School of Biological Sciences, Sydney University, read and criticized the manuscript.

References

Allen, Donald M., and Costello, Thomas J., 1963.—The use of Atkins-type tags on shrimp. *U.S. Fish and Wildl. Serv., Circ.* 161: 88–89.

Costello, Thomas J., 1959.—Marking shrimp with biological stains. *Proc. Gulf and Carib. Fish Inst. 11th Ann. Sess.*, 1958: 1–6.


12
11
10
9
8
7
N.S.W. Fish

COSTELLO, T. J., and ALLEN, D. M., 1960.—Notes on the migration and growth of pink shrimp (*Penaeus duorarum*). *Proc. Gulf and Carib. Fish. Inst. 12th Ann. Sess.*, 1959: 5–9.

————, ————, 1968.—Mortality rates in populations of pink shrimp, *Penaeus duorarum* on the Sanibel and Tortugas grounds, Florida. *U.S. Fish and Wildl. Serv. Fish. Bull.* 66(3): 491–502.

DAWSON, C. E., 1957.—Studies on the marking of commercial shrimp with biological stains. *U.S. Fish and Wildl. Serv., Spec. Sci. Rept.—Fish*, No. 231, 24 pp.

GEORGE, M. J., 1965.—Mark-recovery experiments in crustaceans. *Proc. Symp. Crustacea Part IV*, 1284–1295.

IVERSEN, E. S., and JONES, A. C., 1961.—Growth and migration of the Tortugas pink shrimp, *Penaeus duorarum*, and changes in the catch per unit of effort of the fishery. *Fla. St. Bd. Conserv. Tech. Ser.* No. 34, 30 pp.

KLIMA, Edward F., 1964.—Mark-recapture experiments with brown and white shrimp in the Northern Gulf of Mexico. *Proc. Gulf and Carib. Fish. Inst. 16th Ann. Sess.*, 1963: 52–64.

KOURIST, W., MAUCH, E., and TIEWS, K., 1964.—Ergebnisse von im Jahre 1962 durchgeführten Garnelenmarkierungsexperimenten. *Arch. Fischereiwiss*, 15 (1): 16–22.

LINDNER, Milton J., and ANDERSON, William W., 1956.—Growth, migrations, spawning and size distribution of shrimp *Penaeus setiferus. U.S. Fish and Wildl. Serv. Fish. Bull.* 56: 555–645.

MENZEL, R. W., 1955.—Marking of Shrimp. *Science*, 121 (3143): 446.

NEAL, Richard A., 1968.—Migration, growth, and mortality of commercial shrimps. *U.S. Fish and Wildl. Serv., Circ.* 295: 15–16.

RACEK, A. A., 1955.—Littoral Penaeinae from New South Wales and adjacent Queensland waters. *Aust. J. Mar. Freshw. Res.*, 6 (2): 209–41.

————, 1959.—Prawn investigations in Eastern Australia. *Res. Bull. State Fish. N.S.W.*, 6: 1–57.

RUELLO, Nick V., 1969.—Hunter Region prawn fishery. *The Fisherman*, 3 (5): 20–24.

TIEWS, K., 1965.—The use of plastic tags for tagging small shrimps (Brown shrimp, *Crangon vulgaris* Fabricius) and on the problem of tagging experiments of this species of shrimp. *Proc. Symp. Crustacea. Part IV*, 1296–1300.

EXPLANATION OF PLATE

PLATE XXV

Fig. 1. Photograph of Atkins tags fixed in plasticine in the numbered compartments of a histological slide box.

Fig. 2. Photograph of a tagging needle and a king prawn with an Atkins tag attached. (Scale is in cms).

ABSTRACT OF PROCEEDINGS

ORDINARY GENERAL MEETING

26TH MARCH, 1969

Professor F. V. Mercer, President, in the chair.

The minutes of the last Ordinary General Meeting (27th November, 1968) were taken as read and signed.

The Chairman announced that the Council had elected Mr. R. D. Conacher, Ll.B., Turramurra, N.S.W., an Ordinary Member of the Society.

The Chairman announced that library accessions amounting to 39 volumes, 352 parts or numbers, 22 bulletins, 3 reports and 2 pamphlets, total 418, had been received since the last meeting.

The Chairman drew the attention of members to the Australian Conservation Foundation symposium entitled "Symposium on the Future of the Great Barrier Reef" to be held in the Sydney University Union Theatre, on Saturday, 3rd May, 1969 at 10.15 a.m.

The Chairman drew the attention of members to the invitation of the Australian Research Grants Committee for applications for grants in support of research projects.

PAPERS READ

(By title only, an opportunity for discussion to be given at the April Ordinary General Meeting)

1. Contributions on Palaeozoic flora. 3. *Cordaicladus adamsii* (Feistmantel) Rigby comb. nov. By J. F. Rigby.

2. The submicroscopic structure of the oral mucosa of the phalanger (*Trichosurus vulpecula*). By R. Tucker.

3. The family Ozobranchidae redefined, and a novel ozobranchiform leech from Murray River turtles (Class Hirudinoidea: Order Rhynchobdelliformes). By L. R. Richardson.

4. Geology of the Mt. Tennyson area, south of Yetholme, N.S.W. By B. J. Watts. (*Communicated by Professor T. G. Vallance.*)

EXHIBIT

Mr. G. P. Whitley exhibited photographs (by Mr. Athel D'Ombrain) and sketches of a nine-foot male shark which had been speared off Seal Rocks, New South Wales, in 1961. This had now been identified as *Negaprion queenslandicus* (Whitley, 1939) and constituted a new record for New South Wales and a new record length for the species.

ORDINARY GENERAL MEETING

30TH APRIL, 1969

Professor F. V. Mercer, President, occupied the chair.

The minutes of the last Ordinary General Meeting (26th March, 1969) were read and confirmed.

The Chairman announced that the Council had elected the following office-bearers for the 1969-70 session: *Vice-Presidents:* Professor T. G. Vallance, Mr. L. A. S. Johnson, Professor R. C. Carolin and Dr. D. T. Anderson; *Honorary Treasurer:* Dr. A. B. Walkom; *Honorary Secretary:* Mr. R. H. Anderson.

The Chairman announced that library accessions amounting to 23 volumes, 151 parts or numbers, 5 bulletins and 1 pamphlet, total 180, had been received since the last meeting.

The Chairman announced that no Ordinary General Meeting will be held in May.

The Chairman announced that ANZAAS will be holding a symposium "Science and the Community" on 11th and 12th September, 1969, at the University of New South Wales.

The Chairman drew attention to the Captain James Cook Fellowship established by the New Zealand Government.

Papers read (by title only):

1. Sporozoite rate in *Anopheles farauti* Laveran related to types of catch and seasonal conditions. By Margaret Spencer.
2. A limnological survey of the Wooli Lakes, N.S.W. By B. V. Timms.

Lecturette:

An illustrated lecturette was given by Professor J. Garrick, Zoology Department, Victoria University, Wellington, New Zealand, entitled "Whaler sharks—a source of confusion".

ORDINARY GENERAL MEETING

25th June, 1969

Professor F. V. Mercer, President, occupied the chair.

The minutes of the last Ordinary General Meeting (30th April, 1969) were read and confirmed.

The Chairman announced that Mr. P. G. Flood, Canberra, A.C.T., had been elected a member of the Society.

The Chairman announced that library accessions amounting to 40 volumes, 195 parts or numbers, 8 bulletins, 12 reports and 4 pamphlets, total 259, had been received since the last meeting.

The Chairman announced that no Ordinary General Meeting will be held in August.

Papers read:

1. Australasian Ceratopogonidae (Diptera, Nematocera). Part XI. The Australian species of *Pellucidomyia Macfie,* and a description of the male generic characters. By Margaret L. Debenham.
2. Australasian Ceratopogonidae (Diptera, Nematocera). Part XII. The status of the genus *Heteromyia* Say in the Australian Region. By Margaret L. Debenham.

3. Species of *Attenuatella* Stehli (Brachiopoda) from New South Wales. By J. Armstrong and P. Telford. (*Communicated by Professor T. G. Vallance.*) *By title only.*

4. *Crinia tasmaniensis* (Anura: Leptodactylidae). Geographic distribution, mating call structure and relationships. By M. J. Littlejohn. *By title only.*

5. Another collection of Scolytidae and Platypodidae of economic importance from the Territory of Papua and New Guinea. By K. E. Schedl. (*Communicated by Dr. D. T. Anderson.*) *By title only.*

6. General boundaries in the Podocarpaceae. By C. J. Quinn.

Lecturette:

Dr. Peter Myerscough, Department of Botany, School of Biological Sciences, University of Sydney, delivered an illustrated lecturette entitled "Experimental approach to ecology".

