THE

PROCEEDINGS

OF THE

LINNEAN SOCIETY

OF

NEW SOUTH WALES

FOR THE YEAR

1960

VOL. LXXXV.

WITH TEN PLATES.

324 Text-figures.

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CONTENTS OF PROCEEDINGS, 1960

PART 1 (No. 392).

(Issued 29th July, 1960.)

Corrigendum (1959, Part 3): In the list of new species on page 428 of the PROCEEDINGS, 1959, Part 3, the following new species of *Ranunculus* were omitted: clivicola, p. 319; eichleranus, p. 313; niphophilus, p. 321; pachycarpus, p. 301; productus, p. 321; victoriensis, p. 314; and a new variety, brevicaulis, p. 316.

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(Issued 30th September, 1960.)

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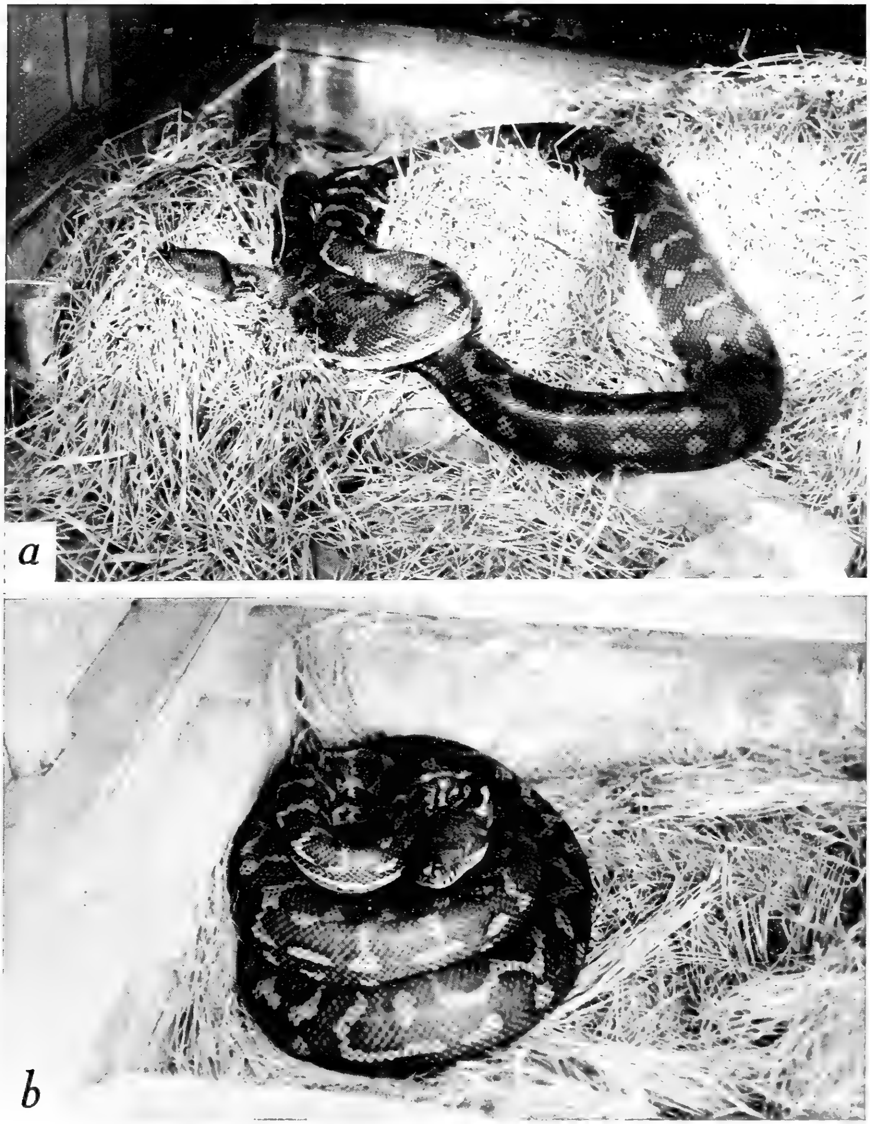
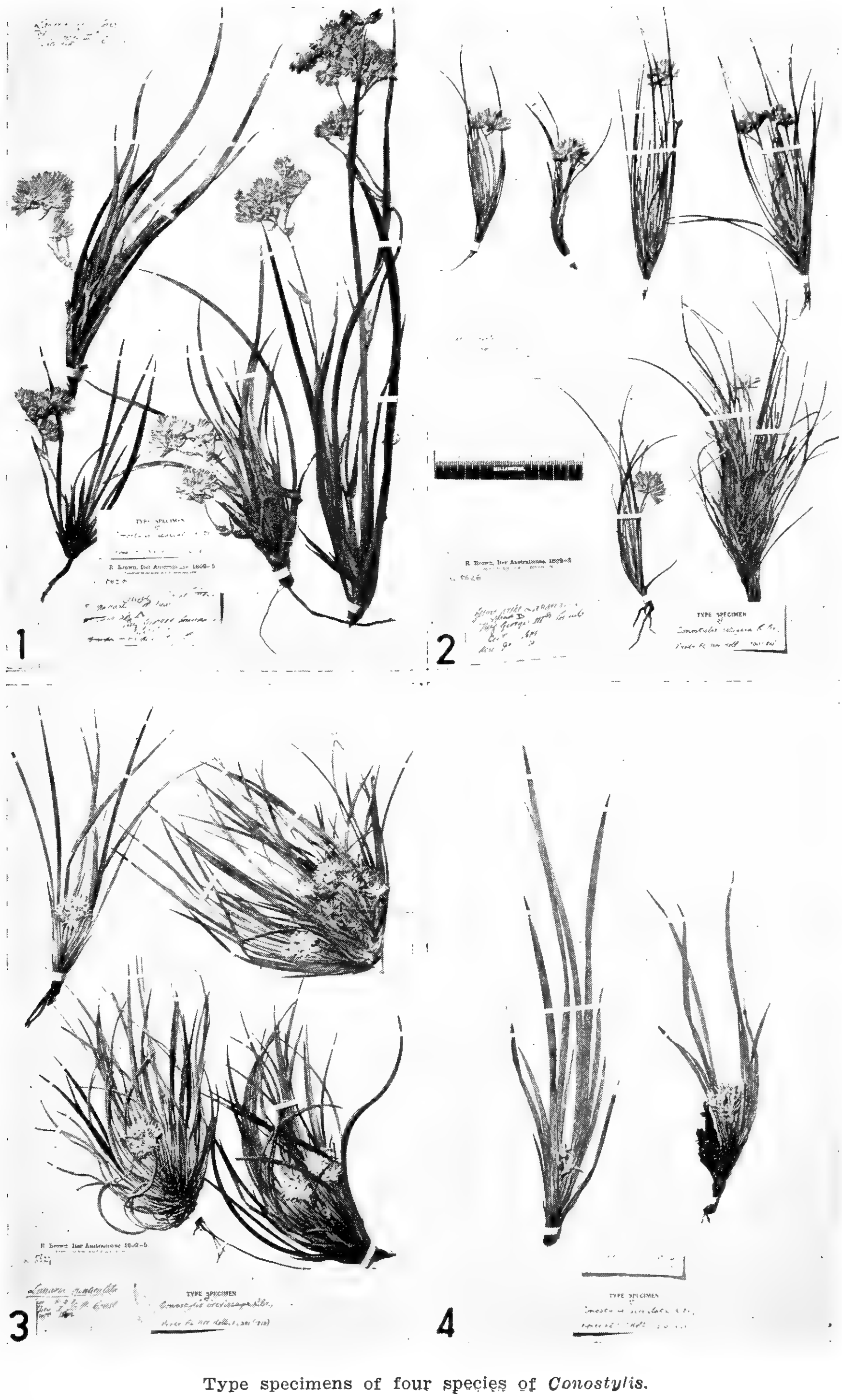
PART 3 (No. 394).

(Issued ...., 1961.)



Morelia spilotes variegata Gray.



Type specimens of four species of *Conostylis*.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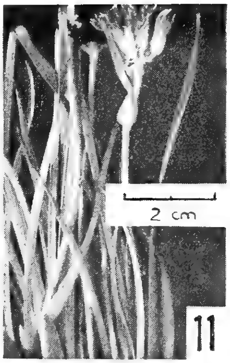
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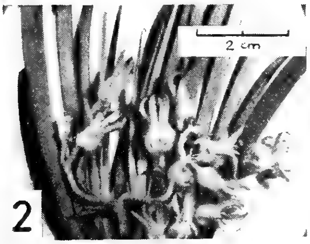
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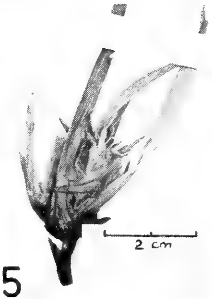
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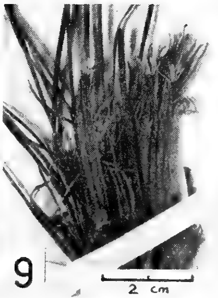
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1409

Species of *Conostylis*.

ANNUAL GENERAL MEETING.

30th MARCH, 1960.

The Eighty-fifth Annual General Meeting was held in the Society's Rooms, Science House, 157 Gloucester Street, Sydney, on Wednesday, 30th March, 1960.

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

The minutes of the Eighty-fourth Annual General Meeting, 25th March, 1959, were read and confirmed.

PRESIDENTIAL ADDRESS.

Before I proceed to bore you with technical jargon there are some important Society matters to which I wish to refer. First of all I want to express my own very warm thanks and I am sure those of all members to our two honorary officers, Dr. A. B. Walkom and Dr. W. R. Browne. These gentlemen have continued to do yeoman service on behalf of the Society and their efforts must not be left unregarded. I should also like at this time to put on record our thanks to our Assistant Secretary, Miss G. Allpress, for her faithful service during the past year.

The Society's PROCEEDINGS for 1959, Volume 84, Parts 1 and 2, were published in 1959 and Part 3 in February, 1960. Volume 84 consists of 432 pages, 23 plates and 287 text-figures. Payment for a two-colour plate to illustrate a paper by E. Gauba and L. D. Pryor entitled "Seed Coat Anatomy and Taxonomy in *Eucalyptus*. II" was made by the Department of the Interior, Canberra. An increase of 10% on charges for printing the PROCEEDINGS was made commencing with Volume 84, Part 2.

During the year nine new members were added to the list, two members died, and nine members resigned. The numerical strength of the Society at 1st March, 1960, was: Ordinary Members, 224; Life Members, 32; Corresponding Members, 2; total, 258.

On 20th May, 1959, Professor B. J. F. Ralph was elected a member of Council in place of Dr. Dorothy A. Thorp.

Lecturettes were given at the following meetings: April, Wild Life of Macquarie Island, by Mr. Durno Murray; June, Fossil Spores and Pollen Grains, by Mr. J. P. F. Hennelly; September, Vegetation of South-East England, by R. F. Cosser; October, Some Problems of New Guinea Zoogeography, by Dr. D. F. McMichael. A symposium on "Laterite" was held at the July meeting, the principal speakers being Dr. W. R. Browne, Mr. P. H. Walker and Professor F. V. Mercer (deputizing for Professor R. L. Crocker). We wish to thank all lecturers and express our appreciation to them and to all members who brought notes and exhibits to meetings, thus ensuring interesting contributions and discussions. Small attendances at Ordinary Monthly Meetings are still causing concern to the Council.

Library accessions from scientific institutions and societies on the exchange list amounted to 2,076 compared with 1,727 in the previous year. Requests for library loans from members and institutions continued to be made as frequently as previously. A small number of volumes in the library was bound. The PROCEEDINGS were offered to the Beaudette Foundation, Solvang, California, in exchange for "Pacific Naturalist"; Tokyo Agricultural University, Tokyo; and Escuela de Biologia, Facultad de Ciencias, Universidad Central de Venezuela, Caracas, Venezuela, for "Acta Biologica Venezuela". Geological Reprints were offered to Geological Institute, Kumamoto University, Kumamoto, Japan. Exchange relations with Faculté des Sciences, Université d'Aix-Marseille, Marseille, France, were discontinued. "Physis", Buenos Aires, Argentina, is now obtained by subscription. Advantage was taken of an opportunity to purchase three volumes and three General Indexes to complete our set of "Journal de Conchyliologie".

The total net return from the Society's one-third ownership of Science House for the year was £1,447 15s. 6d. Owing to the Royal Society of New South Wales relinquishing its tenancy of the Reception Room on the ground floor of Science House as from 31st May, 1959, the Joint Management Committee decided that in future the room should be known as the Edgeworth David Room and be used as a Conference, Committee and Reception Room.

Under the auspices of the Royal Society of New South Wales and the Linnean Society a meeting was held on 3rd June, 1959, to celebrate the centenary of the publication of Darwin's "Origin of Species". The commemorative address entitled "Charles Darwin" was delivered by Professor P. D. F. Murray.

On 5th August, 1959, the Stuart Drawings and some old maps, etc., were handed to the Mitchell Library, Sydney, on the following conditions, which were accepted by the Trustees of the Mitchell Library: (1) That they remain the property of the Society, and be accepted by the Library on permanent loan; (2) that they be suitably housed and cared for; (3) that in any exhibition of them or any reproductions of them made or published, the fact of their being the property of this Society be clearly stated; (4) that facilities for access to them be guaranteed to members of this Society; and (5) that insurance against their loss or damage be effected.

On 29th September, 1959, three swords in the Society's possession for many years were handed to the Museum of Applied Arts and Sciences, Broadway, Sydney, on permanent loan.

Mr. R. H. Anderson was asked to represent the Society at the Third Annual Conference of Nature Conservation Bodies (N.S.W.) held on 8th August, 1959. Professor B. J. Ralph was appointed the Society's representative to the Centenary Symposium (December 7–11, 1959) of the Royal Society of Victoria. Dr. Gordon H. Packham was asked to act as delegate for the Society at the International Geological Congress, XXI Session, Copenhagen, 1960.

During the year an unsuccessful request was made to the Prime Minister for a Commonwealth contribution towards the maintenance of the scientific libraries of the Royal Societies in each State and/or the Linnean Society of New South Wales.

On account of increased postage charges from 1st October, 1959, the postage on the complete volume of the Society's PROCEEDINGS was raised to four shillings.

I should like to take this opportunity to announce that the Second Sir William Macleay Memorial Lecture will be delivered by Professor Theodosius Dobzhansky, Columbia University, New York, on Wednesday, 29th June, 1960, at 8 p.m., in the Main Hall, Science House, Sydney.

Linnean Macleay Fellowships.

Miss Alison McCusker, M.Sc., who was appointed to a Fellowship in Botany for 1959 in November, 1958, studied pollen development in some species of the Styphelieae. In the early part of the year a project of work on local populations of *Astroloma pinifolium*, begun previously, was concluded, and a paper written in conjunction with Dr. S. Smith-White was accepted for publication in the PROCEEDINGS. Material of the same species was collected from Victoria, and a preliminary investigation of its cytological conditions was made. An investigation of the genetic system of *Leucopogon melaleucoides* was undertaken during the second quarter, and as this proved to be especially profitable, the remainder of the year was devoted to it. Extensive studies of meiosis in microspore mother cells were made, and data concerning megaspore development and pollen and seed production were collected from two localities. From June to October these studies were carried out at the laboratories of the University of New England by courtesy of Professor N. C. W. Beadle.

No appointment was made for 1960.

Your Council had for some time been concerned at the fact that the salary offered for a Linnean Macleay Fellowship suffered in comparison with salaries for fellowships and scholarships of somewhat equal standing. It therefore decided to petition the Equity Court for power to offer a salary not exceeding £1,600 per annum for a fellowship. On 17th December, 1959, the petition came before the Court and His Honour Mr. Justice Myers made the following order: (1) The salary of a Fellow shall be an amount not less than £400 and not more than £1,600 per annum as the Council of the Society shall decide; (2) the Council of the Society may, upon the application of a Fellow, make grants to him out of the remaining income from the Linnean Macleay Fellowship Fund received by the Society in any year provided the total sum including the salary or salaries paid to the Fellow or Fellows during such year does not exceed £1,600, to defray field and other research expenses incurred or to be incurred in carrying on work and investigations as such Fellow or Fellows; and (3) that the cost of all parties are to be paid out of the Fund.