ORDINARY GENERAL MEETING

30th July, 1969

Professor F. V. Mercer, President, occupied the chair.

The minutes of the last Ordinary General Meeting (25th June, 1969) were read and confirmed.

The Chairman announced that library accessions amounting to 31 volumes 169 parts or numbers, 4 bulletins and 9 reports, total 213, had been received since the last meeting.

The Chairman announced that no Ordinary General Meeting will be held in August.

Papers read:

1. The family Aneuraceae in Australia and New Guinea. 1. The genus *Aneura*. By Helen J. Hewson. *By title only.*

2. Australasian Ceratopogonidae (Diptera, Nematocera). Part XIII. Australian and New Guinea species of *Echinohelea Macfie*. By Margaret L. Debenham.

3. Australasian Ceratopogonidae (Diptera, Nematocera). Part XIV. The genus *Serromyia* Meigen. By Margaret L. Debenham.

Lecturette:

Dr. Derek Anderson, Australian National University, Canberra, A.C.T., delivered an illustrated lecturette entitled "Ecology of semi-arid areas".

ORDINARY GENERAL MEETING

24th September, 1969

Professor F. V. Mercer, President, occupied the chair.

The minutes of the last Ordinary General Meeting (30th July, 1969) were read and confirmed.

The Chairman stated:

Before continuing with the business of this meeting it is my sad duty to refer to the deaths of two of our members, namely, R. H. Anderson, who was our Honorary Secretary, and K. E. W. Salter, on 17th and 6th August, 1969.

Mr. R. H. Anderson was elected to membership of the Society in 1922. The following resolution was carried in silence, standing, at the meeting of the Council of the Society on 27th August, 1969:

> That this Council records, with sorrow, the death of the Honorary Secretary, Robert Henry Anderson, on 17th August last, and expresses its grateful appreciation of his work for the Society. He was elected to membership of the Council in July, 1936, served for a term as President in 1940-41, and accepted the position of Honorary Secretary of the Society in 1966.

Mr. Keith Eric Wellesley Salter was elected to membership of the Society in 1932 and became a Life Member in 1956. He contributed six papers to the Society's Proceedings.

Announcements:

1. The Chairman announced that the Council is prepared to receive applications for Linnean Macleay Fellowships tenable for one year from 1st January, 1970, from qualified candidates. Each applicant must be a member of this Society and be a graduate in Science or Agricultural Science of the University of Sydney. The range of actual (tax-free) salary is, according to qualifications, up to a maximum of A$3,200 per annum. Applications should be lodged with the Honorary Secretary, who will give further details and information, not later than Wednesday, 5th November, 1969.

2. The Chairman announced that library accessions amounting to 31 volumes, 200 parts or numbers, 5 bulletins, 7 reports and 11 pamphlets, total 254, have been received since the last meeting.

3. The Chairman announced that Dr. W. R. Browne had been elected Honorary Secretary of the Society on 27th August, 1969.

Papers taken as read:

1. Observations on the biology of *Pallidotettix nullarborensis* Richards (Rhaphidophoridae: Orthoptera) from the Nullarbor Plain. By Aola M. Richards.

2. A new species of *Marginaster* (Asteroidea: Poraniidae) from Tasmania. By A. J. Dartnall.

3. A new species of *Erodium* L'Hér. from Australia. By R. C. Carolin.

4. Further new Scolytoidea (Coleoptera) from the Territory of Papua and New Guinea. By K. E. Schedl. (*Communicated by Dr. D. T. Anderson.*)

Address:

An address was given by Professor A. R. Clapham, President, The Linnean Society of London, on "The Linnean Society of London, its Past, Present and Future".

At the conclusion of the address, Professor Clapham, on behalf of the Linnean Society of London, presented to the Linnean Society of New South Wales "Orbis eruditi Judicium de Caroli Linnaei M.D. Scriptis", together with a typed account of the contents of this pamphlet by William T. Stearn, British Museum (Natural History).

ORDINARY GENERAL MEETING

29th October, 1969

Held in the Department of Botany, University of Sydney.

Professor F. V. Mercer, President, in the chair.

The minutes of the last Ordinary General Meeting (24th September, 1969) were read and confirmed.

The Chairman announced that Mr. J. R. Grieve, Collaroy, N.S.W., 2097, and Dr. B. G. M. Jamieson, University of Queensland, St. Lucia, Queensland, 4067, had been elected by the Council to membership of the Society.

The Chairman announced that library accessions amounting to 11 volumes, 93 parts or numbers, 7 bulletins, 3 reports and 1 pamphlet, total 115, had been received since last meeting.

The Chairman announced that the Council is prepared to receive applications for Linnean Macleay Fellowships tenable for one year from 1st January, 1970, from qualified candidates.

Paper read (by title only):

The distribution of alkaloids in orchids from the Territory of Papua and New Guinea. By L. J. Lawler and M. Slaytor (*Communicated by Professor T. G. Vallance.)*

Dr. P. J. Stanbury gave a talk on The Macleay Museum, its history and its work, after which those present proceeded to the Museum for an inspection of the building and the Museum Collections.

ORDINARY GENERAL MEETING

26th November, 1969

Professor F. V. Mercer, President, in the chair.

The minutes of the last Ordinary General Meeting (29th October, 1969) were read and confirmed.

The Chairman announced that library accessions amounting to 14 volumes, 122 parts or numbers, 4 bulletins, 4 reports and 1 pamphlet, total 145, had been received since the last meeting.

Papers read (by title only):

1. An interim account of the Middle Devonian Timor Limestone of North-eastern New South Wales. By A. E. H. Pedder, J. H. Jackson and D. W. Ellenor.
2. The male of *Neocheyletiella artami* Domrow (Acari: Cheyletidae). By R. Domrow.
3. Prawn tagging experiments in New South Wales. By Nick V. Ruello. *(Communicated by Dr. A. A. Racek.)*

Notes and exhibits:

Mr. R. K. Bamber exhibited a disc of wood of *Athrotaxis selaginoides,* King William pine, which has been dated by ring count. The three-foot diameter disc gives an age of 620 years. Because of the difficulty of observing the narrow rings the surface of the disc was carefully sanded and the rings counted by observation with a low-power microscope. Microscopically, the rings are distinct because of the clearly demarcated earlywood and latewood. The tree was obtained from near Zeehan, Tasmania. The cost of growing a tree of King William pine has been compared with the cost of an equivalent sized *Pinus radiata* using the formula for the calculation of compound interest. For simplicity a number of assumptions have been made. Establishment costs have been presumed to be similar and to be the only costs, and based on a final crop of 75 trees/acre to be $13.3/tree; interest rates to remain level at 5%; and the *P. radiata* to be 70 years old to produce a tree of a diameter of three feet. The cost of the *P. radiata* works out to be approximately $390 whereas the King William pine is $\$186 \times 10^{12}$. This suggests that in economic terms King William pine of this rate of growth is irreplaceable.

Professor T. G. Vallance contributed a note on a dyke exposed in 1967 during construction of a tunnel for stormwater drainage at Lurline Bay. between Coogee and Maroubra. A series of photographs, obtained by courtesy of Mr. T. Hanley, engineer in charge of the work for the M.W.S. & D.B., was exhibited. These illustrate the appearance of the dyke as the tunnel face advanced.

Within the tunnel the dyke is confined to a thick shale band in the Hawkesbury Sandstone. The dyke is some 9 ft. wide, nearly vertical and is oriented a few degrees N. of W. Signs of thermal influence on adjacent shales are very restricted but at various stages during excavation excellent examples of brecciation at the dyke margin became apparent.

The dyke material is soft and light in colour when freshly broken. Exposure to the moist atmosphere of the tunnel led, however, to fairly rapid darkening to a rusty brown.

No surface outcrop of the dyke is visible. Its position is, however, indicated with the remark "depression perhaps concealing dyke — trend W 8° N" in Sir Edgeworth David's handwriting on a map of Sydney dated 1897 and preserved in the Geology Department at the University. David's annotations appear to have been added about the turn of the century. The dyke marked as No. 135 on T. L. Willan's geological map of the Sydney district (1925) appears to coincide with David's inferred dyke, the existence of which is now confirmed.

As seen in thin section the present dyke rock retains clear signs of original basaltic texture but olivine and pyroxene have been replaced entirely. Feldspar laths are still visible but take a strong, though patchy, stain with sodium cobaltinitrite after HF etching. The feldspar is evidently potassic in character. Much of the potash present appears to be bound in feldspar but the possibility of the interstitial clay minerals also carrying some potash is not discounted. Optical characters and chemical data indicate that the carbonate phase is distinctly siderite-rich.

Analysis of a pale cream-coloured sample, dried at 105° C, yielded: SiO_2 42·17, Al_2O_3 20·19, Fe_2O_3 0·43, FeO 12·08, MnO 0·10, MgO 1·04, CaO 1·60, Na_2O 0·17, K_2O 7·82, H_2O+ 2·31, TiO_2 3·02, P_2O_5 1·13, CO_2 8·29, total 100·35 (analyst: N. de Faria e Castro; sample: Univ. Sydney Geol. Coll. 37921).

Dykes within the Hawkesbury Sandstone about Sydney are commonly altered to clays and some, indeed, have been worked as a source of kaolinite. The dyke at Lurline Bay is unusual in that alteration of what was presumably an alkali basalt parent has there yielded a product rich in K-feldspar and siderite.

Mr. A. N. Rodd exhibited (1) a bamboo in flower, *Bambusa glaucescens*, a native of China and Japan. Bamboos, which include the largest plants in the Gramineae, or grass family, are rarely known to flower; (2) *Typhonium brownii,* a member of the family Araceae, native to Queensland and New South Wales. The strong odour of dung is presumably instrumental in securing pollination by dung-eating or dung-frequenting insects.

By courtesy of the Acting Director of the Australian Museum, Mr. G. P. Whitley exhibited Bargibant's Sea-horse from New Caledonia. This is a new, dwarf species of *Hippocampus* which mimics in form and colour the stalks and spicules of a gorgonian coral (*Muricella* sp.) to which it clings by its tail. The general colour of the fish is creamy white with spaced orange-yellow streaks becoming ring-like on the tail, and the bumps over its head (coronet and nuchal plates) and along the body-segments imitate the yellow and orange clumps of spicules of the gorgonian. The snout is very short. The male carries the young and releases them from his pouch when he is only 13mm long, the smallest size known for a "pregnant" sea-horse. The type-specimen of this new sea-horse *Hippocampus* sp. nov., is in the Australian Museum. It was collected in 30 metres of water by Mons. Georges Bargibant and presented by Dr. Réné Catala.

Whitley & Allan (1958, *The Sea-horse and its relatives:* 37-42) listed 108 nominal species of *Hippocampus* in the world. To their list should now be added *H. bargibanti* (supra), *H. microstephanus* Slastenenko 1937 (with its synonym, *H. microcoronatus* Slastenenko, 1939), *H. punctatus* Fitzinger, 1864, and *H. zebra* Whitley, 1964.

Mr. D. F. Blaxell, National Herbarium, Sydney, presented a note on a preliminary investigation of the orchid genera in the sub-tribe Drakaeinae, presenting some of the taxonomic problems and showing the Australian genera involved.

On behalf of Dr. L. R. Richardson, Grafton, N.S.W., four slides were exhibited and the following note on red freshwater Euglenal blooms presented. These blooms are relatively rare in other countries. In the past twelve months, they have been seen in two ponds in the Grafton district. The ponds are similar in nature, shallow; without established inlets or outlet; collecting drainage from the surrounding gently sloping, heavily grazed open pasture; lacking rooted aquatic vegetation; and the flat margins trampled by stock. In full sunlight, the bloom exists as a firm skin on the surface of the marginal water and on wet mud, with the appearance and opacity of a dry skin of red oil paint. It consists of a clear gelatinous matrix containing rounded *Euglena* about 47 microns in diameter, arranged in layers, with 750 to 1,000 per square millimetre. There are dense cultures of active swimming forms beneath the skin and in the water at the outer edge of the skin. The bloom continues in the red phase until about an hour before sunset. With the rapid increase in the angle of incidence of the sunlight, small patches of green appear. These spread and within fifteen minutes the whole bloom is dark green. In heavy overcast weather, the bloom remained green throughout the day; but reverted to red in the twilight. In the jar, the red phase is resumed with twilight and continues through the night and day. In the dark, the *Euglena* leave the matrix, become motile, and remain in this form for days or weeks, until again brought into full sunlight. They then aggregate at the surface; secrete a new matrix; and form a new skin on the surface in less than an hour. In the jar, in full sun, a green phase appears as the temperature rises to about 31·0° C.; reverting to red on lowering of the temperature. The old matrix persists as a pale grey gel. In the field this may form a spongy crust up to 5·0 cm. thick on top of the skin.

The general features of the bloom resemble blooms of *E. rubra* and *E. sanguinea* known in North America. The mechanism is the same: the alternation of haematochrome bodies and chloroplasts on the periphery of the endoplasm. The change to green at low intensity and at high temperature in full light, is the same. The abundance of hæmatochrome bodies prevents the determination of the morphology needed for an identification of the species. It differs from *rubra and sanguinea* in being bluntly rounded anteriorly; the pellicle plain, without sculpture; and in the red phase, the chloroplasts packed in the posterior half of the body, which terminates obtusely with a short pellicular spike. The length averages 95 microns. It survives well in the jar. Live material is still available at this date, September 8, 1969.

This meeting concluded the session. The Ninety-fifth Annual General Meeting, together with the next Ordinary General Meeting, will be held on Wednesday, March 25, 1970, at 7.30 p.m.

LIST OF MEMBERS

(15th December, 1969)

ORDINARY MEMBERS

(An asterisk (*) denotes Life Member)

1940 Abbie, Professor Andrew Arthur, M.D., B.S., B.Sc., Ph.D., c/- University of Adelaide, Adelaide, South Australia, 5000.
1940 *Allman, Stuart Leo, B.Sc.Agr., M.Sc., 99 Cumberland Avenue, Collaroy, N.S.W., 2097.
1965 Anderson, Derek John, Ph.D., Australian National University, P.O. Box 4, Canberra, A.C.T., 2601.
1959 Anderson, Donald Thomas, B.Sc., Ph.D., School of Biological Sciences, Department of Zoology, Sydney University, 2006.
1964 Anderson, Mrs. Jennifer Mercianna Elizabeth, B.Sc.Agr., 51 Ocean Street, Woollahra, N.S.W., 2025.
1965 Andrew, Mrs. Phillipa Audrey, M.Sc. (*née* Croucher), 10 Black Street, Watsonia, Victoria, 3087.
1963 Ardley, John Henry, B.Sc. (N.Z.), Messrs. William Cooper and Nephews (Australia) Pty. Ltd., P.O. Box 12, Concord, N.S.W., 2137.
1927 *Armstrong, Jack Walter Trench, " Cullingera ", Nyngan, N.S.W., 2825.
1952 Ashton, David Hungerford, B.Sc., Ph.D., 92 Warrigal Road, Surrey Hills, Victoria, 3127.
1912 Aurousseau, Marcel, B.Sc., 229 Woodland Street, Balgowlah, N.S.W., 2093.