Opinion was obtained from the Society's solicitors that Fellows were not employees in terms of the Workers' Compensation Act or the Income Tax Act. Fellows were to be informed that they were not covered by insurance under the Workers' Compensation Act.

Linnean Macleay Lectureship in Microbiology.

The following is a brief report on the work of Dr. Y. T. Tchan, Linnean Macleay Lecturer in Microbiology, University of Sydney, for the year ended 31st December, 1959: Due to the absence of the Head of the Microbiology Section (Associate Professor J. M. Vincent) he has been heavily loaded with teaching and administration work. However, some research work has been done on the soil algal method. A paper is under preparation for publication. The results of this work indicate that algal techniques could, under certain circumstances, replace the pot trial with higher plants.

Obituaries.

It is recorded with regret that the following members died during the year:

Mr. Anthony Musgrave, F.R.E.S., F.R.Z.S., who was Curator of Insects and Arachnids at the Australian Museum, Sydney, and had been a member of the Society since 1920, died suddenly in Sydney on 4th June, 1959, at the age of 64. Mr. Musgrave was born at Cooktown, Queensland, on 9th July, 1895, his father, Captain the Hon. Anthony Musgrave, C.M.G., being Deputy Commissioner, and later Government Secretary of British New Guinea. He joined the staff of the Museum as a cadet on 7th February, 1910, and, after a year in the library, was appointed assistant to the then entomologist, Mr. W. J. Rainbow. In 1920, after Mr. Rainbow's death, Mr. Musgrave was appointed entomologist, a title later altered to Curator of Insects and Arachnids. He joined the Royal Zoological Society of New South Wales in 1919 or 1920, was a member of its Council from 1920 to 1935, and was elected President in 1929–30 and a Fellow in 1933. He was also a Fellow of the Royal Entomological Society of London, and a member of the Royal Australian Historical Society, serving on the Council of that Society in 1956 and 1957. He was interested in the vast literature on Australasian and Pacific entomology and his bibliographical work was amazingly detailed. His monumental "Bibliography of Australian Entomology, 1775–1930, with Biographical Notes on Authors and Collectors" was published by the Royal Zoological Society of New South Wales in 1932 and was kept up to date by him on cards. He also compiled, for about twenty years, all the zoological entries for "Australian Science Abstracts" until they ceased publication in 1957. A bibliography of his writings is in course of preparation for publication. An obituary notice (with portrait) appears in the *Australian Museum Magazine*, Vol. XIII, No. 3 (September 15, 1959). Mr. Musgrave used the Society's library extensively and was a frequent attendant at monthly meetings, taking an active part in their programmes.

Mrs. Nance (Anne) Zeck, wife of Mr. E. H. Zeck, died in Sydney on 3rd November, 1959. Mrs. Zeck had been a member of the Society since 1949.

PRESIDENTIAL ADDRESS.

Concerning Spilites.

The term spilite was introduced by Brongniart probably before 1819. Originally, rocks of rather diverse character were grouped under this name but today spilite is used most often in the restricted sense of Dewey and Flett (1911), that is, for fine-grained or even partly glassy basic rocks in which the typical feldspar is albite. Spilites in which K-feldspar occurs as well as albite are also recognized. However, not all petrographers regard the presence of alkali feldspars as essential.

Spilites occur most frequently as submarine lavas or shallow intrusive bodies in eugeosynclinal environments. They have also been found in epicontinental and continental associations and in some of these cases may have been subaerial. There are even records of intrusive spilites apparently unrelated to effusive vulcanism. Geosynclinal spilites occur with ultrabasic bodies or with keratophyres and other more acid rocks. Ultrabasic rocks are typically subordinate or lacking in the epicontinental and continental associations.

Spilites, even within, say, a single flow, are variable in fabric, mineralogy and composition. Calculated "average spilites" are suspect because of probable bias in sampling. The bulk composition of spilite bodies may not be much different from the composition of normal basalts, only water and, sometimes, carbon dioxide being more abundant in spilites. Mineral assemblages of the type found in spilites can form in a variety of ways, by magmatic action, hydrothermal alteration, low-grade metamorphism, or diagenesis. In some spilites there is clear evidence of replacement of primary magmatic phases but in others where such evidence is lacking the present phases may themselves be primary, having separated from exceptionally hydrous magmas. There is no unique explanation to account for the genesis of all rocks called spilites. I prefer to regard most of them as essentially basaltic rocks which have become adjusted, either magmatically or post-magmatically, to a low-temperature hydrous environment. (For full text see pp. 8 *et seq.*)

The Honorary Treasurer, Dr. A. B. Walkom, presented the balance sheets for the year ended 29th February, 1960, duly signed by the Auditor, Mr. S. J. Rayment, F.C.A., and his motion that they be received and adopted was carried unanimously.

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

President: I. V. Newman, M.Sc., Ph.D.

Members of Council: W. R. Browne, D.Sc.; R. L. Crocker, D.Sc.; I. V. Newman, M.Sc., Ph.D.; B. J. F. Ralph, B.Sc., Ph.D., A.A.C.I.; A. B. Walkom, D.Sc.; and W. L. Waterhouse, C.M.G., M.C., D.Sc.Agr., D.I.C.

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

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

LINNEAN SOCIETY OF NEW SOUTH WALES.

GENERAL ACCOUNT. Balance Sheet at 29th February, 1960.

LIABILITIES.	£	s.	d.	£	s.	d.
Accumulated Funds—						
Amount received from Sir William Macleay during his lifetime ..	14,000	0	0			
Further sum bequeathed by his will	6,000	0	0			
				20,000	0	0
Contingencies Reserve				14,367	11	4
				34,367	11	4
Current Liabilities—						
Bookbinding Account	1,127	10	1			
Income Account	1,115	17	5			
Suspense	56	9	7			
				2,299	17	1
				£36,667	8	5

ASSETS.	£	s.	d.	£	s.	d.
Fixed Assets—						
Commonwealth Loans, at cost ..	15,048	10	0			
Debentures:						
Metropolitan Water, Sewerage and Drainage Board, at cost	5,344	7	6			
Science House (one-third share), at cost	14,835	4	4			
				35,228	1	10
Current Assets—						
Cash in Hand	10	0	0			
Commercial Banking Co. of Sydney, Ltd.	1,429	6	7			
				1,439	6	7
				£36,667	8	5

INCOME ACCOUNT. Year Ended 29th February, 1960.

	£	s.	d.	£	s.	d.
To Salary				730	10	0
,, Printing Proceedings	2,239	7	4			
,, Printing Reprints	563	9	0			
,, Blocks	367	17	4			
				3,170	13	8
,, Insurance				14	1	3
,, Postage	101	0	2			
,, Petty Cash	32	8	11			
				133	9	1
,, Audit	16	16	0			
,, Printing and Stationery	107	18	11			
,, Expenses	119	19	5			
,, Cleaning	62	17	6			
,, Bank Expenses	2	17	3			
,, Library	38	2	11			
				348	12	0
,, Balance to 1960-61				1,115	17	5
				£5,513	3	5

	£	s.	d.	£	s.	d.
By Balance from 1958-59				660	4	4
,, Subscriptions:						
1959-60	419	18	0			
Arrears	63	0	0			
In Advance	16	16	0			
				499	14	0
,, Entrance Fees				9	9	0
,, Interest				929	1	6
,, Science House				1,447	15	6
,, Rent				21	10	0
,, Sales				511	9	3
,, N.S.W. Government Grant				200	0	0
,, Fellowships Account (surplus income at 29th February, 1960, transferred)				698	11	11
,, Bank Expenses				2	18	2
,, Sale of Reprints				531	6	9
,, Postcard Sales				1	3	0
				£5,513	3	5

A. B. Walkom,
Hon. Treasurer.
4th March, 1960.

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 29th February, 1960, 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 29th February, 1960, as shown by the books. Certificates of the investments have been inspected.

S. J. Rayment, Chartered Accountant (Aust.),
Auditor.

Sydney, 11th March, 1960.

LINNEAN SOCIETY OF NEW SOUTH WALES.

LINNEAN MACLEAY FELLOWSHIPS ACCOUNT.

Balance Sheet at 29th February, 1960.

LIABILITIES.	£	s.	d.
Accumulated Funds—			
Amount bequeathed by Sir William Macleay ..	35,000	0	0
Surplus Income Capitalized	21,635	3	1
	£56,635	3	1

ASSETS.	£	s.	d.	£	s.	d.
Fixed Assets—						
Commonwealth Loans, at cost ..	30,449	0	0			
Debentures:						
Metropolitan Water, Sewerage and Drainage Board, at cost	17,156	14	9			
Rural Bank of N.S.W., at cost	2,172	15	0			
Loan on Mortgage	6,035	0	0			
				55,813	9	9
Current Assets—						
Commercial Banking Company of Sydney Ltd.				821	13	4
				£56,635	3	1

INCOME ACCOUNT. Year Ended 29th February, 1960.

	£	s.	d.
To Salary of Linnean Macleay Fellow	666	13	4
,, Research Expenses	141	17	8
,, Balance, being Surplus Income transferred to General Account	698	11	11
,, Capital Account	791	9	0
	£2,298	11	11

	£	s.	d.
By Interest	2,298	11	11
	£2,298	11	11

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 29th February, 1960, 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 29th February, 1960, as shown by the books. Certificates of the investments have been inspected.

S. J. Rayment, F.C.A., Chartered Accountant,
Auditor.

Sydney, 11th March, 1960.

A. B. Walkom,
Hon. Treasurer.

4th March, 1960.

LINNEAN SOCIETY OF NEW SOUTH WALES.

BACTERIOLOGY ACCOUNT.

Balance Sheet at 29th February, 1960.

LIABILITIES.

	£	s.	d.	£	s.	d.
Accumulated Funds—						
Amount bequeathed by Sir William Macleay	12,000	0	0			
Accumulated Income Capitalized	6,310	0	0			
Research Fund	10	0	0			
				18,320	0	0
Current Liability—						
Income Account at 29th February, 1960				196	8	0
				£18,516	8	0

ASSETS.

	£	s.	d.	£	s.	d.
Fixed Assets—						
Commonwealth Loans, at cost	15,320	0	0			
Debentures:						
Metropolitan Water, Sewerage and Drainage Board, at cost	800	0	0			
Loan on Mortgage	2,200	0	0			
				18,320	0	0
Current Assets—						
Commercial Banking Company of Sydney, Ltd.				196	8	0
				£18,516	8	0

INCOME ACCOUNT. Year Ended 29th February, 1960.

	£	s.	d.
To University of Sydney (towards salary of Lecturer)	700	0	0
,, Insurance		13	5
,, Balance to 1960-61	196	8	0
	£897	1	5

	£	s.	d.
By Balance from 1958-59	86	19	7
,, Interest	810	1	10
	£897	1	5

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 29th February, 1960, 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 29th February, 1960, as shown by the books. Certificates of the investments have been inspected.

S. J. Rayment, F.C.A., Chartered Accountant,
Auditor.

Sydney, 11th March, 1960.

A. B. Walkom,
Hon. Treasurer.

4th March, 1960.

PRESIDENTIAL ADDRESS.

CONCERNING SPILITES.

By T. G. Vallance.

(Five Text-figures.)

[Delivered 30th March, 1960.]

Introduction.

If petrographers were to take a cue from their palaeontological colleagues they might place spilites among a group of problematica. Certainly these rocks, diverse in their occurrence, in their mineralogy and in their composition, provide more than ordinary difficulties to those who wish to classify them. Nevertheless, spilities constitute a group of rocks in which this Society should have more than a passing interest. It was one of our former members, the late Professor W. N. Benson, F.R.S., who first drew attention to the extensive occurrences of spilites in northern New South Wales. Much of Benson's work on these rocks was carried out while he was a Macleay Fellow, and his results, which still command the attention and admiration of petrologists throughout the world, were published in a series of papers in our Proceedings.

After Benson's departure for New Zealand in 1917, the investigation of spilites in Australia lapsed and it is only within the last ten years or so that local interest in these rocks has revived. In 1951, Scott published the first of a group of important papers on spilites in Tasmania and during the past couple of years I have been working over Benson's ground at Nundle.

The more spilites one looks at or reads about the more one is impressed by their widespread distribution, their diversity, and the almost equal variety of theories proposed to account for their genesis. These are the matters I wish to discuss this evening. Because a large number of important works on spilites are not easily available to local petrologists, I have concentrated on collecting information about foreign occurrences.

It seems generally to be believed that the term spilite was introduced by Alexandre Brongniart, the great French mineralogist and ceramist, in 1827. However, it appears (in the form spillite) in an article by de Bonnard published in 1819 with a note that the name had already been proposed by Brongniart in a first course of geology. Whether this course was published or was merely a set of lectures is unknown to me, but at least the term was in use by 1819.

Brongniart (1827) offers no indication as to the etymology of the word spilite, but it seems to have been derived from the Greek σπιλος, meaning spot or blemish. Variolite (from the mediaeval Latin *variolae* = smallpox) has rather similar connotations, but a history going back at least to the *lapis variolatus* listed in a posthumous work of Aldrovandus (Ambrosinus, 1648). Aldrovandus mentions examples from India, and from Lucca in Italy, and gives two woodcuts which are singularly uninformative. In any case, the material, whatever it was, was noted mainly for its supposed medicinal virtues. The reader interested in the early history of variolite should consult Cole and Gregory (1890). Of more immediate interest in the spilite story is the discovery about 1780 in Dauphiny, by Lamanon, later the naturalist with Lapérouse on his Pacific voyage, of a rock called the *variolite du Drac*. This material which Lamanon considered to be a lava—a view bitterly attacked by his contemporaries—was later taken by Brongniart as one of his type spilites.

The rocks classed by Brongniart (1827) as spilites were characterized by the presence of nodules of calcite, and sometimes of agate, in a base (*pâte*) of aphanite.* With the crude chemical information at his disposal Brongniart noted that the aphanite base had, at least in some cases, a composition akin to that of basalt. Disseminated through this base were chlorite, pyroxene, amphibole, feldspar, with epidote and mica rare to very rare, while amethyst, agate, jasper, prehnite, malachite, native copper, stilbite, analcite and talc are mentioned as accessories occurring in patches. Five varieties of spilite were recognized, namely, (1) *spilite commun*—"compact, dark green or purplish brown-red base; round calcareous nodules, sometimes white, sometimes red, sometimes accompanied by agate nodules"; (2) *spilite bufonite* [toadstone]—"black base; round calcareous nodules. It hardly differs from the preceding"; (3) *spilite zootique*—"portions of crinoids [*entrôques*] mixed with calcareous nodules. Base calcareous"; (4) *spilite veiné*—"base of aphanite, with veins and small grains of sparry calcite"; (5) *spilite porphyritique*—"determinable crystals of feldspars, etc., in the base, with calcareous and agate nodules". Each variety is illustrated by examples mainly from Europe.†

It must be realized that Brongniart's classification of rocks is essentially mineralogical and based on features observable in the hand specimen; there are no genetic implications in this scheme. In fact, the several rocks grouped as varieties of spilite almost certainly had quite diverse origins. The examples noted include rocks which we would now call clastic sediments; the *spilite veiné* (= Schalstein) from Dillenburg, as we shall see later, may be pyroclastic in character. Despite the apparent detail in Brongniart's descriptions, the difficulty of accurate mineral identification in fine-grained rocks in those "pre-microscope" days must have been great. A considerable number of fine-grained dark-coloured rocks spotted with calcareous nodules would probably have qualified for the name spilite as used originally. There is no suggestion in Brongniart's work, despite Daly's (1933) claim, that the original spilites were considered to be albitized. Such views were not advanced until well after Brongniart's time.

Brongniart introduced this new term mainly to avoid the confusion associated with the names variolite and amygdaloid. He had himself earlier (Brongniart, 1813) grouped as variolites the rocks he now (1827) proposed to call spilites. In his revision the term variolite was transferred to the rocks called amygdaloids in 1813. De Bonnard (1819) uses "spillite" and amygdaloid as synonyms. Spilite and variolite are used in the "revised" sense by Brongniart (1827), but in the following year he recommended that the name variolite be dropped.