1961 Bain, Miss Joan Maud, M.Sc., Ph.D., 18 Onyx Road, Artarmon, N.S.W., 2064.
1949 Baker, Professor Eldred Percy, B.Sc.Agr., Ph.D., Department of Agricultural Botany, Sydney University, 2006.
1962 Ballantyne, Miss Barbara Jean, B.Sc.Agr., N.S.W. Department of Agriculture, Private Mail Bag No. 10, Rydalmere, N.S.W., 2116.
1959 Bamber, Richard Kenneth, F.S.T.C., 113 Lucinda Avenue South, Wahroonga, N.S.W., 2076.
1950 *Barber, Professor Horace Newton, M.S., Ph.D., F.A.A., School of Biological Sciences, Department of Botany, University of N.S.W., P.O. Box 1, Kensington, N.S.W., 2033.
1955 Barlow, Bryan Alwyn, B.Sc., Ph.D., School of Biological Sciences, The Flinders University of South Australia, Bedford Park, South Australia, 5042.
1965 Basden, Ralph, M.Ed., B.Sc. (Lond.), F.R.A.C.I., A.S.T.C., 183 Parkway Avenue, Hamilton, N.S.W., 2303.
1960 Batley, Alan Francis, A.C.A., 123 Burns Road, Wahroonga, N.S.W., 2076.
1954 Baur, George Norton, B.Sc., B.Sc.For., Dip.For., 3 Mary Street, Beecroft, N.S.W., 2119.
1935 *Beadle, Professor Noel Charles William, D.Sc., University of New England, Armidale, N.S.W., 2350.
1946 Bearup, Arthur Joseph, B.Sc., 66 Pacific Avenue, Penshurst, N.S.fW., 2222.
1940 Beattie, Joan Marion, D.Sc. (*née* Crockford), 2 Grace Avenue, Beecrot, N.S.W., 2119.
1964 Bedford, Geoffrey Owen, B.Sc., 87 Jacob Street, Bankstown, N.S.W., 2200.
1952 Bennett, Miss Isobel Ida, Hon.M.Sc., School of Biological Science,s Department of Zoology, Sydney University, 2006.
1964 Bertus, Anthony Lawrence, B.Sc., Biology Branch, N.S.W. Department of Agriculture, Private Mail Bag, No. 10, Rydalmere, N.S.W., 2116.
1948 Besly, Miss Mary Ann Catherine, B.A., School of Biological Sciences, Department of Zoology, Sydney University, 2006.
1961 Bishop, James Arthur, Department of Genetics, The University of Liverpool, Liverpool 3, England.
1964 Blackmore, John Allan Philip, LL.B. (Syd. Univ.), 25 Holden Street, Ashfield, N.S.W., 2131.
1958 Blake, Clifford Douglas, B.Sc.Agr., Ph.D., Faculty of Agriculture, Sydney University, 2006.
1941 Blake, Stanley Thatcher, D.Sc. (Q'ld.), 1110 Waterworks Road, The Gap, Queensland, 4061.
1968 Blaxell, Donald Frederick, D.D.A., B.Sc., Royal Botanic Gardens, Sydney, 2000.
1960 Bourke, Terrence Victor, B.Sc.Agr., c/- Department of Agriculture, Stock and Fisheries, Popondetta, Papua.
1967 Boyd, Robert Alexander, B.Sc., Department of Botany, University of New England, Armidale, N.S.W., 2350.
1946 Brett, Robert Gordon Lindsay, B.Sc., 48 Main Road, Lindisfarne, Tasmania, 7015.
1960 Brewer, Ilma Mary, D.Sc., 13 Wentworth Road, Vaucluse, N.S.W., 2030.
1955 Briggs, Miss Barbara Gillian, Ph.D., National Herbarium of N.S.W., Royal Botanic Gardens, Sydney, 2000.
1924 Browne, Ida Alison, D.Sc. (*née* Brown), 363 Edgecliff Road, Edgecliff, N.S.W., 2027.
1911 Browne, William Rowan, D.Sc., F.A.A., 363 Edgecliff Road, Edgecliff, N.S.W., 2927.
1949 Burden, John Henry, 1 Havilah Street, Chatswood, N.S.W., 2067.

1931 *Burges, Professor Norman Alan, M.Sc., Ph.D., Vice-Chancellor, The New University of Ulster, Coleraine, County Londonderry, Northern Ireland.
1959 Burgess, The Rev. Colin E. B. H., Parks and Gardens Section, Department of the Interior, Canberra, A.C.T., 2600.
1962 Burgess, Ian Peter, B.Sc.For., Dip.For., The Forestry Office, Coff's Harbour, N.S.W., 2450.
1968 Burns, James, A.A.S.A., 127 Plateau Road, Avalon Beach, N.S.W., 2107.

1960 Cady, Leo Isaac, P.O. Box 88, Kiama, N.S.W., 2533.
1959 Campbell, Keith George, D.F.C., B.Sc.For., Dip.For., M.Sc., 17 Third Avenue, Epping, N.S.W., 2121.
1927 Campbell, Thomas Graham, Division of Entomology, C.S.I.R.O., P.O. Box 109, City, Canberra, A.C.T., 2601.
1968 Canning, Miss Estelle Margaret, B.Sc. (Melb.), c/- Canberra Botanic Gardens, Parks and Gardens Branch, Department of Interior, Canberra, A.C.T., 2600.
1934 *Carey, Professor Samuel Warren, D.Sc., Geology Department, University of Tasmania, Hobart, Tasmania, 7000.
1949 Carne, Phillip Broughton, B.Agr.Sci. (Melb.), Ph.D. (London), D.I.C., C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T., 2601.
1956 Carolin, Professor Roger Charles, B.Sc., A.R.C.S., Ph.D., School of Biological Sciences, Department of Botany, Sydney University, 2006.
1957 Casimir, Max, B.Sc.Agr., Entomological Branch, N.S.W. Department of Agriculture, Private Mail Bag, No. 10, Rydalmere, N.S.W., 2116.
1936 *Chadwick, Clarence Earl, B.Sc., Entomological Branch, N.S.W. Department of Agriculture, Private Mail Bag No. 10, Rydalmere, N.S.W., 2116.
1956 Chambers, Thomas Carrick, M.Sc. (N.Z.), Ph.D., Botany School, University of Melbourne, Parkville, Victoria, 3052.
1966 Child, John, M.A., B.Comm. (N.Z.), D.Phil. (Oxon.), Department of Economics, Otago University, Box 56, Dunedin, New Zealand.
1959 Chippendale, George McCartney, B.Sc., 4 Raoul Place, Lyons, A.C.T., 2606.
1947 Christian, Stanley Hinton, Malaria Research Unit and School, Kundiawa, Eastern Highlands, Territory of Papua and New Guinea.
1932 *Churchward, John Gordon, B.Sc.Agr., Ph.D., " Erlangga ", Glen Shian Lane, Mount Eliza, Victoria, 3930.
1946 Clark, Laurance Ross, M.Sc., c/- C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T., 2601.
1968 Clarke, Miss Christine Dorothea, B.Sc.(Hons.), 26A Alfred Street, Milson's Point, N.S.W., 2061.
1961 Clarke, Miss Lesley Dorothy, Ph.D., 4 Gordon Crescent, Eastwood, N.S.W., 2122.
1947 Clarke, Mrs. Muriel Catherine, M.Sc. (*née* Morris), 122 Swan Street, Morpeth, N.S.W. 2321.
1901 Cleland, Professor Sir John Burton, M.D., Ch.M., C.B.E., 1 Dashwood Road, Beaumont, Adelaide, South Australia, 5066.
1966 Clough, Barry Francis, B.Sc.Agr., School of Biological Sciences, Department of Botany, Sydney University, 2006.
1966 Clyne, Mrs. Densey, 7 Catalpa Crescent, Turramurra, N.S.W., 2074.
1956 Cogger, Harold George, M.Sc., Ph.D., Australian Museum, P.O. Box A285, Sydney South, N.S.W., 2000.
1946 Colless, Donald Henry, Ph.D. (Univ. of Malaya), c/- Division of Entomology, C.S.I.R.O., P.O. Box 109, City, Canberra, A.C.T., 2601.
1956 Common, Ian Francis Bell, M.A., M.Sc.Agr., C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T., 2601.
1969 Conacher, Robert Davy, LL.B., 15 Terrigal Avenue, Turramurra, N.S.W., 2074.
1966 Conroy, Brian Alfred, International House, Sydney University, 2006.
1942 Copland, Stephen John, M.Sc., 15 Chilton Parade, Warrawee, N.S.W., 2074.
1947 Costin, Alex Baillie, B.Sc.Agr., C.S.I.R.O., Division of Plant Industry, P.O. Box 109, City, Canberra, A.C.T., 2601.
1964 Craddock, Miss Elysse Margaret, 36 Lyons Road, Drummoyne, N.S.W., 2047.
1950 Crawford, Lindsay Dinham, B.Sc., c/- Victorian Plant Research Institute, Department of Agriculture, Burnley Gardens, Melbourne, Victoria, 3000.
1957 Crook, Keith Alan Waterhouse, M.Sc., Ph.D. (New England), Department of Geology, Australian National University, G.P.O. Box 197, Canberra, A.C.T., 2601.

1965 Dandie, Miss Alison Kay, B.Sc.(Hons.), Dip.Ed., 69 Waitara Parade, Hurstville, N.S.W., N.S.W., 2220.
1960 Dart, Peter John, B.Sc.Agr., Ph.D., Soil Microbiology Department, Rothamsted Experimental Station, Harpenden, Herts., England.
1968 Dartnall, Alan John, B.Sc., 7 Forbes Avenue, West Hobart, Tasmania, 7000.
1957 Davies, Stephen John James Frank, B.A. (Cantab.), Ph.D., C.S.I.R.O., Private Bag, Nedlands, Western Australia, 6009.
1945 Davis, Professor Gwenda Louise, Ph.D., B.Sc., Faculty of Science, University of New England, Armidale, N.S.W., 2350.

1968 Debenham, Miss Margaret Lee, B.Sc., 42 Hunter Street, Strathfield, N.S.W., 2135.
1967 De Nardi, Mrs. Jan Christina, B.Sc. (Q'ld.) (*née* Morrow), 6/81 New South Head Road, Vaucluse, N.S.W., 2030.
1953 Dobrotworsky, Nikolai V., M.Sc., Ph.D., Department of Zoology, University of Melbourne, Parkville, Victoria, 3052.
1954 Domrow, Robert, B.A., B.Sc., Queensland Institute of Medical Research, Herston Road, Herston, Queensland, 4006.
1960 Dorman, Herbert Clifford, J.P., A.S.T.C. (Dip.Chem.), Dip.Soc.Stud. (Sydney), Rodgers Street, Teralba, N.S.W., 2284.
1954 Douglas, Geoffrey William, B.Agr.Sc., Deputy Chairman, Vermin and Noxious Weeds Destruction Board, Department of Crown Lands and Survey, Treasury Place, Melbourne, Victoria, 3002.
1946 Durie, Peter Harold, M.Sc., C.S.I.R.O., Veterinary Parasitology Laboratory, Yeerongpilly, Queensland, 4105.
1952 Dyce, Alan Lindsay, B.Sc.Agr., 48 Queen's Road, Asquith, N.S.W., 2078.

1953 Edwards, Dare William, B.Sc.Agr., Forestry Commission of N.S.W., Division of Wood Technology, 96 Harrington Street, Sydney, 2000.
1967 Edwards, Edward John, B.A., B.Sc., Dip.Ed., 38 Shirlow Avenue, Faulconbridge, N.S.W., 2776.
1947 Endean, Robert, M.Sc., Ph.D., Department of Zoology, University of Queensland, St. Lucia, Queensland, 4067.
1930 English, Miss Kathleen Mary Isabel, B.Sc., 6/168 Norton Street, Leichhardt, N.S.W., 2040.
1957 Evans, Miss Gretchen Pamela, M.Sc., 27 Frederick Street, Taringa, Queensland, 4066.

1964 Facer, Richard Andrew, Department of Geology, Wollongong University College, Wollongong, N.S.W., 2500.
1955 *Fairey, Kenneth David, Box 1176, G.P.O., Sydney, 2001.
1957 Filewood, Lionel Winston Charles, c/- Department of Agriculture, Stock and Fisheries, Konedobu, Papua.
1969 Flood, Peter Gerard, B.Sc.(Hons.), Aminco and Associates Pty. Ltd., 275 George Street, Sydney, 2000.
1966 Ford, Miss Judith Helen, 18 Central Avenue, Mosman, N.S.W., 2088.
1930 Fraser, Miss Lilian Ross, D.Sc., 1 Laurence Street, Pennant Hills, N.S.W., 2120.
1968 French, John Richard Joseph, B.Sc.(For.), A.I.W.Sc., 5 Brierley Street, Cremorne, N.S.W., 2090.

1935 *Garretty, Michael Duhan, D.Sc., Box 763, Melbourne, Victoria, 3001.
1969 Goodfellow, David Ralph, 3 Tobruk Avenue, Carlingford, N.S.W., 2118.
1944 Greenwood, William Frederick Neville, 11 Wentworth Avenue, Waitara, N.S.W., 2077.
1965 Griffin, David Michael, M.A., Ph.D. (Cantab.), School of Agriculture, Sydney University, 2006.
1946 *Griffiths, Mrs. Mabel, B.Sc. (*née* Crust), 54 Delmar Parade, Dee Why, N.S.W., 2099.
1936 Griffiths, Mervyn Edward, D.Sc., Wildlife Survey Section, C.S.I.R.O., P.O. Box 109, City, Canberra, A.C.T., 2601.
1939 *Gunther, Carl Ernest Mitchelmore, M.B., B.S., D.T.M., D.T.M. & H. (England), M.B.E., 29 Flaumont Avenue, Lane Cove, N.S.W., 2066.

1959 Hadlington, Phillip Walter, B.Sc.Agr., 129 Condamine Street, Balgowlah, N.S.W., 2093.
1952 Hannon, Miss Nola Jean, B.Sc., Ph.D., 22 Leeder Avenue, Penshurst, N.S.W., 2222.
1964 Harden, Mrs. Gwenneth Jean, M.Sc. (*née* Hindmarsh), Kellys Plains Road, Armidale, N.S.W., 2350.
1967 Hardwick, Reginald Leslie, B.Sc., 183 Richmond Road, Kingswood, N.S.W., 2750.
1968 Hayden, Mrs. Elizabeth Jean, B.Sc. (Melb.), Botany Department, Australian National University, P.O. Box 4, Canberra, A.C.T., 2600.
1958 Hennelly, John Patten Forde, B.Sc., Highs Road, West Pennant Hills, N.S.W., 2120.
1951 Hewitt, Bernard Robert, B.A. (Q'ld.), B.Sc. (Syd.), M.Sc. (N.S.W.), A.R.A.C.I., Senior Lecturer in Chemistry, University of Malawi, Limbe, Malawi, Africa.
1963 Hewson, Miss Helen Joan, B.Sc.(Hons.), Ph.D., Department of Botany, School of General Studies, Australian National University, P.O. Box 4, Canberra, A.C.T., 2600.
1964 Higginson, Francis Ross, B.Sc.Agr.(Hons.), Ph.D., Soil Conservation Service of N.S.W., Box 4293, G.P.O., Sydney, 2001.
1938 Hill, Miss Dorothy, M.Sc., Ph.D., Department of Geology, University of Queensland, Brisbane, Queensland, 4067.
1943 *Hindmarsh, Miss Mary Maclean, B.Sc., Ph.D., 4 Recreation Avenue, Roseville, N.S.W., 2069.
1967 Holland, Ray James Thurstan, M.A. (Syd.), M.A.C.E., c/- Sydney Grammar School, College Street, Sydney, 2000.
1953 *Hotchkiss, Professor Arland Tillotson, M.S., Ph.D. (Cornell), Department of Biology, University of Louisville, Louisville, Kentucky, 40208, U.S.A.
1956 *Hotchkiss, Mrs. Doreen Elizabeth, Ph.D., B.A., M.A. (*née* Maxwell), 2440 Longest Avenue, Louisville, Kentucky, 40208, U.S.A.

1967 Hoult, Errol Hubert, B.Sc.(Hons.), Department of Botany, University of New England, Armidale, N.S.W., 2350.
1969 Howie, Miss Alison Anne, B.Sc., Ph.D. (Cantab.), School of Biological Sciences, Department of Zoology, Sydney University, 2006.
1942 Humphrey, George Frederick, M.Sc., Ph.D., C.S.I.R.O. Marine Biological Laboratory, Box 21, Cronulla, N.S.W., 2230.

1960 Ingram, Cyril Keith, B.A., B.Ec., Office of Inspector of Schools, 2/306 Malton Road, Epping North, N.S.W., 2121.

1957 Jackes, Mrs. Betsy Rivers, B.Sc., Ph.D. (Univ. Chicago) (*née* Paterson), 21 Nebo Road, Mackay, Queensland, 4740.
1963 Jacobs, Miss Janice Lorraine, B.Sc., School of Biological Sciences, Department of Botany, Sydney University, 2006.
1938 Jacobs, Maxwell Ralph, D.Ing., M.Sc., Dip.For., 32 Arthur Circle, Forrest, A.C.T., 2603.
1966 Jacobs, Surrey Wilfred Laurence, 7 Yarrara Road, Pymble, N.S.W., 2073.
1961 Jacobson, Miss Constance Mary, M.Sc., Ph.D., School of Biological Sciences, Department of Zoology, Sydney University, 2006.
1960 James, Sidney Herbert, M.Sc., 54 Holmfirth Street, Mt. Lawley, Western Australia, 6050.
1969 Jamieson, Barrie Gillean Molyneux, B.Sc., Ph.D. (Bristol), Zoology Department, University of Queensland, St. Lucia, Queensland, 4067.
1964 Jancey, Robert Christopher, M.Sc., Ph.D., c/- Department of Botany, University of Western Ontario, London, Ontario, Canada.
1963 Jefferies, Mrs. Lesly Joan, 33 Barry Street, Northcote, Victoria, 3070.
1960 Jenkins, Thomas Benjamin Huw, Ph.D., Department of Geology and Geophysics, Sydney University, 2006.
1947 Johnson, Lawrence Alexander Sidney, B.Sc., c/- National Herbarium, Royal Botanic Gardens, Sydney, 2000.
1945 Johnston, Arthur Nelson, B.Sc.Agr., 22A Greville Street, Chatswood, N.S.W., 2067.
1960 Jolly, Violet Hilary, M.Sc., Ph.D., 2 Hauraki Road, Takapuna, Auckland 9, New Zealand.
1958 Jones, Edwin Llewelyn, B.A., P.O. Box 196, Leeton, N.S.W., 2705.
1930 Joplin, Miss Germaine Anne, B.A., Ph.D., D.Sc., Department of Geophysics, Australian National University, Canberra, A.C.T., 2600.
1960 Judd, Howard Kenniwell, Minnamurra Falls Forest Reserve, Box 14, P.O., Jamberoo, N.S.W., 2533.