Brongniart's hope of reducing terminological ambiguity was not realized. For one thing, the name spilite was not generally accepted outside France, and with this limited use synonyms or partial synonyms proliferated. Names such as amygdaloid (or mandelstein), variolite, trapp, greenstone, and even vakite or wacke continued to be applied to rocks which Brongniart would have called spilites. In the French literature we note an increasing tendency for the name spilite to be restricted to the type known as *variolites du Drac* (Brongniart's *spilites communs*), although as late as 1857, Delesse refers to certain lime-bearing argillaceous rocks affected by contact with "trappean rocks" as spilites. Brongniart had distinguished between spilites and melaphyres according to supposed mineralogical differences in the bases of the two rocks. Melaphyres, he considered, had a base of amphibole in contrast to the aphanite bases in spilites. The difficulties in applying these criteria are apparent. A more

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* The word *aphanite,* due to Haüy, was applied at that time to a specific rock material. According to Haüy's definition, aphanites were compact rocks of homogeneous appearance, dark green or black, with constituents indiscernible to the naked eye. Haüy considered them to be made of amphibole and feldspar intimately mixed.

† Under variolite, Brongniart (1827) lists an example from King Island, Bass Strait—a specimen probably collected during the Baudin expedition (1800-1804).

widely accepted view, that of Buch (1830), regarded melaphyre as a synonym for augite porphyry (porphyrite), a rock which, in fact, was called spilite by Élie de Beaumont (according to Hochstetter, 1864). In the works of the mid-19th century German lithologists (e.g., Naumann, 1850; Cotta, 1862), spilites are usually regarded as melaphyres.

The introduction of thin section petrography in the second half of the century led to considerable refinements in the techniques of mineral identification and fabric investigation. However, as far as the nomenclature of basic rocks was concerned, the advantages of this newly acquired precision may not be very obvious. Both Rosenbusch and Zirkel, the master petrographers of the 19th century, retained the notion derived, one supposes, originally from Werner, that relative age was an important criterion. Thus, according to Rosenbusch (1901), the terms basalt, melaphyre and diabase, relating to effusive plagioclase-augite rocks, had certain time significance, diabase being the oldest geologically while basalt was of most recent (Tertiary and post-Tertiary) origin. Rosenbusch (1901) contrasts granular diabases with compact (fine-grained) diabases or spilites. The latter were separated from the melaphyres, though he was forced to admit that the distinction between diabase and melaphyre "was becoming obliterated". In addition to noting the fine-grained character of his spilites, Rosenbusch also drew attention to their frequent glassy patches and the tendency for feldspar and pyroxene to occur as radiating units. Variolites he regarded as types of spilite in which this radiating character was especially apparent. Earlier (Rosenbusch, 1887) he had recognized spilite as a plagioclase-pyroxene rock, rich in amygdules, and sometimes with variolitic fabric and a few phenocrysts. His definition of 1887 has spilite equivalent to an augite porphyrite. The rocks called spilites under both the 1887 and 1901 definitions are fine-grained with fabrics of the type called microlitic by Michel-Lévy (1889), in contrast to the fabrics of ophitic and granular diabases. Zirkel appears to have avoided the term spilite and simply refers the rocks called spilites by the French to his amygdaloidal diabases (Zirkel, 1894). If we accept the interpretation that Brongniart's "nodules" (*noyaux*) are amygdules there is really no great difference in character between the spilites of Rosenbusch and the common spilites of the original definition. Only the implications of age are foreign. By analogy with the porphyrites or diabases with which the spilites were grouped it would seem that Rosenbusch regarded the feldspars of his spilites as calcic.

English-speaking geologists made little or no use of the term spilite during the 19th century. Rocks which would have been called spilites by the French were usually known as greenstones. In view of this lack of interest it is somewhat surprising to find Johnston (1888, p. 370) in his work on Tasmania listing spilite as a variety of dolerite (basalt, trap). Although no examples are given, this is almost certainly the first appearance of spilite in the literature of Australian geology. In 1893, Bonney and Raisin published a short account of some older Palaeozoic fine-grained basic rocks from the island of Jersey. These rocks had been called spilites by earlier French workers, and this name Bonney and Raisin accepted, though not without qualification. Bonney and Raisin noted that the spilites showed signs of extensive alteration of the original feldspars and ferromagnesian minerals. The rocks were regarded as the products of a vulcanism contemporaneous with the associated sediments which included breccias and banded green flinty argillites. This short study by Bonney and Raisin was most opportune. Geikie had recently drawn the attention of geologists to the problems posed by the older volcanic rocks of Britain. Some years before, the so-called greenstones of Cornwall had been described in a series of papers by J. A. Phillips. Ellipsoidal structures in some of these Cornish greenstones had been known at least since the time of de la Beche, and in 1894 Teall noted the common association of ellipsoidal greenstones and radiolarian rocks at Mullion Island, Cornwall. To describe the ellipsoidal nature of these greenstones believed to be of submarine origin Teall coined the term "pillow structure"—hence the name pillow lava for effusive rocks exhibiting this character. During the period of Teall's directorship (1901–1914), a good deal of work was done by the officers of H.M. Geological Survey, especially in Cornwall, on pillow lavas and associated intrusive rocks. The name spilite was adopted by the Survey in 1907 to designate these pillow lavas (Flett, 1907), and in 1911, Dewey and Flett published their review on British pillow lavas or spilites. This latter work deserves special attention because of its great influence on subsequent studies. Dewey and Flett pointed out that the rocks called spilite in Britain often show signs of decomposition. The feldspars are always rich in soda, and although pyroxenes are seen occasionally, it is more common to find them completely replaced by secondary products such as chlorite, calcite and epidote. Following Bailey and Grabham (1909) the sodic feldspars were regarded as of secondary origin. Fresh olivine is never present. Dewey and Flett observed that many of their spilites contain devitrified glassy material. Porphyritic varieties are rare, and most of the feldspar occurs as microlites or fine laths sometimes arranged in fluidal fashion and occasionally in radiating groups. The few chemical analyses available to Dewey and Flett indicated markedly high soda, carbonate and water and low potash contents compared with those of other basic rocks. In calling these sodic rocks spilites Dewey and Flett claimed that they are of the same type as the rocks called spilites by Brongniart. This is, in fact, true, but it must be realized that the mineralogical criteria, especially that of sodic feldspars, and the chemical features of high soda and low potash, used by Dewey and Flett, effect a considerable restriction. In addition, Dewey and Flett endowed the term with certain genetic features of a distinctly hypothetical nature. The pillow lavas or spilites were believed to form part of a group of rocks, called the spilitic suite, which could be "clearly distinguished from the Atlantic and Pacific suites". This spilitic suite included types ranging from ultrabasic to acid in composition and was regarded as typical "of districts that have undergone a long-continued and gentle subsidence, with few or slight upward movements, and no important folding". Dewey and Flett considered the spilites as submarine lavas, and the sodic feldspar found both in them and in associated intrusive diabases resulted from the albitization of pre-existing calcic feldspars.

The hypothetical views of Dewey and Flett have been rejected by many workers. Eskola complained in 1925 that "to use the term spilite would mean to accept a theory", and accordingly preferred "longer but more descriptive and more neutral mineralogical names such as ophitic albite-clinopyroxene rock". Misgivings about the use of the name had been expressed earlier by Benson (1915*a*).

The important diagnostic features listed by Dewey and Flett, namely, sodic feldspar (albite or sodic oligoclase) and high Na_2O, H_2O and CO_2, with low K_2O are recognizable only by the use of special techniques. A spilite in the sense of Dewey and Flett cannot be recognized without laboratory examination. Pillow structures, commonly noted in spilitic rocks, are by no means characteristic of spilites. There are numerous records, for example, the pillow lavas on Mull, of normal basaltic pillow-bearing rocks. Again, we might point out here that pillow structures, though common in submarine lavas, are not restricted to these cases. Lewis (1914) argued that pillows might also form in subaerial flows and Stark (1938) has found evidence of this at Borabora in the Pacific.

Nevertheless, most recent workers, who have used the term spilite, tend to follow Dewey and Flett in so far as mineralogy and chemical composition are concerned. There are still some, however, who impose genetic restrictions. I have mentioned that Dewey and Flett believed that most of the albite in their spilites was of a secondary character; others have considered the albite of spilites to be primary. This matter will have to be considered in more detail at a later stage, but for the moment suffice it to say that the situation has given rise to some extraordinary contradictions. As an example, von Eckermann (1936) objected to the use of spilite as a name for certain greenstones in Sweden because they offer evidence of albitization of primary calcic plagioclase. On the other hand, Lehmann (1940) apparently declined to use the name spilite for rocks he called weilburgites because, among other things, the albite in them was not produced by albitization of a calcic feldspar. Van Overeem (1948) rejects as spilites those rocks with secondary albite in which the albitizing solutions have been derived from an external source even though the composition of these rocks may be identical with that of "real" spilites.

In 1917, H. C. Sargent published an account of his studies on the Carboniferous lavas of Derbyshire, rocks known locally as toadstones and, in fact, called spilites (*spilites bufonites*) by Brongniart. Sargent claimed that these rocks were allied genetically to the spilites of Dewey and Flett, but, unlike the latter, contained appreciable amounts of both sodium and potassium, often carrying K-feldspar in addition to a sodic plagioclase. Sargent coined the term potash-spilite for these lavas. Shortly after the introduction of the term, Wells (1923) recommended that it be dropped, but in recent times Tomkeieff (1941) has not only used the term, but added what he considers to be another example. Basic rocks containing adularia and associated with sodic spilites in Timor have been called poenites by de Roever (1942). Many of the so-called weilburgites of the Lahn region are also rich in potash (Lehmann, 1949).

The name spilite has been used over a period in excess of fifty years for an important group of basic rocks in the Pre-Cambrian of Bohemia (e.g., Slavik, 1928; Kutina, 1955). These Bohemian spilites commonly have calcic feldspars (andesine or labradorite) and are so named because of their aphanitic fabric—a usage harking back to Rosenbusch's compact diabases. Backlund (1930) has also given the name spilite to fine-grained lavas containing andesine as the typical feldspar.

There appear to be four main criteria used in the recognition of spilites, namely, fabric, mineralogy, chemical composition and geological occurrence. Much of the confusion associated with the name spilite derives from the fact that various workers have emphasized different features. Most would agree that spilites are mainly basic rocks and usually occur as flows or shallow intrusions. Some, for example, Backlund (1932), insist that spilites belong to a particular tectonic environment, namely, that of the early "evolutionary" phase in a geosyncline. To Backlund it was a matter of secondary importance whether spilites contained albite or a calcic feldspar. Richards and Bryan (1924) applied the name spilite to a rock containing andesine because they claimed that the chemical composition of this rock was similar to that of known spilites; furthermore they argued that their spilite occurred with radiolarian cherts. We have already seen that Bohemian petrographers use the term spilite for rocks with a certain type of fabric. Dewey and Flett attempted to combine all four criteria in their definition.

Some would say that the variety of meanings attached to the name spilite is just too great for the term to be of any use (Johannsen, 1937). However, the fact remains that not only is it still used, but the list of examples of rocks called spilites increases annually. For the present discussion I propose to accept all spilites identified as such in the recent literature. It seems to me far better to start from this position than to set out by excluding types which do not satisfy the requirements of a preferred definition.

THE OCCURRENCE OF SPILITES.

Although spilitic rocks have not been recorded among the products of recent igneous action they are represented throughout most of the geological column. Archaean spilites are known from several parts of the world and recently Ramos (1958) has claimed that spilites of Pleistocene age occur in northern Brazil. Amstutz (1958) believes that spilitic rocks have decreased in frequency and volume during the period from the Pre-Cambrian to the Tertiary, though this, I feel, has yet to be demonstrated.

The reader of textbooks on petrology and structural geology may be excused for believing that spilites are exclusively the property of geosynclinal tracts and that, furthermore, these rocks belong to the early period of sinking and sedimentary accumulation within a eugeosyncline. Were we to follow Backlund, such, of course, would be the case. The majority of examples are indeed recorded from geosynclinal environments, but spilites are by no means so confined in occurrence. Epicontinental and even continental types are known and documented. Again, although many spilites are effusive in character, some are definitely intrusive and apparently unrelated to effusive vulcanism.

Swiss geologists recognize an ophiolite association as representative of early magmatic activity in the Alpine orogen. These ophiolites occur typically in the Pennine nappes as concordant bodies among Mesozoic sediments now often metamorphosed to *schistes lustrés* and rich in porphyroblasts of albite. As used originally by Brongniart, the term ophiolite was applied to serpentines, but as a group name it now includes, as well as ultrabasic types, coarse-grained gabbroic rocks, fine-grained diabases, basic breccias, and greenschists probably derived from more than one variety of basic material (Cadisch, 1953). In general, more acid rocks such as rhyolites or keratophyres are missing, though a minor exception is noted by Jaffé (1955). Among the gabbros we have to recognize types with saussuritized basic plagioclase and types containing albite. Diabases seem to be the most abundant of the ophiolitic rocks and are apparently of effusive or very shallow intrusive character. Recently, pillow structures have been recognized in them (Vuagnat, 1948). Many of the diabases as well as the albite gabbros are now regarded as spilites (Jaffé, 1955; Vuagnat, 1954) and in some cases they are essentially unmetamorphosed. However, as dislocation has been intense in parts of the Pennine zone, it is hardly unusual to find metamorphosed units of the ophiolite group. Bearth (1959) has recently described from the western Alps eclogites and glaucophane schists which retain traces of an original pillow lava character. Greenschists with compositions similar to the Alpine spilites are known from the Grisons (Grubenmann, 1909; Roothaan, 1919), but many greenschists are non-spilitic.*

Accompanying the ophiolites we find typically marine sediments including breccias, radiolarian cherts and lime-bearing rocks of Flysch type. Although the term is not used widely by Alpine geologists, many of these Flysch-type rocks may be regarded as greywackes. Many of the breccias are made up largely of igneous material and are really ophiolite breccias (Jaffé, 1955). The radiolarian rocks, in particular, have received a great deal of attention from geologists. Once thought to belong exclusively to an abyssal environment (e.g., Steinmann, 1927), there is now some evidence, not only in the Alps (see Cadisch, 1953, pp. 233–234), but in many other places (Tromp, 1948), that radiolarian rocks may have formed in shallower water. Nevertheless, it must be recognized that the ophiolites of the Pennine zone appear to belong to an axial geosynclinal environment. Vuagnat (1954) envisages a depth of sea water up to about 1,000 metres in this trench. There can be no doubt because of the close association with marine sediments that the recorded ophiolitic spilites represent contemporaneous submarine igneous activity. However, the Eocene-Oligocene Taveyannaz Sandstone in the north helvetic Flysch contains a great deal of spilitic material. According to Cadisch (1953), Vuagnat (1943) has recognized, using supposed textural criteria, spilites of both submarine and subaerial types as fragments in the sandstone. Although the subaerial spilites cannot be related to any known eruptive rocks in the western Alps, Vuagnat considers all the volcanic fragments as connected with ophiolites of the Pennine zone.

The association of radiolarian rocks and ophiolites has been recognized for many years, at least, in fact, since the 1880s when Pantanelli and Lotti independently drew attention to it in Tuscany. Steinmann (1905, 1927) later emphasized that the association was common not only in the Apennines but also in the Swiss Alps. Steinmann's work is now well known and the association dignified by the name "Steinmann's Trinity" referring to the grouping of serpentines, spilites and radiolarian cherts (Hess, 1955). As Steinmann recognized three main groups among the ophiolites (serpentines, gabbros and diabase spilites), the nickname is not especially illuminating. Although we are

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* Among the greenschists of the (? Pre-Permian) Casanna schists in Valais, Vallet (1950) distinguishes ovardites (albite and chlorite) and prasinites (albite and chlorite + Ca minerals). Vallet considers the ovardites only as metamorphosed spilites. Prasinites are also common in the ophiolite group.

not concerned at the moment with the genesis of spilites, it should be remembered that Steinmann believed that all three ophiolite members were derived from the same magmatic source and, further, that there was a succession in time with serpentines earliest and spilites latest. This succession does, in fact, exist in parts of the Apennines. Van der Waals (1946), for example, finds this order in the Upper Jurassic rocks near Spezia. Here radiolarian rocks are associated with the ophiolites, but are claimed to ante-date the spilite members. Steinmann's succession is not, however, universal. In the ophiolites of Chablais (Haute Savoie), for example, the ultrabasic rocks are later than the spilitic members, with the gabbros in this case being quite subordinate (Jaffé, 1955).