1949 Keast, James Allen, M.Sc., M.A., Ph.D. (Harvard), Professor of Biology, Department of Biology, Queen's University, Kingston, Ontario, Canada.
1951 Kerr, Harland Benson, B.Sc.Agr., Ph.D., Summer Institute of Linguistics, P.O. Ukarumpa, E.H.D., Territory of New Guinea.
1937 Kesteven, Geoffrey Leighton, D.Sc., c/- Division of Fisheries and Oceanography C.S.I.R.O., P.O. Box 21, Cronulla, N.S.W., 2230.
1966 Khan, Abdul Ghaffar, M.Sc., Botany Department, Panjab University, New-Campus, Lahore, West-Pakistan.
1957 Kindred, Miss Berenice May, B.Sc., Fachbereich Biologie, Universitat Konstanz, 775 Konstanz, Postfach 733, Germany.

1956 Langdon, Raymond Forbes Newton, M.Agr.Sc., Ph.D., Department of Botany, University of Queensland, St. Lucia, Queensland, 4067.
1964 Lanyon, Miss Joyce Winifred, B.Sc., Dip.Ed., 35 Gordon Street, Eastwood, N.S.W., 2122.
1932 Lawson, Albert Augustus, " Rego House ", 23-25 Foster Street, Sydney, 2000.
1934 Lee, Mrs. Alma Theodora, M.Sc. (*née* Melvaine), Manor Road, Hornsby, N.S.W., 2077.
1936 Lee, Professor David Joseph, B.Sc., School of Public Health and Tropical Medicine, Sydney University, 2006.
1964 Littlejohn, Murray John, B.Sc., Ph.D. (W.A.), Department of Zoology, University of Melbourne, Parkville, Victoria, 3052.
1943 Lothian, Thomas Robert Noel, Botanic Gardens, Adelaide, South Australia, 5000.
1966 Lovedee, Miss Lois Jacqueline, B.Sc. (A.N.U.), 11 Dundilla Road, French's Forest, N.S.W., 2086.
1957 Luig, Norbert Harold, Ph.D., c/- Faculty of Agriculture, Sydney University, 2006.
1958 Lyne, Arthur Gordon, B.Sc., Ph.D., C.S.I.R.O., Ian Clunies Ross Animal Research Laboratory, P.O. Box 144, Parramatta, N.S.W., 2150.

1951 Macdonald, Colin Lewis, 7 Watford Close, North Epping, N.S.W., 2121.
1948 Macintosh, Professor Neil William George, M.B., B.S., Department of Anatomy, Sydney University, 2006.
1922 Mackerras, Ian Murray, M.B., Ch.M., B.Sc., C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T., 2601.
1931 *Mair, Herbert Knowles Charles, B.Sc., 111 Deepwater Road, Castle Cove, N.S.W. 2069-

1948 Marks, Miss Elizabeth Nesta, M.Sc., Ph.D., Department of Entomology, University of Queensland, Brisbane, Queensland, 4067.
1966 Martin, Angus Anderson, B.Sc. (Hons.), Rand, Department of Zoology, University of Melbourne, Parkville, Victoria, 3052.
1957 Martin, Anthony Richard Henry, M.A., Ph.D., School of Biological Sciences, Department of Botany, Sydney University, 2006.
1953 Martin, Mrs. Hilda Ruth Brownell, B.Sc. (*née* Simons), c/- Mrs. H. F. Simons, 43 Spencer Road, Killara, N.S.W., 2071.
1964 Martin, Peter Marcus, M.Sc.Agr., Dip.Ed., School of Biological Sciences, Department of Botany, Sydney University, 2006.
1966 Mather, Mrs. Patricia (*née* Kott), M.Sc., Ph.D. (W.A. and Q'ld), Department of Zoology, University of Queensland, St. Lucia, Queensland, 4067.
1951 McAlpine, David Kendray, M.Sc., Ph.D., Australian Museum, P.O. Box A285, Sydney South, N.S.W., 2000.
1932 McCulloch, Robert Nicholson, M.B.E., D.Sc.Agr., B.Sc., Cattle Tick Research Station, Wollongbar, N.S.W., 2480.
1957 *McCusker, Miss Alison, M.Sc., Botany Department, University College, Box 9184, Dar es Salaam, Tanzania.
1954 McDonald, Miss Patricia M.. B.Sc., Dip.Ed., 33 Holdsworth Street, Neutral Bay, N.S.W., 2089.
1956 McGarity, John William, M.Sc.Agr., Ph.D., Agronomy Department, School of Rural Science, University of New England, Armidale, N.S.W., 2350.
1965 McGillivray, Donald John, B.Sc.For. (Syd.), Dip.For. (Canb.), c/- Royal Botanic Gardens, Kew, Richmond, Surrey, England.
1948 McKee, Hugh Shaw, B.A., D.Phil. (Oxon.), Service des Eaux et Forêts, B.P. 285, Noumea, New Caledonia.
1957 McKenna, Nigel Reece, Department of Education, Konedobu, Papua.
1944 Mercer, Professor Frank Verdun, B.Sc., Ph.D. (Camb.), School of Biological Sciences, Macquarie University, North Ryde, N.S.W., 2113.
1947 Messmer, Mrs. Pearl Ray, " Wychwood ", 11 Kuring-gai Avenue, Turramurra, N.S.W., 2074.
1952 *Meyer, George Rex, B.Sc., Dip.Ed., B.A., M.Ed., Centre for Advancement of Teaching, Macquarie University, North Ryde, N.S.W., 2113.
1949 *Miller, Allen Horace, B.Sc., Dip.Ed., 89 Kentucky Street, Armidale, N.S.W., 2350.
1948 Millerd, Miss Alison Adèle, Ph.D., C.S.I.R.O., Division of Plant Industry, P.O. Box 109, City, Canberra, A.C.T., 2601.
1947 Millett, Mervyn Richard Oke, B.A., " Beeyung ". 72 McNicol Road, Tecoma, Victoria, 3160.
1965 Milward, Norman Edward, B.Sc. (Hons.), M.Sc., Department of Zoology, University College of Townsville, Pimlico, Townsville, Queensland, 4810.
1956 *Moffat, Mrs. Lynette Anne, B.Sc. (*née* Holder), 48 Rutledge Street, Eastwood, N.S.W., 2122.
1963 Moore, Barry Philip, B.Sc., Ph.D., D.Phil., C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T., 2601.
1958 Moore, Kenneth Milton, Cutrock Road, Lisarow, N.S.W., 2251.
1960 Moore, Raymond Milton, D.Sc.Agr., 94 Arthur Circle, Forrest, A.C.T., 2603.
1955 Morgan, Mrs. Eva, M.Sc., 5317 Borland Road, Los Angeles, California, 90032, U.S.A.
1961 Morrison, Gordon Cyril, 34 Leuna Avenue, Wahroonga, N.S.W., 2076.
1955 Muirhead, Warren Alexander, B.Sc.Agr., C.S.I.R.O., Irrigation Research Station, Private Mail Bag, Griffith, N.S.W., 2680.
1926 Mungomery, Reginald William, c/- Bureau of Sugar Experiment Stations, 99 Gregory Terrace, Brisbane, Queensland, 4000.