The ophiolite type of spilite occurrence is by no means confined to the Alpine regions. We have already mentioned examples in the Apennines of Italy. Netelbeek (1951), Ritsema (1952) and Routhier (1946) have described similar cases in Corsica. Very considerable thicknesses of ophiolitic material were apparently extruded during the Jurassic in the Dinaric geosyncline of N.W. Greece (Brunn, 1954). Brunn records spilites, basalts and even andesites among the fine-grained members of his ophiolite suite. Radiolarian rocks appear at the contacts with the fine-grained ophiolites or tuffs. It is of interest to note that in this case the ophiolitic material apparently issued marginally to the geosyncline, and as well as spreading towards the axis it also extended towards what was probably foreland. From the eastern seaboard of the Mediterranean, Dubertret (1954) has described an enormous mass, up to 3,000 metres in thickness, of ophiolitic material ranging upwards from peridotites and serpentines at the base to gabbros, to uralitized basalts and finally to "sakhalavites", sometimes partly glassy and with pillow structures. These "sakhalavites" are associated with radiolarian rocks, and although the exact nature of the sakhalavites is not clear from the work cited, Rittman (1958) claims that they (he calls them "sakavalites") are spilitic. Dubertret regards them as submarine lavas which acted as a cover for the successive intrusion of the gabbros and ultrabasic types. The field evidence seems to indicate a location in what was a foreland margin and not the typical axial, geosynclinal zone.

Ophiolitic spilite associations are common in those orogenic zones which suffered Tertiary folding—the so-called alpine zones. Van Bemmelen (1949), for example, records many typical occurrences in the Indonesian region. Recently, Reinhard and Wenk (1951) have added considerably to our knowledge of the ophiolites in the pre-Tertiary Danau Formation of North Borneo. Their ophiolite group is essentially unmetamorphosed and occurs, as usual, with radiolarites, argillites and Flysch-like sandstones. The spilites are regarded as submarine lavas, but pillow-structures are rare. Manganese deposits are associated with radiolarian cherts and spilites of early Tertiary age in North Borneo (Stephens, 1956).

The potash spilites or poenites of Permian age in Timor (de Roever, 1942) occur with olivine basalts, soda spilites, trachybasalts, alkali trachytes and alkali rhyolites. According to van Bemmelen (1949), all of the Permian sediments of Timor are of neritic facies and the poenites, etc., belong to a "weakly Atlantic suite" within these sediments. On the other hand, post-Permian eruptive rocks in Timor are ophiolitic and include spilites (sodic) with ultrabasic and other basic types as well as andesites and keratophyres. The ophiolites formed at a time of strong down-warping.

The spilites described by Greenly (1919) from the Gwna and New Harbour Groups of the Mona complex in Anglesey represent early (Pre-Cambrian) activity in the Caledonian geosyncline. The Gwna Group contains detrital sediments of Flysch type (Vuagnat, 1949*a*; Termier and Termier, 1956*b*, p. 270), and according to the latter authors these detrital sediments and the associated jaspers, spilites and tuffs accumulated near the margins of a filling geosyncline. Pillow structures are well preserved in many of the spilites. Greenly records a few keratophyres in the Gwna beds. Subordinate rhyolitic material, mainly as ejectamenta, occurs with the spilites, while later intrusive bodies ranging from serpentinites to alkali granites also belong to the complex. Locally, spilites have been converted to glaucophane rocks. Early igneous activity in the

Caledonian geosyncline is also represented by the more or less metamorphosed Dalradian spilites (and albite diabases) of the Tayvallich Peninsula, Argyllshire (Flett, 1911; Vuagnat, 1949*b*). Again, pillow structures are preserved in the spilites and basic rocks predominate. Flett records occasional keratophyres and soda felsites. Dalradian basic pillow lavas, which may or may not be spilitic, have also been reported from Ireland (McCallien, 1936).

Spilitic rocks make their appearance again within the Ordovician succession of the Caledonian chain in Britain. At Ballantrae, Ayrshire (Balsillie, 1932, 1937; Bloxam, 1960), pillowy spilites are closely associated with agglomerates, tuffs, radiolarian cherts and graptolitic shales. These rocks are invaded by intrusive bodies ranging from serpentinites to granites. By way of contrast, the Ordovician spilites in Wales, also within the Caledonides, belong to a rather different association. Early Arenig vulcanism in this region produced mainly andesites with some basalts and dacites. However, pillowy spilites are found in the Arenig of Ireland (Gardiner and Reynolds, 1912, 1914). Extensive spilitic bodies are associated with Llanvirnian marine sediments (chiefly black graptolitic shales). The Fishguard Volcanic Series, described by Thomas and Thomas (1956), reaches a thickness of about 3,600 feet near Strumble Head, Pembrokeshire. Pillow-bearing spilites as well as columnar spilites, spilitic breccias and agglomerates, "oligoclase basalts of Mugeary type", feldspathic sands, ashes and cherty rocks occur here between rhyolitic horizons. Mugearites are also said to occur as lavas on Skomer and adjacent parts of Pembrokeshire, with albite-oligoclase-bearing basic rocks of doubtful affiliations (and called marloesites and skomerites) as well as trachybasalts, keratophyres and soda rhyolites. These rocks were subaerial in character (Thomas, 1911). Many of the basic lavas in the Ordovician of North Wales are regarded as spilitic and carry pillows. However, it must be emphasized that basaltic rocks with normal calcic feldspars occur with these spilites. Andesitic and rhyolitic (often sodic) lavas, with very considerable thicknesses of acid fragmental material recently recognized as ignimbrites, are commonly found with these spilites. East of Rhobell Fawr, Merionethshire (Wells, 1925), spilitic lavas are locally associated with variolitic basic lavas containing labradorite. Followed northwards, the submarine spilites give way to subaerial hypersthene andesites (Fearnsides, 1905). Spilitic pillow lavas occur with acid lavas and tuffs in the Cader Idris area. Davies (1959) has recently described these rocks briefly and notes that intrusive doleritic bodies associated with the basic lavas vary from "little altered, ophitic augite dolerites, with andesine or even labradorite, to very highly autometasomatic spilitic rocks". The occurrence of albite-bearing basic intrusive rocks with spilitic lavas is, in fact, quite common in the Welsh Ordovician. Some of these dolerites have converted the invaded mudstones into adinoles.

The Welsh Ordovician spilites were preceded by andesites, and were succeeded by andesites during Llandeilo times. The spilites at Cader Idris and at Llanwrtyd (Stamp and Wooldridge, 1923) are high in the stratigraphic sequence. The Welsh spilites appear to have been submarine flows or shallow intrusives, and the association of spilites with subaerial acid flows and ash beds suggests that some of the spilites may have formed in fairly shallow water near shorelines. The differences between these occurrences and those of the ophiolite spilites are obvious. Not only are serpentine bodies apparently absent in the Welsh Ordovician, but there is a vast development of intermediate and acid lavas. On the other hand the Ordovician spilites at Ballantrae may be ophiolitic. Ultrabasic and spilitic rocks occur in the Trondhjem area of Norway (Carstens, 1924) and are succeeded by plutonic intrusions of trondhjemite belonging to the "revolution phase" in the history of the Caledonides. Some of the greenschists at Sulitelma, Norway, are spilitic in composition (Vogt, 1927). In Södra Storfjället, southern Lapland, Beskow (1929) has found keratophyres with basic effusives, at least akin to spilites, in sediments supposedly of Silurian age. Backlund (1932) records spilites, albite diabases, and keratophyres in the "Caledonian" chain of east Greenland, though more recent workers regard these rocks as Devonian in age.

In Fennoscandia, spilites or spilitic greenstones have been recognized in several of the Pre-Cambrian mountain chains. Near Petsamo, in the western part of the Saamide chain of the Kola Peninsula, a region discussed by von Bubnoff (1937), spilitic pillow lavas occur with tuffs, diabases and sandstones and conglomerates of molassic type (Termier and Termier, 1956*b*, p. 238). If this interpretation is correct and molassic sediments occupy a place here comparable with that of the Alpine molasse then we have another variation in the pattern of spilite occurrences. The spilitic greenstones of the Kiruna area of Sweden (Sundius, 1915) occupy a part of the Svecofennide chain according to Termier and Termier. Pillow structures are still evident in these rocks despite the metamorphism. At Kiruna, a wide variety of more acid igneous rocks including keratophyres (sometimes called syenites, e.g., by Geijer, 1916) and quartz porphyries is associated with greenstones, tuffs, breccias, cherts and impure limestones. Gjelsvik (1958) has described spilitic greenstones representing extensive basic vulcanism in the late Pre-Cambrian Karelic geosyncline in northern Norway. Intrusive albite-rich rocks (diabases, soda-granites and albite syenites) also occur here. The spilites from south-eastern Karelia described by Eskola (1925) are well known. Near Petrozavodsk, Karelian A.S.S.R., pyroxene-bearing spilites appear mainly as submarine effusive bodies, often agglomeratic and sometimes with pillows, in an environment of shales and dolomites. Basaltic rocks with calcic feldspars occur with the spilites. To the north, hornblende-bearing assemblages are commoner and with increase in metamorphic grade there is a transition to amphibolites. The amphibole-bearing spilites occur typically as thin bodies invading quartzites; signs of effusive action are rare. Apart from rare granophyric albite-hornblende rocks associated with the spilites, this region seems to have been characterized by basic igneous activity. Further north, around Seg Ozero in Karelia, pillowy spilitic flows, succeeded by quartz keratophyres, may have been poured out during marine regressions (Kharitanov, 1937). The environment here seems to have been epicontinental.

Spilitic rocks occur in various associations in the Hercynian or Variscan chain of western Europe. The well-known examples in the Devonian and Carboniferous of Devon and Cornwall (Dewey and Flett, 1911; Flett, 1907) are essentially pillow lavas with related fragmental rocks. Acid lavas, variously called sodic rhyolites or quartz keratophyres, are quite subordinate. A considerable variety of minor intrusive rocks ranging in character from basic to ultrabasic (picrites) are found with the spilites. Some of the intrusive dolerites contain albite as the typical feldspar, but quartz-bearing dolerites, also regarded by Dewey and Flett as belonging to the same epoch as the spilites, are notable because they contain labradorite. Adinoles are common at the contacts with albite dolerites (Agrell, 1939). In this region, cherts and detrital sediments, regarded as of Flysch-type by Hendricks (1939), are associated with the spilites which seem to have accumulated well within the geosynclinal zone. Pillowy spilites with keratophyres and tuffs have been reported from Belgium (Corin, 1935). In the Rhenish Schiefergebirge, also within the Hercynian chain, basic lavas (often with pillow structures) and intrusives are associated with abundant keratophyric rocks. Examples are to be found among the Devonian rocks of Sauerland and the Lahn region of Nassau (e.g., Götz, 1937; Lehmann, 1952). Perhaps a rather similar association exists to the east in the Fichtelgebirge from whence came the original keratophyres (Gümbel, 1874). The magmatic rocks of the Lahn area have been the objects of considerable petrological study, partly, I suppose, because of the associated iron and manganese deposits. In older works (e.g., Brauns, 1909) the basic rocks are called essexites, while more recent investigators have called them spilites, keratophyric spilites or weilburgites. This latter term, due to Lehmann, was introduced in the belief that the rocks are primary crystallization products (Lehmann, 1949, 1952*a*). Such genetic interpretations have been combated by Hentschel (1952*a*, *b*, 1953) and others. The weilburgites (or spilites) are associated mainly with the manifestations of the second of three great cycles of effusive or subeffusive igneous activity (Pilger, 1952). Keratophyric rocks predominate in the first (Lower Devonian) cycle. After this initial acid activity, keratophyres occur with weilburgites, basaltic lavas and *Schalsteine*, mainly in the upper Middle Devonian. The so-called *Deckdiabas* in the Lower Carboniferous concludes the group. Pyroclastic rocks are abundant throughout the sequence, though Lehmann (1952*a*) claims that weilburgite tuffs are missing. The *Schalsteine* present special problems about which controversy has continued for many years (see, e.g., Lehmann, 1952*c*; Hentschel, 1952*b*). The term *Schalstein** is an old one dating from 1789 (Lehmann, 1933), and like many old terms seems to have had various meanings. These rocks have been regarded as brecciated magmatic rocks, as tuffs, as redistributed tuffs, or as altered basic rocks, though many of them are now highly siliceous. According to Pilger (1952) the Devonian eruptive rocks are connected with a rapidly sinking part of the Rhenish trough. In the graben-like trough of the Lahn area subsidence was apparently very rapid. Thick accumulations of sediments in the Middle Devonian here carry essentially pelagic organisms. The final group ot eruptive rocks, the *Deckdiabas*, includes pillowy diabases and is associated with greywackes and radiolarian cherts (lydites). Pilger considers the *Deckdiabas* as ophiolitic in character.

Chenevoy (1958) has recently recognized spilites and keratophyres with basic and ultrabasic intrusives and Flysch-type sediments in the Massif Central of France. The calcic feldspar-bearing spilites in the Algonkian of Bohemia (Slavik, 1928, 1945) deserve special mention. In the region of Kladno (Cepek, Hynie, Kodym and Matejka, 1936), for example, granular diabases, variolites and glassy breccias are found with these spilites in a geosynclinal succession of greywackes and cherts (phtanites). The spilite-greywacke-chert association is preceded by deep-water facies and succeeded by coarse detrital sediments. The spilites are thought to have solidified under only moderate depths of sea water. Pillow structures are common; recently submarine pillow lavas with cherts have also been found in the Ordovician of western Bohemia (Hejtman, 1954). Keratophyres appear in the Cambrian of this region, but do not occur with the spilites of the Algonkian.

In Russia, there are numerous occurrences of spilitic rocks in both the Uralian (Hercynian) and Caucasian (Alpine) chains. Spilites with diabases, gabbros, and albitophyres (keratophyres?) appear first in the Lower Ordovician of the Urals. This activity continued at intervals through the Silurian and Devonian into Carboniferous times. Signs of andesitic-dacitic vulcanism during this period are also found in parts of the Urals. Ultrabasic bodies were emplaced during the Devonian and Carboniferous, but the spilites do not seem to be typically ophiolitic. Mashkovzev (1933) has described an area in the northern Urals where basic pillow lavas and spilites are the most abundant igneous rocks in a succession with greywackes and other geosynclinal sediments. In this locality pre-Tournaisian basic effusives are commonly albitic, whereas the Carboniferous rocks often contain labradorite. Important sulphide deposits have been found with spilites and keratophyres in both the northern and southern Urals (Zavaritsky, 1943*a*, *b*, 1945, 1946; Kurshakova, 1958). Ronov (1946) has attempted to correlate quantitatively the various effusive rocks with tectonic events in the Uralian geosyncline. The Devonian spilites reported by Backlund (1930) from Nowaya Zemlya, on one of the northern branches of the Uralian chain, contain andesine and occur with picrites, quartz keratophyres and albite diabases. In general the intrusive types are richer in sodic feldspar than the effusives, though there does seem to be a regional variation in the character of the diabases. Kupletsky (1932) claims that albite diabases are confined to the northern island, normal diabases occurring in the southern island. Cissarz (1928) considered the sediments associated with the effusive spilites of Nowaya Zemlya to be of epicontinental marine type, while Backlund (1930) thought that the spilites might even have been subaerial.

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* Dewey and Flett (1911) used the word to denote sheared spilites. In Japan, the name is applied to basic tuffs of pre-Tertiary age (Takabatake, 1956).

What is now the Great Caucasus in the southern U.S.S.R. was the site of extensive vulcanism during Jurassic times. The area was then a trough adjacent to the Russian platform and the Lower and Middle Lias volcanic rocks are submarine in character. Later in the Jurassic, this geosynclinal trough was separated by a rising geanticline from the main Caucasian geosyncline. Loewinson-Lessing and Diakonova-Savelieva (1933) have recognized three cycles among the Jurassic igneous rocks at Karadagh in the Crimea, situated on the line of the Great Caucasus. The first cycle is of minor importance, but the second is marked by numerous flows, tuffs and agglomerates ranging in order of appearance from basic to acid. This cycle includes spilites, keratospilites (a new name), keratophyres, oxykeratophyres and palaeoliparites. Both spilites and keratospilites have pillow structures. The final cycle is represented mainly by intrusive bodies ranging from basalts to dacites and liparites.

Pichamuthu (1938, 1946*b*) claims that spilitic rocks and keratophyres occur in the Archaean Dharwar System of peninsular India. Pillow structures are recorded in the Jogimardi traps which Pichamuthu regards as spilitic. However, if these traps were formed immediately *after* an orogenic revolution, as Pichamuthu (1946*a*) suggests, this occurrence of spilite is unusual. Spilite, keratophyre and schalstein are represented among the products of Palaeozoic and Mesozoic volcanic activity in Japan (Suzuki and Minato, 1954; Takabatake, 1956). They occur typically with greywackes, tuffs, and radiolarian cherts in geosynclinal associations. Takabatake considers that both spilites and basalts are represented as pillow lavas, spilites being especially common among the Mesozoic lavas. Manganese ores are found as layers in the cherts and tuffs and usually near contacts with the basic lavas.

Taliaferro (1943) has described Californian occurrences of manganiferous cherts associated with spilitic lavas in both the Amador and Franciscan-Knoxville Groups. The Amador Group (Jurassic; pre-Nevadan) consists largely of volcanics and cherty sediments. Spilitic pillow basalts are briefly noted by Taliaferro, but andesitic-dacitic vulcanism is more typical of the Amador. The post-Nevadan, late Jurassic, Franciscan occurring typically in the Coast Ranges is, by contrast, rich in coarse feldspathic greywackes. The vulcanism in the Franciscan is more basic in character and spilites are common, although in most cases they are now severely deformed. As ultrabasic bodies appear to be closely related in time to the basic vulcanism, this association is reminiscent of the Alpine ophiolites. Further north, in the Olympic Peninsula of Washington, Park (1946) records 30,000 feet of Eocene greywackes, argillites, volcanics, and limestones with manganese ores and jaspers. Spilitic pillow lavas are abundant and are thought to have formed in deep water. In the upper parts of the section, normal basalts occur. The preponderance of basic material here is in contrast to the extensive development of keratophyres with spilite in the Permian rocks of eastern Oregon, discussed by Gilluly (1935). Pillow structures are absent, but there is clear evidence that the association is marine and geosynclinal. This occurrence is of especial interest because of the development of trondhjemitic and albite granite bodies subsequent to the formation of the keratophyres. From the eastern side of the continent, Flaherty (1934) has recorded a thick succession of spilite, keratophyre, tuff, phyllite, quartzite and conglomerate invaded by plutonic bodies of quartz diorite and albite granite.

The Pre-Cambrian Keewatin lavas in Canada include ellipsoidal greenstones, andesites, dacites and rhyolites (Wilson, 1913, 1960; Satterly, 1941). They occur in sequences of arkoses, greywackes, argillites and conglomerates. Although the greenstones are not usually called spilites by Canadian geologists, they show many of the features of spilites; they are referred to as such by Termier and Termier (1956*b*).

Spilites were first recognized (on the Three Kings Islands) in New Zealand by Bartrum in 1936. This occurrence in which spilites are associated with keratophyre and sediments "of the greywacke facies" has recently been studied in detail by Battey (1955, 1956). Since 1936, spilites, always associated with geosynclinal sediments, have been found in both of the main islands. Late Palaeozoic (? Permian) spilites are recognized in various parts of Southland. In each case spilites and albite diabases occur with greywackes and argillites. Keratophyres are commonly present, though at Mossburn (Reed, 1950) they are subordinate. Ultrabasic rocks invade the Mossburn Group in the latter area, but the age of these ultrabasic rocks is not really known, though Reed inclines to a belief in an ophiolitic association. Radiolarian cherts have also been found at Mossburn. In the Eglinton Valley (Grindley, 1958), ultrabasic rocks are apparently just older than the spilites. Wood (1956) has found albite granite invading spilites and keratophyres at Gore. Sodic granite also appears in the Eglinton Valley, but is older than the spilite; keratophyres in this area are also distinctly older than the spilites. Reed (1957) has found spilites unaccompanied by either keratophyres or ultrabasic rocks, in the Lower Mesozoic succession of the Wellington district. In this case the spilites occur with feldspathic greywackes, argillites, conglomerates, autoclastic breccias, jaspers and cherts belonging to the so-called Alpine Facies, a facies found along the main mountain chain in the South Island and probably representing the deepest part of the New Zealand geosyncline.

In Australia, records of spilites are confined to three States, Queensland, New South Wales and Tasmania. Examples are known only from Palaeozoic rocks, and in each case the spilites are related to geosynclinal activity.

Both Scott (1954) and Banks (1956) have reviewed the igneous action indicated by rocks in the Cambrian Dundas Group in Tasmania. Picrite basalt, olivine spilite, porphyritic pyroxene basalt, spilite, hornblende andesite or keratophyre, biotite keratophyre, quartz keratophyre and rhyolite, according to Banks, occur in this Group. Although the origin of the acid representatives has been much discussed, Banks considers most of them to represent originally acid lavas. Both Banks and Scott regard the series from picrite basalts to acid lavas as representative of a spilitic suite. The associated sedimentary pile is made up largely of greywackes, conglomerates, argillites, cherts and pyroclastic material. Ultrabasic rocks invade the Dundas Group, but their relation to the spilites is not clear. On King Island, Scott (1951*a*) has identified Cambrian spilites, picrite basalts, breccias and tuffs comprising a volcanic suite associated with tillite and varves. Massive, pahoehoe, aa, and pillow lavas are represented, and Scott suggests that the pillows are developed where subaerial pahoehoe lava has flowed into lakes of glacial meltwater. On lithological grounds these lavas are correlated with those of the Dundas Group.

Stevens (1952) has found pillowy spilites with andesites, basalts, tuffs and breccias underlying massive and shaly limestones of Middle Ordovician age near Woodstock, N.S.W. The environment was probably geanticlinal. Ordovician albite-bearing pillow lavas also occur to the east, near the Abercrombie River, but in this case they appear in a thick sequence of greywacke-type sediments (pers. comm. from Mr. B. Hobbs). Spilites are known from both the Woolomin (Silurian-Devonian?) and Tamworth (Devonian) Groups in northern New South Wales. Benson (1913*b*) and Spry (1954) refer briefly to spilites in the Woolomin Group. In the area studied by Benson they are usually deformed, and in general very little is known of them. It is evident, however, from their association with greywackes, breccias and jaspers that the Woolomin spilites were geosynclinal and, presumably, submarine. The situation in the Tamworth Group is clear to the extent that the spilitic rocks in the group are essentially unmetamorphosed. These latter spilites are known mainly through the work of Benson (1913*b*, 1915*a*, 1915*b*) at Nundle and Tamworth. In the Nundle area, a geosynclinal succession of greywackes, breccias, limestones and argillites or cherts carries a considerable amount of basic igneous material. Radiolarian remains have been found in the cherts both here and at Tamworth. David (1896) considered a shallow water origin likely for the cherts at Tamworth. Sill-like bodies of albite dolerite, some of them hundreds of feet thick, occur particularly in the lower part of the succession at Nundle. This succession is of the order of 6,000 feet thick. As Benson (1915*a*) remarked, the albite dolerites are distinguished from spilites only on the basis of differences in grain size and a complete gradation exists between the two. Locally, a spilite unit invades a dolerite; in another place the opposite relation holds. Both dolerites and spilites clearly belong to the same period of igneous action. Despite the thickness of the dolerite sills they must have been intruded under very little cover. Pillow structures are common in the spilites and seem to be more abundant near the tops of individual "flows". I use the word "flows" in parenthesis because many of these spilite units were, as Benson realized, partly intrusive in unconsolidated, wet sediments. The term "ploughing" used by Geijer (1916) with reference to lava action at Kiruna seems most appropriate in this connection. Benson (1915*b*) mentions subordinate keratophyres as occurring with the spilites at Nundle, but points out that the more acid rocks are commoner to the north. I must admit that, so far, I have not found any keratophyres in the spilite succession at Nundle; light coloured pegmatitic veins and patches are, however, present in the albite dolerites. Great pods of serpentinite appear beneath the dolerites and spilites, but it is now generally recognized that this ultrabasic material was introduced during Carboniferous or Permian times. An association of spilites with greywackes, breccias and cherts was recognized at Bundook, some 60 miles south-east of Nundle, by Benson (1916). Voisey (1939) correlates this occurrence with the Tamworth Group at Tamworth and Nundle.

The Devonian spilite from the Silverwood–Lucky Valley area in Queensland (Richards and Bryan, 1924) represents the only example of this rock, so far as I know, in Queensland. The associated sediments are tuffs (? greywackes) and radiolarian cherts, and the spilite, which contains an intermediate plagioclase, occurs with other effusive types described as andesites. In fact, Richards and Bryan suggest andesite as an alternative name for the rock in question.

Some years ago, Vuagnat (1949*a*) pointed out that there exist in the Alpine region at least two groups of rocks possessing spilitic characters. One of these, the ophiolitic spilites, we have noted already. The other group mentioned by Vuagnat includes the spilites of Glarus and those of Pelvoux and the Aar massif. In these latter cases the spilites are associated typically with detrital sediments of epicontinental or even continental type. Amstutz (1954) has recently described such a group of spilites from the Verrucano (Permian) of the Helvetic Zone in the Alps. These rocks were first called spilites about the middle of the last century; later they were known as melaphyres, as weiselbergites, as navites, and even as olivine tholeiites. As some of these names were bestowed in the belief that the rocks contained calcic feldspar, Amstutz prefers the name spilite; certainly they are akin both chemically and mineralogically to spilites from other environments. In the Verrucano, spilites are associated with red conglomerates, sandstones and red clay-slates, indicating perhaps an arid environment. Pillow structures have not been found and some of the spilites may have been subaerial. Keratophyres and quartz porphyries (? = rhyolite) also occur here and, in general, the more siliceous rocks are more abundant in the younger horizons. These effusive rocks appear to represent the last manifestations of Hercynian igneous activity (Cadisch, 1953). Vuagnat (1947), in a short note, has emphasized the spilitic character of the so-called melaphyres of Pelvoux (Termier, 1898) which include the original *variolites du Drac.* These spilites, like those of similar age (Upper Triassic–Lower Lias) from the Belledonne massif (den Tex, 1950), are apparently epicontinental.

The suite of spilitic greenstones from the Pre-Cambrian Dalformation of S.W. Sweden, studied by van Overeem (1948), offers another example of epicontinental spilites. These rocks are effusive or "subeffusive", and although pillow structures have not been found the lavas seem to be mainly submarine. One flow has a scoriaceous top and shows ropy lava features; it may have been subaerial. Some of the spilites show signs of autobrecciation and the associated sandstones are tuffaceous; other sediments in the succession include arkoses, slates and marls. Keratophyres or other more acid types of effusives are quite lacking in this occurrence. Epicontinental spilites in Karelia have already been noted.

An interesting case of spilites in an epicontinental environment is provided by Norin (1937). In the eastern T'ien Shan (western China) late Pre-Cambrian arkosic quartzites, slates, tuffs and lavas lap over a highly metamorphosed Archaean basement. Acid lavas (keratophyres and quartz porphyries) and tuffs inaugurated an eruptive cycle. Spilitic lavas, regarded as submarine but lacking in pillow structures, accumulated during a later phase which was succeeded by a glaciation. Higher in the sequence, in Lower Palaeozoic beds, a spilite unit occurs with calcareous sediments and with cherts (phtanites), some of which may be radiolarian and others contain material like anthracite. Norin comments on the association of cherts and spilites as a common one; but this particular occurrence is somewhat unusual.

The Lower Permian (Rotliegende) of Lower Silesia includes a succession of volcanic and "subvolcanic" rocks interlayered with shales and sandstones. Rocks called melaphyres, but now interpreted as spilites by Dziedzicowa (1958), with quartz dolerites, quartz porphyries and pyroclastic material represent contemporaneous igneous activity—activity which Kozlowski (1958) regards as the final eruptive manifestations in the Variscan cycle. Dziedzicowa claims that the spilites, which are distinctly more potassic than the majority of rocks called spilites, are not submarine; they may have been subaerial or extruded into local basins. Pillow structures are apparently absent.

The toadstones of Derbyshire, regarded as spilites by Brongniart and called potash spilites by Sargent (1917), represent contemporaneous igneous activity during Visean times. These rocks occur as flows and intrusive bodies with pyroclastic types ranging from agglomerates to fine tuffs within the Carboniferous Limestone. The association is distinctly lacking in normal detrital sediments, but in view of its close connection in time and place with the deposition of limestones the vulcanism was almost certainly submarine and in a shallow water environment. Some of the limestones near the lavas appear to be silicified. Within the igneous units there is considerable variation in the nature of the feldspar. Sargent records both labradorite/andesine and albite/oligoclase; orthoclase is inferred from the chemical composition of the rocks. He considered the rocks had affinities both to the spilites of Dewey and Flett and to mugearites. Lavas in the Carboniferous limestone of the Bristol area were regarded as similar to the toadstones. Pillow structures are absent from Sargent's rocks, though pillow lavas are recorded elsewhere in the Pennine region (Fearnsides and Templeman, 1932). Sargent's diagnosis of these rocks as potash spilites has not met with general recognition and they are sometimes regarded as altered olivine basalts. More recently, Tomkeieff (1941) has described a potash spilite from an intrusive body in the Lower Carboniferous Kelso traps of Roxburghshire. The traps were mainly subaerial flows and belong to the late Palaeozoic alkaline (sodic) province of the south of Scotland. In this occurrence fresh olivine basalt of the Dunsapie type grades into metabasalt with progressive replacement of calcic feldspars by albite and the ferromagnesian minerals by chlorite. The rock described as potash spilite occurs as a small mass within the metabasalt with a rapid but continuous transition between the two types. Veins rich in carbonates and/or quartz are numerous and penetrate the complex.

Spilitic andesites, amygdaloidal spilites and spilitic olivine diabases have invaded Cambrian shales and sandstones, locally overlain by Lower Silurian beds, near Malvern in Worcestershire (Blyth, 1935). Albitization of the shales has occurred on a restricted scale. There are no local signs of effusive action, but as the rocks are post-Cambrian and pre-Lower Silurian, Blyth links them with the Ordovician spilites in Wales. Tomkeieff and Marshall (1940) have recognized spilites (sometimes variolitic) with olivine dolerites, olivine basalts and trachybasalts as Tertiary dyke rocks invading lower Palaeozoic grits and slates in Co. Down, Northern Ireland. These dykes are presumably related to the Tertiary plateau basaltic extrusions in Northern Ireland, though I am not aware of any record of spilites in the flows; mugearite, however, is recorded (Walker, 1960).

An intrusive spilitic body in New Mexico apparently unrelated to surface vulcanism has recently been described by Duschatko and Poldervaart (1955). This intrusion, one of a number in the area, is a partly discordant sheet 100 to 150 feet thick and invades Permian siltstones and gypsum, the siltstones being locally converted to adinoles. Rock types ranging from spilitic basalts and spilitic dolerites to albitites occur in the intrusion; intrusion breccias appear locally. Duschatko and Poldervaart consider that the depth of cover under which this body consolidated was probably of the order of 1,500 feet.

TEXTURE AND MINERALOGY OF SPILITES.

We saw earlier that Rosenbusch (1901) distinguished between granular diabases and fine-grained diabases or spilites. This notion of spilites as fine-grained rocks harks back to the original definition. Dewey and Flett likewise separated their spilites from the associated coarser-grained albite diabases. As the albite diabases (or dolerites) are usually similar to the fine spilites in mineralogy and chemical composition some authors have regarded both groups as spilites. This is the view taken by most Swiss students of the ophiolite associations. Benson (1915*b*) states that at Nundle, "the distinction between the dolerites and spilites is one of grain size only, and is a most indefinite one". Intersertal and ophitic fabrics are recorded by Benson in the Nundle dolerites, while the associated fine-grained spilites are commonly somewhat glomeroporphyritic with groups of feldspar and pyroxene units, the pyroxene often attached to the ends of feldspar laths in a sub-ophitic fashion. Terms such as ophitic, subophitic and intergranular should not be used, however, for the fabrics of many spilitic rocks without some explanation. As the term ophitic, for example, has definite mineral connotations, namely, a certain relation between feldspar and pyroxene, it cannot be used without qualification for those spilites which carry no fresh pyroxene but have only pseudomorphs of, say, chlorite after ophitic pyroxene. Vuagnat (1946) has given attention to this matter and decided to use the term intersertal for his Alpine spilites. In applying this name Vuagnat wanted to have a textural term which could be used in a general sense independent of the nature and size of the units involved. His use of intersertal accords with the original definition (Zirkel, 1870), which is general enough to include ophitic, diabasic (doleritic) and even hyalopilitic textures. More recently, van Overeem (1948) has recognized varieties of intersertal textures in the spilites of the Dalformation in S.W. Sweden. The thicker spilite units studied by van Overeem contain "pegmatitic facies" which also display intersertal textures, the spaces between the feldspar laths being filled with hornblende or aggregates of epidote, chlorite and ore minerals.