1947 Nashar, Professor Beryl, B.Sc., Ph.D., Dip.Ed. (*née* Scott), 43 Princeton Avenue, Adamstown Heights, N.S.W., 2289.
1925 Newman, Ivor Vickery, M.Sc., Ph.D., F.R.M.S., F.L.S., School of Biological Sciences, Macquarie University, North Ryde, N.S.W., 2113.
1967 Nicholls, Anthony Oldham, B.Sc., School of Botany, University of Melbourne, Parkville, Victoria, 3052.
1968 Nielsen, Lloyd Alwyn, P.O. Box 12, Jandowae, Queensland, 4410.
1935 *Noble, Norman Scott, D.Sc.Agr., M.Sc., D.I.C., Unit 21, 1 Lauderdale Avenue, Fairlight, N.S.W., 2094.
1920 Noble, Robert Jackson, B.Sc.Agr., Ph.D., 32A Middle Harbour Road, Lindfield, N.S.W., 2070.

1948 O'Farrell, Professor Antony Frederick Louis, A.R.C.Sc., B.Sc., F.R.E.S., Department of Zoology, University of New England, Armidale, N.S.W., 2350.
1950 O'Gower, Professor Alan Kenneth, M.Sc., Ph.D., 20 Gaerloch Avenue, Bondi, N.S.W., 2026.
1927 Osborn, Professor Theodore George Bentley, D.Sc., F.L.S., 34 Invergowrie Avenue, Highgate, South Australia, 5063.
1950 Oxenford, Reginald Augustus, B.Sc., 10 Greaves Street, Grafton, N.S.W., 2460.

1952 Packham, Gordon Howard, B.Sc., Ph.D., Department of Geology, Sydney University, 2006.
1940 *Pasfield, Gordon, B.Sc.Agr., 8 McDonald Crescent, Strathfield, N.S.W., 2135.
1966 Patrick, John William, B.Sc.Ag.(Hons.), School of Biological Sciences, Macquarie University, North Ryde, N.S.W., 2113.
1962 Payne, William Herbert, A.S.T.C., A.M.I.E.Aust., M.A.P.E., 250 Picnic Point Road, Picnic Point, N.S.W., 2213.
1957 Peacock, William James, B.Sc., Ph.D., C.S.I.R.O., Division of Plant Industry, P.O. Box 109, Canberra City, A.C.T., 2601.
1964 Pedder, Alan Edwin Hardy, M.A. (Cantab.), Ph.D., Institute of Sedimentary and Petroleum Geology, 3303 33rd Street, N.W. Calgary 44, Alberta, Canada.
1922 Perkins, Frederick Athol, B.Sc.Agr., 93 Bellevue Terrace, Clayfield, Queensland, 4011.
1962 Philip, Graeme Maxwell, M.Sc. (Melb.), Ph.D. (Cantab.), F.G.S., Department of Geology, University of New England, Armidale, N.S.W., 2350.
1947 Phillips, Miss Marie Elizabeth, M.Sc., Ph.D., Parks and Gardens Section, Department of the Interior, Canberra, A.C.T., 2600.
1969 Phippard, John Harry, B.Pharm., 51 Wyong Road, Mosman, N.S.W., 2088.
1969 Pickard, John, B.Sc.Agr., National Herbarium of N.S.W., Royal Botanic Gardens, Sydney, 2000.
1935 Pope, Miss Elizabeth Carington, M.Sc., C.M.Z.S., Australian Museum, P.O. Box A285, Sydney South, N.S.W., 2000.
1938 Pryor, Professor Lindsay Dixon, M.Sc., Dip.For., Department of Botany, School of General Studies, Australian National University, Box 197, P.O., City, Canberra, A.C.T., 2601.
1967 Pulley, Mrs. Jean May, B.Sc.Agr., Dip.Ed., 12 Clisby Close, Cook, A.C.T., 2614.

1969 Quinn, Christopher John, B.Sc.(Hons.), Ph.D., Department of Botany, School of Biological Sciences, University of New South Wales, P.O. Box 1, Kensington, N.S.W., 2033.

1960 Racek, Albrecht Adalbert, Dr.rer.nat. (Brno, Czechoslovakia), School of Biological Sciences, Department of Zoology, Sydney University, 2006.
1962 Rade, Janis, M.Sc., Flat 28A, 601 St. Kilda Road, Melbourne, Victoria, 3000.
1951 Ralph, Professor Bernhard John Frederick, B.Sc., Ph.D. (Liverpool), A.A.C.I., School of Biological Sciences, University of New South Wales, P.O. Box 1, Kensington, N.S.W., 2033.
1952 Ramsay, Mrs. Helen Patricia, M.Sc., Ph.D., School of Biological Sciences, University of New South Wales, P.O. Box 1, Kensington, N.S.W., 2033.
1953 Reye, Eric James, M.B., B.S. (Univ. Q'ld.), Entomology Department, University of Queensland, St. Lucia, Queensland, 4067.
1957 Reynolds, Miss Judith Louise, Ph.D., 118 Homer Street, Earlwood, N.S.W., 2206.
1961 Richards, Miss Aola Mary, M.Sc. (Hons.), Ph.D. (N.Z.), School of Biological Sciences, University of New South Wales, P.O. Box 1, Kensington, N.S.W., 2033.
1968 Richards, Bryant Neville, B.Sc.For., Ph.D. (Q'ld.), 21 College Avenue, Armidale, N.S.W., 2350.
1964 Richardson, Barry John, 12 Bowden Street, Parramatta North, N.S.W., 2150.
1967 Richardson, Laurence Robert, M.Sc., Ph.D., F.R.S.N.Z., 4 Bacon Street, Grafton, N.S.W., 2460.
1946 Riek, Edgar Frederick, B.Sc., Division of Entomology, C.S.I.R.O., P.O. Box 109, City, Canberra, A.C.T., 2601.
1958 Rigby, John Francis, B.Sc., Geological Survey of Queensland, 2 Edward Street, Brisbane, Queensland, 4000.
1932 *Robertson, Professor Rutherford Ness, C.M.G., F.R.S., B.Sc., Ph.D., F.A.A., Master, University House, Australian National University, Box 4, Canberra, A.C.T., 2600.
1967 Rodd, Anthony Norman, Royal Botanic Gardens, Sydney, 2000.

1960 Salkilld, Barry William, Dip.Soc.Stud. (Univ. Syd.), 71 Beresford Road, Thornleigh, N.S.W., 2120.
1962 Sands, Miss Valerie Elizabeth, M.Sc., Flat 3, 2 William Street, Dunedin, New Zealand.
1919 *Scammell, George Vance, B.Sc., 7 David Street, Clifton Gardens, N.S.W., 2088.
1965 Selkirk, David Robert, School of Biological Sciences, Botany Building, Sydney University, 2006.
1961 Selwood, Mrs. Lynne, B.Sc., Ph.D., (*née* Bedford), School of Anatomy, University of New South Wales, P.O. Box 1, Kensington, N.S.W., 2033.
1950 *Sharp, Kenneth Raeburn, B.Sc., Eng. Geology, S.M.H.E.A., Cooma, N.S.W., 2630.
1948 Shaw, Miss Dorothy Edith, M.Sc.Agr., Ph.D., Department of Agriculture, Stock and Fisheries, Port Moresby, Papua-New Guinea.
1930 Sherrard, Mrs. Kathleen Margaret, M.Sc., 43 Robertson Road, Centennial Park, Sydney, 2021.
1947 Shipp, Erik, Ph.D., 23 Princes Street, Turramurra, N.S.W., 2074.
1959 Simons, John Ronald, M.Sc., Ph.D., 242 Kissing Point Road, Turramurra, N.S.W., 2074.
1955 Slack-Smith, Richard J., 7 Kingston Street, Shenton Park, Western Australia, 6008.
1953 Smith, Eugene Thomas, 22 Talmage Street, Sunshine, Victoria, 3020.

1943 Smith-White, Spencer, D.Sc.Agr., F.A.A., 51 Abingdon Road, Roseville, N.S.W., 2069.
1967 South, Stanley A., B.Sc., 47 Miowera Road, Turramurra, N.S.W., 2074.
1945 Southcott, Ronald Vernon, D.Sc., M.D., D.T.M. & H., F.A.C.M.A., 2 Taylors Road, Mitcham, South Australia, 5062.
1937 Spencer, Mrs. Dora Margaret, M.Sc. (*née* Cumpston), No. 1 George Street, Tenterfield, N.S.W., 2372.
1960 Staff, Ian Allen, B.Sc., Dip.Ed., Ph.D., Department of Botany, School of Biological Sciences, La Trobe University, Bundoora, Victoria, 3083.
1968 Stanbury, Peter John, Ph.D., The Macleay Museum, School of Biological Sciences, Sydney University, 2006.
1932 Stead, Mrs. Thistle Yolette, B.Sc. (*née* Harris), 14 Pacific Street, Watson's Bay, N.S.W. 2030.
1956 Stephenson, Neville George, M.Sc. (N.Z.), Ph.D. (Lond.), School of Biological Sciences, Department of Zoology, Sydney University, 2006.
1965 Stephenson, Professor William, B.Sc. (Hons.), Ph.D. (Durham, Eng.), Diploma of Education, member Aust. Coll. Educ., Fellow Zoological Society, Department of Zoology, University of Queensland, St. Lucia, Queensland, 4067.
1962 Strahan, Ronald, M.Sc., Director, Taronga Zoo, P.O. Box 20, Mosman, N.S.W., 2088.
1965 Straughan, Mrs. Isdale Margaret, B.Sc., Ph.D., Allan Hancock Foundation, University of Southern California, University Park, Los Angeles, California, 90007, U.S.A.
1952 Sullivan, George Emmerson, M.Sc. (N.Z.), Ph.D., Department of Histology and Embryology, Sydney University, 2006.
1962 Sweeney, Anthony William, Malaria Institute, Public Health Department, Rabaul, Territory of Papua and New Guinea.
1962 *Swinbourne, Robert Frederick George, 4 Leeds Avenue, Northfield, South Australia, 5085.

1965 Talbot, Frank Hamilton, M.Sc., Ph.D., F.L.S., Australian Museum, P.O. Box A285, Sydney South, N.S.W., 2000.
1940 Taylor, Keith Lind, B.Sc.Agr., c/- C.S.I.R.O., Division of Entomology, Stowell Avenue, Hobart, Tasmania, 7000.
1950 Tchan, Professor Yao-tseng, Dr., es Sciences (Paris), Department of Microbiology, Sydney University, 2006.
1950 Thompson, Mrs. Joy Gardiner, B.Sc.Agr. (*née* Garden), 21 Middle Head Road, Mosman, N.S.W., 2088.
1956 Thomson, James Miln, D.Sc. (W.A.), Department of Zoology, University of Queensland, St. Lucia, Queensland, 4067.
1960 Thorne, Alan Gordon, B.A., Department of Anatomy, Sydney University, 2006.
1949 Thorp, Mrs. Dorothy Aubourne, B.Sc. (Lond.), Ph.D., "Sylvan Close", Mt. Wilson, N.S.W., 2740.
1944 Thorpe, Ellis William Ray, B.Sc., University of New England, Armidale, N.S.W., 2350.
1968 Timms, Brian Victor, B.Sc.(Hons.), Zoology Department, Monash University, P.O. Box 92, Clayton, Victoria, 3168.
1943 Tindale, Miss Mary Douglas, D.Sc., 60 Spruson Street, Neutral Bay, N.S.W., 2089.
1921 *Troughton, Ellis Le Geyt, C.M.Z.S., F.R.Z.S., c/- Australian Museum, P.O. Box A285, Sydney South, N.S.W., 2000.
1965 Tucker, Richard, B.V.Sc., Dr.Vet.M., Veterinary School, Department of Veterinary Anatomy, University of Queensland, St. Lucia, Queensland, 4067.

1952 Valder, Peter George, B.Sc.Agr., Ph.D. (Camb.), School of Biological Sciences, Department of Botany, Sydney University, 2006.
1949 Vallance, Professor Thomas George, B.Sc., Ph.D., Department of Geology and Geophysics, Sydney University, 2006.
1917 Veitch, Robert, B.Sc., F.R.E.S., 24 Sefton Avenue, Clayfield, Queensland, 4011.
1930 Vickery, Miss Joyce Winifred, M.B.E., D.Sc., Royal Botanic Gardens, Sydney, 2000.
1940 Vincent, Professor James Matthew, D.Sc.Agr., Dip.Bact., Department of Microbiology, School of Biological Sciences, University of New South Wales, P.O. Box 1, Kensington, N.S.W., 2033.
1934 *Voisey, Professor Alan Heywood, D.Sc., School of Earth Sciences, Macquarie University, North Ryde, N.S.W., 2113.

1961 Walker, Donald, B.Sc., M.A., Ph.D., F.L.S., 18 Cobby Street, Campbell, Canberra, A.C.T., 2601.
1952 Walker, John, B.Sc.Agr., Biological Branch, N.S.W. Department of Agriculture, Private Mail Bag No. 10, Rydalmere, N.S.W., 2116.
1909 Walkom, Arthur Bache, D.Sc., 5/521 Pacific Highway, Killara, N.S.W., 2071.
1946 Wallace, Murray McCadam Hay, B.Sc., C.S.I.R.O., W.A. Regional Laboratory, Nedlands Western Australia, 6009.
1947 Ward, Mrs. Judith, B.Sc., 16 Mortimer Avenue, New Town Hobart, Tasmania, 7008.
1911 Wardlaw, Henry Sloane Halcro, D.Sc., F.R.A.C.I., 71 McIntosh Street, Gordon, N.S.W., 2072.
1966 Wass, Robin Edgar, B.Sc. (Hons., Q'ld.), Ph.D., Department of Geology and Geophysics, Sydney University, 2006.

1936 Waterhouse, Douglas Frew, C.M.G., D.Sc., F.R.S., C.S.I.R.O., P.O. Box 109, City, Canberra, A.C.T., 2601.

1947 *Waterhouse, John Teast, B.Sc., School of Biological Sciences, University of New South Wales, P.O. Box 1, Kensington, N.S.W., 2033.

1941 Watson, Professor Irvine Armstrong, Ph.D., B.Sc.Agr., Faculty of Agriculture, Sydney University, 2006.

1964 Webb, Mrs. Marie Valma, B.Sc., 30 Talfourd Street, Glebe, N.S.W., 2037.

1963 Webby, Barry Deane, Ph.D., M.Sc., Department of Geology and Geophysics, Sydney University, 2006.

1963 Webster, Miss Elsie May, 20 Tiley Street, Cammeray, N.S.W., 2062.

1946 Wharton, Ronald Harry, M.Sc., Ph.D., C.S.I.R.O., 677 Fairfield Road, Yeerongpilly, Queensland, 4105.

1926 *Whitley, Gilbert Percy, F.R.Z.S., Australian Museum, P.O. Box A285, Sydney South, N.S.W., 2000.

1962 Whitten, Maxwell John, Ph.D., C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T., 2601.

1960 Wildon, David Conrad, B.Sc.Agr., Box 108, Rozelle, N.S.W., 2039.

1954 Williams John Beaumont, B.Sc., University of New England, Armidale, N.S.W., 2350.

1954 Williams, Mrs. Mary Beth, B.Sc. (*née* Macdonald), 902D Rockvale Road, Armidale, N.S.W., 2350.

1960 Williams, Neville John, B.Sc., Zoologisch Laboratorium der Rijksuniversiteit te Groningen, Rijksstraatweg 78, Haren (Gr.), Nederland.

1952 Williams, Owen Benson, M.Agr.Sc. (Melbourne), c/- C.S.I.R.O., The Ian Clunies Ross Animal Research Laboratory, P.O. Box 144, Parramatta, N.S.W., 2150.

1950 Willis, Jack Lehane, M.Sc., A.A.C.I., 26 Inverallan Avenue, Pymble, N.S.W., 2073.

1947 Winkworth, Robert Ernest, Rangelands Research Unit, C.S.I.R.O. ,P.O. Box 109, Canberra City, A.C.T., 2601.

1968 Wood, Alec Edward, B.Sc.Agr., Ph.D., 25 George Street, Bexley, N.S.W., 2207.

1965 Woodward, Thomas Emmanuel, M.Sc. (N.Z.), Ph.D. (Lond.), D.I.C., Department of Entomology, University of Queensland, St. Lucia, Queensland, 4067.

1964 Wright, Anthony James Taperell, B.Sc., Geology Department, Victoria University of Wellington, P.O. Box 196, Wellington, C.1., New Zealand.

1964 Yaldwyn, John Cameron, Ph.D. (N.Z.), M.Sc., Dominion Museum, Private Bag, Wellington, New Zealand.

1965 Young, Graham Rhys, 8 Spark Street, Earlwood, N.S.W., 2206.

CORRESPONDING MEMBER

1949 Jensen, Hans Laurits, D.Sc.Agr. (Copenhagen), State Laboratory of Plant Culture, Department of Bacteriology, Lyngby, Denmark.

LIST OF PLATES

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Bullough, W. S., 1939.—A Study of the Reproductive Cycle of the Minnow in Relation to the Environment. *Proc. zool. Soc. Lond.*, 109, A: 79–108.

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