Variolitic textures are common in many spilites and, in addition to radiating feldspar groups, arborescent or plumose growths of femic minerals have been noted (e.g., Taliaferro, 1943; Vuagnat, 1949*a*; Reinhard and Wenk, 1951; Scott, 1951; Battey, 1956). Scott (1951) illustrates examples of intergrowths of augite and albite in spilites from King Island, Tasmania, while van Overeem (1948) has found irregular intergrowths of albite and hornblende. Fluidal arrangements of feldspar microlites are sometimes sufficiently well developed to merit the term trachytic (Lehmann, 1933; Reinhard and Wenk, 1951). The larger feldspar microlites in the spilites at Nundle are commonly bent, and as there are locally no signs of post-consolidational deformation it may be inferred that the bending is a primary magmatic character. Similar bent feldspars have been observed in some of the Swiss spilites (Amstutz, 1954) and in Sweden (van Overeem, 1948).

Amygdules and veins appear in almost all recorded spilites, but unfilled cavities, on the other hand, seem to be rare. In addition to the concentration of certain phases in amygdules and veins one often finds minerals such as epidote or chlorites in irregular or even pseudomorphous patches scattered through the groundmass. Although the variety of textures observed in spilites may not be great, there is often a good deal of textural inhomogeneity even on the scale of a thin section. Local variations in fabric are especially common in the pillowy spilites. The term *spilitische Struktur* once applied to rocks characterized by the absence or rarity of so-called intratelluric segregations (Loewinson-Lessing, 1901) fortunately has disappeared from use.

In general, we may conclude that the majority of rocks called spilites display textural features analogous to those observed in basalts, dolerites, and perhaps andesites. There are, however, important mineralogical differences between the two groups, and these differences are reflected in such features as colour and specific gravity.

Following Dewey and Flett, most modern petrologists recognize alkaline feldspars as characteristic of the spilitic rocks. Commonly the alkaline feldspar involved is albite (or, less frequently, sodic oligoclase). Considerable variation exists as to the state of this feldspar. Sometimes clear and transparent with few, if any, included mineral grains, the feldspars of spilites are at least equally often patchy, clouded, and in some cases quite choked with inclusions. Where clear and clouded feldspars appear in the same rock it may occasionally be demonstrable that the clear units are outgrowths or overgrowths (e.g., Gilluly, 1935; Nicholls, 1959) or occur in veins or nodules (e.g., van Overeem, 1948). In the fine-grained spilites at Nundle the feldspar is almost always clear with very few inclusions. The nature of the included material in spilitic feldspar varies, and if one is to judge from the literature the significance attached to these inclusions is also variable. Dewey and Flett showed that in their British spilites many of the feldspar individuals are filled with minute grains of chlorite and epidote and suggested that the lime of the epidote was supplied through the replacement of a more calcic feldspar by the present albite host. Inclusions of other lime-bearing minerals have also been observed in the feldspars of spilites; thus, for example, Nicholls (1959) records calcite, prehnite and sphene, while Scott (1951) notes the occurrence of hydrogrossular. The feldspars of the spilitic Kiruna greenstones sometimes carry inclusions of hornblende and scapolite (Sundius, 1915). On the other hand, many spilites from the Alps have feldspars containing chlorites and sometimes micas, but few, if any, inclusions of calcic minerals, certainly few inclusions of epidote-clinozoisite (e.g., Amstutz, 1954). Van Overeem (1948) finds a similar absence of calcic inclusions in the albites of his Swedish rocks; in some cases, chlorite and sericite inclusions are confined to single twin lamellae. Chlorite flecks in the feldspars of some New Zealand spilites are regarded by Battey (1956) as primary inclusions or at least the alteration products of primary inclusions. This accords essentially with the view of Amstutz. The term "*gefüllte Feldspate*" is used by some Swiss petrologists with reference to the feldspars of spilites; it has the great advantage of no genetic connotations.

Data relating to the optical and chemical characteristics of spilitic feldspars are unfortunately scarce. Apart from the analysis (corresponding to $Or_5 Ab_{90} An_5$) given by Sundius (1915) for a feldspar from a Kiruna greenstone I know of no analysed spilite feldspars. Several authors (e.g., Gilluly, 1935) have offered suggestions based on bulk (rock) analyses regarding the potash contents of these feldspars, but specific information is lacking. Especially desirable are data on phases such as the so-called "Na-potassiumfelspar" of van Overeem (1948). At the present time, determinations of the compositions of spilitic feldspars are made exclusively using optical techniques. Most of these feldspars apparently fall in the range An_{0-8} with only a very minor proportion grading into the sodic oligoclase range. Regular compositional zoning is not common, though there are numerous records of albite zones around patchy, inclusion-rich cores. Since about 1930 a great deal of attention has been devoted to the study, structural, optical and chemical, of the plagioclase feldspars. One of the important results of this work has been the demonstration that the plagioclases exist in different optical and structural modifications dependent mainly on their thermal history. Briefly, and with much over-simplification, the situation is that a plagioclase chilled rapidly from a high temperature tends to show a set of optical and structural characters contrasted to those found in a feldspar of the same composition which has been allowed to cool from a melt over a considerable period of time (as, for example, in a plutonic environment). The former modification, common in many rapidly chilled lavas, is known as a high temperature feldspar, while plutonic and metamorphic plagioclases are usually of low temperature type; transitional varieties are also known.

Van der Kaaden (1951) records low temperature optics in the albites of spilitic material in the Taveyannaz sandstone of the Grisons. Low temperature albite is also characteristic of spilites from North Auckland, New Zealand (Battey, 1956). Nicholls (1959) has found low-albite in spilites from Wales. A check of thin sections of spilitic rocks from eastern Cornwall, from the Lahn area of Germany, and from Russian Karelia (Lake Onega area), in the collections of the University of Sydney, shows a consistent development of low-temperature albite. Over the past few years I have collected several hundred spilitic rocks in the Nundle area of N.S.W. and all of the albites have low-temperature optics (see Figs 1 and 2). It is important to recognize that many of these albites are from rocks which were once partly glassy. However, a couple of once partly glassy rocks, occurring with the spilites at Nundle and texturally indistinguishable from the latter, carry small laths of clear calcic andesine (avge. An$_{48}$) of high-temperature or transitional type. Reference to Figure 2 will indicate that the albites studied have optic axial angles greater than those expected of low-temperature plagioclases of corresponding composition. Van der Kaaden (1951, p. 29, fig. 10) has found a similar character in his spilitic albites. There may, however, be a complete gradation to "normal" low-temperature values in spilitic albites as both van Overeem (1948) and den Tex (1950) give examples of such albites with lower values of 2V. The albite with 2V of 76° (−) listed by Jaffé (1955) is quite exceptional.

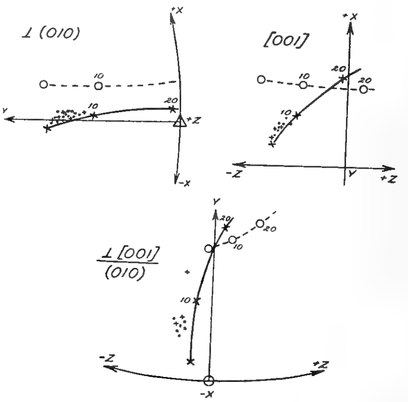

Figure 1.—Optical variation curves of Albite, Carlsbad, and Albite-Carlsbad twins in sodic plagioclases (data from van der Kaaden, 1951). The low-temperature curves are drawn as solid lines, the high-temperatures curves are dashed. Spilitic feldspars from Nundle are represented by spots, feldspars from associated greywackes are marked by crosses.

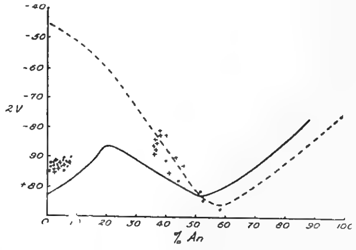

Figure 2.—Chart showing variations in 2V with composition for high- and low-plagioclases (curve from J. R. Smith, *Ann. Rept. Carnegie Inst.*, 1955-56). The high-plagioclase curve is dashed. Spilitic feldspars from Nundle are marked by spots, feldspars from associated greywackes by crosses. Although many andesines and labradorites are plotted, these are quite subordinate to albite in the Nundle rocks.

Twinning is common in the albite microlites and phenocrysts of most spilites. At Nundle, twins with (010) as composition plane are particularly common; Albite twins being abundant with Carlsbad and Albite-Carlsbad twins much less frequent but developed in roughly equal proportions. Pericline twins are scarce, and although Acline (Manebach-Ala) and Ala A (Manebach Acline) twins have been measured, these (001) twins are quite rare. Some of the feldspar microlites are untwinned, while many of the small laths exhibit only 2 or 3 lamellae. Phenocrysts (10–15 mm. in length) often carry 3 or more lamellae of varying width; not uncommonly these feldspars show combinations of Albite, Carlsbad and Albite-Carlsbad twins. Both van der Kaaden (1951) and Amstutz (1954) record Albite twins as commonest in their spilites, while van Overeem (1948) notes that Carlsbad twins are especially abundant in some of his albites.* Dziedzicowa (1958) records only Albite twins in the alkaline feldspars of her spilites, though other laws are represented in the calcic feldspars of a group of associated dolerites. Ala-B twins have been recognized by Rittmann (1940) in a spilite from Greenland. In addition to the twin laws mentioned above, van Overeem has recognized Mànebach twins, while van der Kaaden lists Baveno twins, Banate 'twins' and Penetration twins, and Amstutz has discovered Roc Tourné twins in Swiss spilites. Although these authors supply some information on the width and frequency of twin lamellae in spilite albites, I know of no systematic statistical studies of these features.

We have noted already Gilluly's suggestion based on bulk composition that some spilitic albite may contain small but varying amounts of potassium. There are cases (potash spilites, poenites, weilburgites), however, in which recognizable potassic feldspars are developed. Small amounts of potassic feldspar have even been observed in "normal" spilites. Thus Eskola (1925) records antiperthitic growths from Karelia. Sargent (1917), the first worker to apply the name spilite to rocks rich in potassium, offered little optical information on his feldspars. A toadstone from Miller's Dale, Derbyshire, in the University of Sydney collection, contains calcic andesine and labradorite with high to transitional optics; a little untwinned orthoclase occurs interstitially. The study on a potash spilite from near Kelso, Scotland (Tomkeieff, 1941), includes optical information on seven phenocrysts. Plagioclases range in composition from about An_{25} to An_{60} and, apart from two ambiguous cases, these feldspars all correspond to low-temperature types. Associated with the plagioclases, Tomkeieff records sanidine, orthoclase and anorthoclase.

Lehmann (1949) claims that his weilburgites (formerly spilites or keratophyric spilites) in the Lahn Trough, Hesse, Germany, carry orthoclase, albite, anorthoclase and "Kalinatronfeldspat". The distribution of these minerals is variable, in some weilburgites albite predominates, others have chiefly K-feldspar, while yet others contain both sodic and potassic feldspars. According to Turner and Verhoogen (1951, p. 203), the poenites of Timor contain adularia, but, unfortunately, I have not seen the original description of these rocks (de Roever, 1942). One would certainly expect to find adularia in potash spilites by analogy with the low-temperature albites of sodic spilites.

In the fine-grained spilites at Nundle, recognizable quartz is rare except in veins where it may occur with clear, anhedral and sometimes untwinned grains of albite. The originally glassy patches may have carried excess SiO_2, though free quartz has not been observed among the products of devitrification. The coarse-grained rocks (albite dolerites of Benson (1915*a*)) on the other hand often contain up to 5% of granular quartz interstitial to albite laths. Quartz is, in fact, present in minor amounts in a great many spilitic rocks described in the literature. Flett (1911), Vuagnat (1949*b*) and Scott (1951*a*), for example, record disseminated quartz as a minor constituent of spilites. It occurs more often as interstitial patches (e.g., den Tex, 1950; Nicholls, 1959) in the groundmass, or, in rocks with doleritic fabrics (cf. the albite dolerites at Nundle), as units interstitial to the feldspar laths (Eskola, 1925). Most frequently, however,

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* The optical distinction between Albite and Carlsbad twins in albitic feldspars may be almost impossible unless, say, a second cleavage (001) is apparent.

quartz is recorded as vein or cavity fillings (e.g., Dewey and Flett, 1911; Eskola, 1925; Gilluly, 1935; Nicholls, 1959). Some of the quartz studied by Nicholls may have inverted from the high form.

Micropegmatitic intergrowths of quartz and potash feldspar occur in the "sodium potassium spilites" at Swierki, Lower Silesia (Dziedzicowa, 1958). Benson (1915*a*) claims that interstitial micropegmatitic intergrowths of quartz and feldspar sometimes occur in the dolerites at Nundle. These latter intergrowths must involve quartz and albite, as Benson states that potassic feldspar is absent from the dolerites and spilites. Minute quartz-albite intergrowths are reported by Duschatko and Poldervaart (1955) in an albitite associated with spilitic rocks in New Mexico. From the common occurrence of quartz in cavities and veins it is apparent that this mineral is often of late-formation in spilitic rocks. In addition, some authors (e.g., Amstutz, 1954) also mention quartz as one of the alteration products of primary minerals such as pyroxene. Chalcedony (Wells, 1925) and opal (Reinhard and Wenk, 1951) have also been found in spilites.

I know of no examples of spilites containing fresh olivine, though pseudomorphous aggregates after olivine have been frequently observed in spilites from various parts of the world. Considerable variety apparently exists as to the material replacing olivine. Sundius (1915) notes hornblende aggregates after olivine. Van Overeem (1948) records pseudomorphs of "serpentine and actinolite" replacing olivine crystals, the cleavages of which are now outlined by granules of ore minerals. Pseudomorphs identified as "chlorite" are mentioned by Gilluly (1935), Vuagnat (1946), Scott (1951*a*) and Jaffé (1955). In a spilitic pillow diabase from Oberhalbstein (Grisons), Vuagnat (1948) has noted olivines replaced by a green substance, with optical characters "intermediate between those of bowlingite and those of iddingsite". The Swiss spilites studied by Amstutz (1954) contain pseudomorphs after olivine and augite, and as alteration products he lists (p. 72): haematite, limonite, chlorite, serpentine, iddingsite, bowlingite, calcite, quartz, and perhaps also sphene and leucoxene. Calcite pseudomorphs after olivine are mentioned by Dziedzicowa (1958), while Scott (1951*a*) gives an example of olivine replaced by hydrogrossular in a picritic rock. In many of these replacements it is apparent that considerable migration of material must have taken place. Traces of original olivine have not been seen in spilites from North Auckland (Battey, 1956), Tayvallich (Flett, 1911; Vuagnat, 1949*b*) and Builth (Nicholls, 1959). Benson (1915*a*) does not mention any signs of olivine in the spilites at Nundle; I have found none in these rocks.

Fresh pyroxene is an important constituent of some spilites such as those from Nundle (Benson, 1915*a*), Karelia (Eskola, 1925), Tasmania (Scott, 1951*a*) and New Zealand (Battey, 1956). In New South Wales unaltered pyroxene has also been observed in spilites at Bundook and Woodstock. There are, however, many spilitic rocks which carry partly or completely replaced pyroxene grains (e.g., Sundius, 1915; van der Waals, 1946; Amstutz, 1954; Backlund, 1932; Dziedzicowa, 1958; Nicholls, 1959), while some others such as those at Tayvallich (Flett, 1911; Vuagnat, 1949*b*), some of the ophiolite spilites of the Alps (Vuagnat, 1946, 1948; Jaffé, 1955) and probably the spilites of the Dalformation, Sweden (van Overeem, 1948), show no signs of having once contained pyroxene.

Despite numerous records of spilites containing pyroxenes, little information as to the optical and chemical properties of these minerals is available. The analysis given by Scott (1954) of a pyroxene from a spilitic lava at Queenstown, Tasmania, appears to be unique. Pyroxenes from spilites at Nundle are being studied at present, though only one incomplete analysis is now available. Both of these analysed pyroxenes are alumina-rich and moderately titaniferous types. The Tasmanian example is regarded as a salite, the Nundle pyroxene, with a little less lime, is a common augite according to the nomenclature of Hess (1941). In Table 1 some optical properties of spilitic pyroxenes are listed. Apart from a few examples from Borneo, these pyroxenes appear to be salites or common augites with apparently ferroaugite represented in the suite from Builth.

Reinhard and Wenk (1951) record pigeonite as occurring occasionally in the spilites of North Borneo. According to Kurshakova (1958), pigeonite is found in spilites from the Blyava district of the southern Urals; no optical details are given and the definitive study on this area (Zavaritsky, 1946) is not available in Australia. Some of the albite dolerites of Dinas Head, Cornwall, carry pigeonite (Agrell, 1939), but the few specimens of albite dolerites from south-eastern Cornwall (Saltash area) which I have examined contain common augite. On the whole, pigeonite appears to be rare in spilitic rocks, the common pyroxenes of which are common augites, salites and ferro-augites. To judge from the colours noted many spilitic pyroxenes are titaniferous. I know of no record of rhombic pyroxenes in these rocks. Grunau (1947) lists aegirine augite in a spilite from Arosa, Switzerland. Soda pyroxenes, however, appear to be exceptional.

TABLE 1.
Optical Characters of Pyroxenes from Spilites.

Locality.	Sign.	2V.	$\widehat{Z\,c}$.	R.I.	Source.
Bundook, N.S.W. ..	+	50° (average)	45° (average)		T.G.V.
Nundle, N.S.W. ..	(+)	42°–48°			Benson (1915*a*).
	+	49° (average)	46° (average)		T.G.V.
Woodstock, N.S.W.	+	51° ,,	47° ,,		T.G.V.
King Is., Tasmania	+	51°	40°		Scott (1951*a*).
Queenstown, Tasmania.	+	51°	50°	γ 1·72	Scott (1954) anal.
North Auckland, N.Z.	+	47° (average)	42°–45°	β 1·698	Battey (1956).
Mossburn, N.Z. ..	+	50°	40°		Reed (1950).
Borneo	+	40°–60°	40°–50°		Reinhard and Wenk (1951).
	+	20°–30°			Reinhard and Wenk (1951).
Karelia	+	50°	39°	α 1·697; γ 1·720	Eskola (1925).
	+		40°	α 1·685; γ 1·708	Eskola (1925).
Nowaya Zemlya ..	+	44°	40°		Backlund (1930).
New Mexico ..	+	50°–55°		β 1·680–1·685	Duschatko and Poldervaart (1955).
	+	46°–50°			Duschatko and Poldervaart (1955).
Builth, Wales ..	+	47°–49°		β 1·704–1·708	Nicholls (1959).
	+	46°		β 1·712	Nicholls (1959).
	+	48°		β 1·695	Nicholls (1959).

Some spilitic rocks carry amphiboles, though considerable diversity exists as to the nature and occurrence of these minerals. Fibrous uralite or tremolite-acintolite may occur as replacements of olivine, pyroxene and hornblende (e.g., Sundius, 1915; van der Waals, 1946; van Overeem, 1948; Vuagnat, 1949*a*). The albite dolerites at Nundle sometimes have augite partly or even completely replaced by fibrous amphibole; amphibole is rare, however, in the finer spilites. In other cases, blades or nodules of tremolite-actinolite may occur interstitially to feldspar, scattered through the groundmass, or even as cavity fillings. Smulikowski (1957) records a rare example in which riebeckite has formed at the expense of olivine and augite. Occasionally, brown or green hornblende is noted (Benson, 1915*a*; Sundius, 1915; Carstens, 1924; Eskola, 1925; Gilluly, 1935; van Overeem, 1948, p. 51; Lehmann, 1949; Jaffé, 1955). Albite-hornblende rocks (intrusive spilites) occur in the northern part of the Karelian region studied by Eskola (1925). Eskola has described one analysed amphibole from these intrusive spilites. The sample is moderately aluminous, but is chiefly notable for refractive indices lower than those found in amphiboles with comparable Mg:Fe. Eskola suggests that amphiboles of the type analysed may be common in these rocks. Väyrynen (1928) offers a similar example in a spilitic greenstone from Kainuu, Finland. Amphiboles do not appear to be common in the spilites of the Alpine region, and where seen in these rocks amphibole is often partly replaced by chlorite (e.g., Jaffé, 1955). Nicholls (1959) illustrates a chlorite-calcite group probably pseudomorphing hornblende in the Builth spilites. In the spilites of the Dalformation hornblende is commonly replaced by chlorite or biotite (van Overeem, 1948). Battey (1956) observed that amphibole becomes common in the North Auckland spilites only when these rocks are found within the aureole of a later intrusion.

Micas occur rarely and then only in subordinate amounts in most spilites. The occurrence of biotite after hornblende in the Dalformation has just been noted; van Overeem has also found green biotite included in feldspar. Biotite is similarly associated with amphibole and albite at Kiruna (Sundius, 1915). Some of the spilites in the Dalformation have been subjected to dynamometamorphism, and these types contain green biotite and actinolite, though van Overeem (1948, p. 71) considers that the biotite is original. Flett (1911) observed a bright green strongly birefringent biotite, associated with quartz and carbonate filling cavities in the spilites at Tayvallich, while Vuagnat (1949*b*) records green biotite and a golden-brown, rather weakly birefringent "biotite" from spilitic pillow lavas in the same area. Vuagnat suggests that a colourless mica noted in the marginal zone of one of these pillows is paragonite. Paragonite may also occur in spilitic rocks in New Brunswick (Flaherty, 1934). "Sericite" mica is often reported as an alteration product of feldspars.

Next to the alkaline feldspars members of the chlorite group are perhaps the commonest and most characteristic minerals in spilites. In many cases, such as the Alpine spilites and the so-called weilburgites, chlorites may be the chief mafic minerals present. Even in those spilites which contain unaltered pyroxene, chlorite minerals are usually abundant. As an example, the North Auckland spilites (Battey, 1956) contain bright green chlorite filling "angular intersertal areas, in little rounded pools, in fine veinlets . . . and in amygdules". Chlorite occurs similarly in the spilites at Nundle. On the other hand, there are many records of chlorite minerals replacing and pseudomorphing olivine, pyroxene, or hornblende. Included patches of chlorite in albite units have been variously regarded as normal inclusions or as due to partial replacements. Originally glassy spilites often contain chlorite-rich aggregates produced in the devitrification. Glassy fragmental rocks associated with spilites also frequently show this replacement by chlorites (e.g., Hentschel, 1953). Within a single rock, chlorite minerals may occur as both direct replacement products and as cavity fillings. Apart from minerals grouped as "serpentine" (and mainly replacing olivine) there appears to be a great variety of chlorites in the spilitic rocks, although many authors simply note the presence of "chlorite". Types recorded include: pennine (Taliaferro, 1943; Scott, 1951*a*; den Tex, 1950; Reed, 1950; Thomas and Thomas, 1956; Duschatko and Poldervaart, 1955), delessite (Eskola, 1925; Reinhard and Wenk, 1951; Thomas and Thomas, 1956), ripidolite (Vuagnat, 1949*a*), clinochlore (Duschatko and Poldervaart, 1955), diabantite (Thomas and Thomas, 1956), brunsvigite (Battey, 1956), aphrosiderite (= thuringite of Hey, 1954) (Holzner, 1938). Battey has analysed an intersertal brunsvigite from a North Auckland spilite; this with the two analyses of chlorites from German spilites which he quotes apparently completes the list of analysed spilitic chlorites. A few chlorites have been checked by X-ray powder methods (e.g., the pennine of Scott (1951*a*) and the ripidolite of Vuagnat (1949*a*)), but the majority have been identified by optical examination. Nicholls (1959) quotes compositions of chlorite (apparently mainly brunsvigite and diabantite) from amygdules in the Builth spilites. These identifications are based on optical characters related to the chart given by Hey (1954). An immediate difficulty in this method is that according to Hey variations in the oxidation state of iron in chlorites lead to variations in refractive indices and birefringence. As some spilitic chlorites are distinctly oxidized (e.g., the "aphrosiderite" of Holzner) a certain degree of doubt must be attached to determinations of composition based on optical characters. Nicholls was aware of this difficulty, but all his chlorites are given formulae as ferric iron-free types. It would appear that the range of composition in these amygdule chlorites from Builth is not great. Lehmann (1949) claims that the weilburgites of Lahn carry both orthochlorites and leptochlorites, the latter confined to small cracks and amygdules. Unfortunately, insufficient data are supplied to enable one to establish differences between these types. To conclude, on the basis of scrappy information, the common chlorites of spilitic rocks fall within the ranges $Si_{2\cdot5}.Al_{1\cdot5}$ to $Si_{3\cdot5}.Al_{0\cdot5}$ (for a formula with 18 O.OH), total Fe/Fe+Mg values from nearly zero to nearly unity, and Fe_2O_3 up to at least 12·5% (wt.). Of doubtful status is the "celadonite chlorite" in the spilites of Mossburn, N.Z. (Reed, 1950).

Minerals of the epidote-clinozoisite group are commonly reported in spilites, though in some cases these minerals are little more than accessories. The ferriferous epidote, pistacite, appears to be the commonest representative of the group in spilites, if one may judge from the colours and birefringences recorded. A possibly manganian epidote is reported by van Overeem as occurring with nodules in spilites; many of these nodules are rich in pistacite. In the spilites at Nundle, epidote is extremely variable in its distribution. Some of the pillow lavas contain a fine greenish material which is almost pure epidote in the spaces between the pillows. Epidote also occurs at Nundle as a vein and vesicle filling and as disseminated grains sometimes included in feldspar laths but more often scattered through the groundmass. Flett (1911) mentions epidosites associated with spilitic pillow lavas. Although epidote fillings between pillows appear to be somewhat unusual in other spilites there are many descriptions of accessory granular epidote occurring as inclusions (or alteration products) or as groundmass constituents (Dewey and Flett, 1911; Amstutz, 1954; Eskola, 1925; van Overeem, 1948). Epidote minerals as vesicle and vein fillings are also commonly reported. Van der Waals (1946) records zoisite, clinozoisite and epidote (presumably iron-rich) in the spilites of south-east Liguria. In Karelia, some albite-amphibole-epidote (pistacite) rocks, mostly lacking in chlorites, are regarded as spilitic by Eskola (1925), mainly on account of their high soda content. However, as "the soda percentage apparently decreases as the quantity of epidote increases", the epidote-rich members are distinguished as "non-spilitic" (Eskola, 1925).

The epidote-like mineral pumpellyite has been recorded in many spilites (Reed, 1950, 1957; Battey, 1956; Nicholls, 1959; de Roever, 1947; Coombs, 1953; Reinhard and Wenk, 1951; Bloxam, 1958). The mineral usually occurs in vesicles, or veins, in aggregates in the groundmass or as inclusions or patches in feldspar crystals. Coombs *et al.* (1959) mention pumpellyite with or without prehnite taking the place of epidote in some New Zealand spilites. Pumpellyite fills vesicles in spilites from Bundook, N.S.W., but has not, as yet, been definitely identified in similar rocks at Nundle.

Although magnetite is reported in some cases (Sundius, 1915; Benson, 1915*a* (magnetitic spilite, p. 132); Flaherty, 1934; Blyth, 1935; Pichamuthu, 1938; Taliaferro, 1943; van Overeem, 1948; Lehmann, 1949; Scott, 1951), it is apparently less common than haematite or ilmenite. Examples of haematitic spilites are reported from many localities (Flaherty, 1934; Vuagnat, 1946, 1948, 1949*a*, 1949*b*; van Overeem, 1948; Park, 1946; Lehmann, 1949; den Tex, 1950; Amstutz, 1954; Jaffé, 1955; Dziedzicowa, 1958; Nicholls, 1959). In one case at least (Flaherty, 1934) the haematite appears to be pseudomorphing pyroxene crystals and not magnetite or some other iron ore. Both den Tex (1950) and Amstutz (1954) record limonite. Perhaps the most frequently recorded ore mineral is ilmenite, and identification in this case is usually facilitated by extensive alteration to so-called leucoxene. Flett (1911), Benson (1915*a*), Sundius (1915), Wells (1925), Eskola (1925), Blyth (1935), Grunau (1947), van Overeem (1948), Lehmann (1949), den Tex (1950), Reed (1950), Jaffé (1955) and Thomas and Thomas (1956) all offer examples of ilmenite in spilites, while other cases are known of leucoxene completely replacing ilmenite. In fact, the list could be lengthened considerably if recorded cases of leucoxene were added. The leucoxene is usually regarded as a variety of sphene, but in many spilites rich in ilmenite/leucoxene separate grains of recognizable sphene are commonly distributed through the groundmass.

According to Amstutz (1954), Lehmann (1949), Kurshakova (1958) and possibly Battey (1956), titanomagnetite also occurs in spilites. Duschatko and Poldervaart (1955) record sphene occasionally replaced by rutile, a mineral also noted as a rare accessory by Lehmann (1949) and Dziedzicowa (1958). Anatase has been identified by X-ray methods in a spilite from the French Alps (den Tex, 1950).

Some authors (e.g., Tomkeieff, 1941) consider that carbonate minerals are present in all rocks called spilites. There are, however, on record many analyses of rocks given this name which contain no carbonate material (see Table 2). The carbonate minerals often have a highly variable occurrence. They are quite lacking in parts of some spilitic bodies at Nundle. In general, carbonates are found in spilites as replacements (e.g., to olivine or pyroxene), as vein or cavity fillings, or as grains or aggregates of grains arranged interstitially. Despite the analysed examples noted above, it must be pointed out that the majority of spilitic rocks contain carbonates and often in quite high proportions. As an extreme case we may refer to a "spilite albito-calcitique" with 70% modal calcite (Jaffé, 1955). The carbonate in spilites is usually identified as calcite, though this should be regarded often as a "sack name". Flett (1915), Sundius (1915) and Thomas and Thomas (1956) mention ferriferous carbonates (? ankerite or siderite). Both dolomite and calcite are supposed to occur in rocks called spilites by Perrin and Roubault (1941). Reinhard and Wenk (1951) record rare aragonite in addition to the much commoner calcite in the spilites of North Borneo. Manganese-bearing carbonates are associated with the spilites described by Park (1946).

Duschatko and Poldervaart (1955) observed barite associated with prehnite, zeolites and calcite in spilite from New Mexico. Barite is apparently a very rare accessory in such rocks, and the only other record I have is that in Blyth (1935). Prehnite and zeolites are rather more common. Geijer (1916) remarked on the lack of zeolites in spilites, but since 1916 a number of examples of zeolite-bearing spilitic rocks have been described. Most of the recorded zeolites are calcic types. Laumontite is abundant in the spilites of the Olympic Peninsula, Washington, and according to Park (1946) is of late formation. The laumontite is associated with minor analcite and other unidentified zeolites. Possible pseudomorphs after analcite are mentioned by Carstens (1924). Chabazite (?) occurs in one spilite from Mossburn, N.Z. (Reed, 1951). The commonest zeolite in the rocks described by Duschatko and Poldervaart is thomsonite. Zeolites are also recorded by Blyth (1935) and Reinhard and Wenk (1951). In most of these cases the zeolites occupy vesicles and veins. Inclusions of prehnite in feldspar are mentioned by van der Waals (1946), Duschatko and Poldervaart (1955) and Nicholls (1959), though prehnite is not restricted to this type of occurrence—Scott (1951*a*) has observed prehnite as a vesicle filling; in brecciated spilites at Nundle I have seen veins of prehnite serving essentially as a cement.

The mineral babingtonite sometimes occurs with prehnite in veins in the spilites of the North Auckland region (Battey, 1956). Babingtonite is also found there in veinlets with quartz and as isolated units in intersertal chlorite. It is apparently a late stage mineral. Another late mineral rarely recorded in spilites is hydrogrossular (Scott, 1951*a*, 1951*b*). Like babingtonite, hydrogrossular may occur in veins and cavities, but has also been observed by Scott pseudomorphing olivine and feldspar, and apparently replacing originally glassy material. Iddingsite replacement of olivine is apparently not common in spilites (Scott, 1951*a*; Amstutz, 1954). We have already noted Vuagnat's (1948) observation of a mineral intermediate in optics between iddingsite and bowlingite replacing olivine. Den Tex (1950) mentions bowlingite and xylotile in a spilite from the Alps, while Thomas and Thomas (1956) have bowlingite pseudomorphing pyroxene in albite diabases near Strumble Head, Pembrokeshire.

Apatite, usually as disseminated small elongate crystals, is a common accessory in spilites (e.g., Flett, 1909, 1911; Benson, 1915*a*; Sundius, 1915; Carstens, 1924; Blyth, 1935; Grunau, 1947; van Overeem, 1948; Vuagnat, 1949*b*; Lehmann, 1949; Jaffé, 1955; Duschatko and Poldervaart, 1955; Battey, 1956). Zircon is apparently a very rare accessory. I know of only one record (Duschatko and Poldervaart, 1955).

Benson (1915*a*) has observed axinite in veins and vesicles in the spilitic rocks at Nundle. In this area axinite is rather irregular in its distribution, though it appears to be commoner towards the top of the sequence. Axinite occurs in veins associated with spilitic rocks in the mineralized area near L. Pertjärvi, Karelia (Eskola, 1925). Some of the Cornish spilites (e.g., Flett, 1909) contain axinite, and occasionally tourmaline as well, but these borosilicate-bearing spilites are apparently found only within the contact aureoles of granitic intrusions. One brecciated spilitic rock from Bundook, N.S.W., contains datolite in patches, the datolite serving as a sort of cement. Rodolico (1933) has recorded another occurrence of this mineral, in the ophiolites of Tuscany. Scapolite is also occasionally encountered in spilites; examples are given by Sundius (1915) and Spry (1954). In the latter case, at any rate, the scapolite reflects the influence of an intrusive granite body. The iron-rich mineral stilpnomelane has been found by Eskola (1925) in veins in the spilitic region of Karelia. Carstens (1924) had earlier reported the same mineral in magnetite-rich layers associated with the spilitic greenstones in the Trondhjem area of Norway. Stilpnomelane also occurs in a rock of uncertain status in the spilite-keratophyre terrain of Lahn (Holzner, 1933). The region studied by Eskola (1925) includes the type locality of the material called shungite, one example of which, containing 98·77% carbon, was taken from a vesicle in a pillow lava. In Karelia, shungite occurs typically in veins and amygdules where it is usually associated with various forms of silica, with carbonates and sometimes with pyrite. More recently, Aleksandrov (1956) has found shungite in spilitic rocks in the Middle Urals. The occurrence is apparently similar to that in Karelia. Perhaps the puzzling carbonaceous material in some of the Builth spilites (Nicholls, 1959) is akin to this shungite.

Some spilitic rocks are associated with ore deposits of economic importance (e.g., Lehmann, 1940; Zavaritsky, 1946; Amstutz, 1958). The spilites of the Olympic Peninsula, Washington (Park, 1946), for example, are associated with manganese deposits. Hausmannite (Mn_3O_4) and manganese silicates occur in some of these spilites and Park records instances of whole pillows being replaced by manganese minerals. Disseminated sulphides are frequently observed in spilites. Pyrite is usually the commonest of these, and examples are offered by Flett (1909, 1911), Benson (1915*a*), Sundius (1915), Carstens (1924), Wells (1925), Blyth (1935), Pichamuthu (1938), Perrin and Roubault (1941), Lehmann (1949), Reed (1950) and den Tex (1950). Eskola (1925) lists a number of sulphides, including pyrite, pyrrhotite, chalcopyrite, bornite and sphalerite, occurring in veins in spilitic greenstones. Galena is another sulphide occasionally found in spilitic rocks (Lehmann, 1949).

We have seen that a great variety of silicates (many of them hydrous), carbonates, oxides and sulphide minerals may occur in rocks called spilites. From the few modes recorded in the literature it is apparent that there is also a considerable range in the proportions of the major constituents. For example, a so-called spilite from the Urals (Kurshakova, 1958) carries only about 5% of albite, but has over 50% chlorite with the rest of the rock mainly quartz and ore minerals. Duschatko and Poldervaart (1955) list spilitic basalts and dolerites containing up to 76% feldspar; these rocks are associated with albitites carrying up to 95% feldspar. The extremely carbonate-rich spilite (70% calcite, 29% albite, 1% chlorite) described by Jaffé (1955) was mentioned earlier. Amstutz (1954), in his study of spilites and keratophyres in the Swiss Verrucano, limited these names to eruptive rocks with 40–90% albite and 0–50% chlorite with iron ores, mostly hæmatite, and occasional noteworthy amounts of epidote, calcite, and titanium minerals. Within this scheme "spilites are the basic, keratophyres are the acid, albite-rich, members of the series". Clearly other authors interpret the term spilite more generously, at least as far as the mode is concerned. It would seem, however, that the main mineral assemblages found in spilites are relatively few in number. The commonest of these assemblages are: albite-clinopyroxene-chlorite, albite-chlorite, albite-chlorite-epidote, albite-chlorite-epidote-calcite, albite-chlorite-pumpellyite calcite, albite-calcite, albite-amphibole-epidote, and albite-amphibole-chlorite. In each of these cases iron ore minerals are usually present. Magnetite and/or ilmenite are more often found in spilites of the albite-clinopyroxene type, while haematite and completely leucoxenized ilmenite seem to be commoner in spilites lacking in pyroxenes. In a few cases the albite may be joined by potassic feldspars.

CHEMICAL COMPOSITION.

The crude analysis of a Derbyshire toadstone carried out by Withering and communicated to the Royal Society in 1782 by Joseph Priestley is almost certainly the earliest chemical study on a spilitic rock. Though now of mainly historical interest, Withering's results indicated that the toadstones were akin to basalt, but had a greater carbonate content than the latter. In 1850, Gueymard published a group of analyses of the *variolite du Drac.* Although, again, these results are not completely reliable, a number of general features are evident. The silica content is of the same order as in basalt, the alumina, iron and magnesia contents are variable, but "non-carbonate" lime (where determined) is very low and the alkali content is distinctly high. Gueymard stated that he had not found potash in his rocks. The later work by Termier (1898) on these same rocks indicates that potash is present, but always in very small amounts.

I have gathered in Table 2 92 published analyses available to me of rocks actually named spilites. In each case I have accepted the author's identification and have only

TABLE 2.

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2 ..	36·94	39·20	39·28	39·35	40·42	40·55	42·17	43·13	43·73	43·96	44·89	44·98
Al_2O_3 ..	17·11	18·80	12·14	16·54	18·15	16·65	13·36	23·25	18·09	17·26	15·80	15·84
Fe_2O_3 ..	1·48	8·61	2·80	5·76	7·46	1·13	3·80	1·87	7·74	9·20	1·40	1·26
FeO ..	5·70	4·99	7·52	6·97	3·53	9·46	1·35	4·81	5·21	2·69	9·10	6·57
MgO ..	2·55	10·03	3·66	10·00	13·52	5·20	3·11	6·50	7·38	8·84	4·76	5·78
CaO ..	15·95	9·69	12·82	5·58	5·39	6·06	18·59	5·58	4·77	7·27	5·44	9·66
Na_2O ..	2·99	1·88	4·56	3·50	2·65	4·76	1·27	3·60	3·02	3·21	5·53	3·00
K_2O ..	0·76	0·16	0·08	0·48	1·91	0·27	0·64	3·04	1·85	1·67	0·18	0·83
H_2O^+ ..	3·78	4·52	2·77	6·71	4·32	3·89	4·52	3·76	4·17	3·21	4·94	3·08
H_2O^- ..		0·10	0·19	0·36	0·17	0·27		1·06	0·13	0·15	0·52	0·36
TiO_2 ..	1·02	2·21	3·53	4·27	1·68	2·95	0·62	—	2·74	1·49	4·06	1·87
MnO ..	1·36	0·00	0·37	0·28	0·17	0·20	0·77	tr.	—	—	0·08	0·13
P_2O_5 ..	—	—	0·57	0·20	tr.	0·73	—	—	—	—	1·10	—
CO_2 ..	9·66	0·00	10·06	0·34	0·42	7·85	10·33	3·50	0·87	1·30	2·80	6·88
Etc. ..	0·18	—	0·01	—	—	0·17	—	—	—	—	—	—
Total ..	99·48	100·19	100·36	100·34	99·79	100·14	100·53	100·10	99·70*	100·25	100·60	100·24

	13	14	15	16	17	18	19	20	21	22	23	24
SiO_2 ..	45·11	45·21	45·26	45·42	45·42	45·56	45·86	45·91	45·92	46·4	46·47	47·03
Al_2O_3 ..	14·89	17·82	15·86	15·94	17·26	16·46	14·29	17·35	15·19	20·4	19·27	22·45
Fe_2O_3 ..	6·58	5·28	1·43	1·70	4·19	6·58	3·99	6·52	5·53	6·9	4·80	7·00
FeO ..	3·49	6·08	6·32	6·04	6·09	4·40	8·11	5·29	7·06		4·03	
MgO ..	5·24	10·20	5·35	5·62	3·70	7·74	6·73	9·24	6·64	3·5	9·27	8·79
CaO ..	6·27	3·33	9·24	8·82	7·50	3·72	9·51	3·15	6·87	7·7	2·12	2·92
Na_2O ..	4·13	3·51	3·37	3·46	4·51	4·15	3·13	2·77	3·22	6·93	5·53	2·63
K_2O ..	3·41	1·70	0·91	0·86	1·43	1·72	0·88	2·18	0·30	0·54	0·78	4·55
H_2O^+ ..	5·83	3·70	3·27	3·46	6·34	3·77	1·61	4·68	7·75	—	4·99	3·65
H_2O^- ..		0·25	0·54	0·61		2·38	0·59	0·35		—	0·33	
TiO_2 ..	1·67	—	1·68	2·00	0·87	1·37	1·98	2·29	1·78	0·24	1·54	—
MnO ..	0·19	—	0·25	0·18	0·14	0·26	0·21	—	—	—	0·08	—
P_2O_5 ..	—	—	—	—	—	0·62	0·26	—	—	—	0·56	—
CO_2 ..	2·72	—	6·34	5·98	2·96	1·25	3·96	0·49	—	5·8	0·14	1·90
Etc. ..	—	—	—	—	—	0·05	0·03	—	—	1·1	—	—
Total ..	99·53	97·08*	99·82	100·09	100·41	100·03	101·14*	100·22	100·26	99·51	99·91	100·92

TABLE 2.—*Continued.*

	25	26	27	28	29	30	31	32	33	34	35	36
SiO_2	47·37	47·4	47·40	47·45	47·49	47·53	47·56	47·95	48·05	48·22	48·24	48·35
Al_2O_3	21·71	15·7	19·19	17·54	17·33	17·58	14·27	15·82	18·49	14·82	17·55	16·82
Fe_2O_3	3·76	2·4	1·48	2·04	8·63	2·17	1·63	1·44	3·00	0·56	1·05	2·85
FeO	4·65	9·1	8·26	7·44	4·66	8·85	6·80	2·56	5·52	9·25	7·04	10·21
MgO	5·57	4·4	3·60	6·72	4·76	5·94	4·90	3·64	3·74	5·58	5·27	4·46
CaO	4·59	7·7	11·25	10·96	7·16	9·48	10·95	8·09	4·63	8·81	10·43	9·55
Na_2O	5·08	4·0	3·40	3·93	4·35	2·40	4·61	3·23	6·95	4·95	5·58	3·78
K_2O	1·98	1·28	1·31	0·00?	1·74	1·08	0·27	5·24	0·90	0·44	0·97	0·42
H_2O^+	4·00	4·1	3·32	2·67	1·90	3·26	2·65	1·42	7·81	2·54	2·88	2·32
H_2O^-	0·04	0·34	0·34	0·23	0·09	0·10	0·42	0·00		0·15	0·17	0·32
TiO_2	1·04	3·6	0·29	—	2·22	1·79	2·40	2·58	0·84	2·68	0·70	0·78
MnO	0·07	0·20	0·13	—	—	—	0·30	0·03	0·49	0·23	0·12	0·10
P_2O_5.	0·22	0·88	n.d.	—	—	—	0·19	0·93	—	0·23	0·10	—
CO_2	0·00	—	—	0·55	—	0·31	2·95	6·98	—	1·40	0·11	—
Etc	—	—	—	—	—	—	0·35	—	—	0·40	—	—
Total	100·08	101·1	99·97	99·53	100·33	100·49	100·25	99·91	100·42	100·26	100·21	99·96

	37	38	39	40	41	42	43	44	45	46	47	48
SiO_2	48·39	48·49	48·52	48·55	48·58	48·6	48·70	48·89	49·23	49·30	49·68	49·73
Al_2O_3	13·43	18·18	19·36	16·94	14·58	16·1	20·14	18·87	14·95	12·89	15·78	15·63
Fe_2O_3	9·19	1·28	2·20	1·12	1·89	7·6	1·84	2·55	6·17	3·72	5·63	3·69
FeO	4·65	7·40	8·12	2·59	7·65	4·0	6·53	5·77	5·47	3·79	5·45	3·75
MgO	4·26	5·59	4·24	7·02	6·36	3·6	4·79	3·84	5·50	3·97	5·31	6·55
CaO	12·83	6·12	7·65	9·89	9·80	6·2	6·67	7·56	4·72	10·49	6·48	5·79
Na_2O	3·23	3·94	4·42	5·28	4·02	4·5	4·26	4·14	4·69	5·59	5·07	6·85
K_2O	0·99	2·02	0·18	1·63	0·43	1·76	1·07	1·06	1·89	2·05	0·43	0·23
H_2O^+	2·98	3·66	3·38	3·88	2·93	2·9	3·67	2·93	3·95	4·07	3·22	3·89
H_2O^-		0·82		0·15	0·68	0·22	0·52	0·66	0·29	0·98	0·26	0·24
TiO_2	—	1·40	1·00	1·23	1·77	1·94	1·28	2·42	1·60	1·04	2·04	2·05
MnO	tr.	0·14	0·20	0·05	0·46	0·34	0·09	—	0·07	n.d.	—	0·19
P_2O_5	0·35	0·22	—	0·37	0·19	0·34	0·11	0·39	0·39	—	—	0·24
CO_2	—	0·72	0·47	1·03	1·00	1·45	0·39	0·80	0·72	2·82	—	1·42
Etc.	—	—	—	—	0·29	—	—	0·10	—	—	—	0·01
Total	100·30	99·98	99·74	99·73	100·63	99·6	100·06	99·98	99·64	100·71	99·35	100·26

	49	50	51	52	53	54	55	56	57	58	59	60
SiO_2	49·74	49·80	49·96	50·01	50·04	50·05	50·72	50·76	51·06	51·31	51·46	51·47
Al_2O_3	14·85	17·94	11·39	15·38	17·44	18·87	15·37	14·57	15·24	12·67	11·58	15·46
Fe_2O_3	1·04	2·37	4·50	4·86	4·90	0·73	1·69	4·11	5·69	0·54	6·63	4·73
FeO	10·61	6·74	13·61	9·21	8·16	5·73	6·61	10·59	4·82	7·99	10·25	5·11
MgO	2·48	4·02	3·31	5·85	9·36	4·45	7·66	2·86	4·03	2·19	2·88	4·08
CaO	6·17	9·00	5·24	6·35	tr.	6·09	9·04	7·54	6·99	8·17	5·60	5·59
Na_2O	4·52	4·03	4·62	4·77	0·61	4·93	6·04	5·54	4·50	5·21	4·68	6·05
K_2O	0·53	0·20	1·33	0·40	0·17	1·67	0·71	1·04	2·34	0·54	1·02	1·09
H_2O^+	3·37	3·54	3·09	2·60	5·41	3·22	0·58	0·94	2·57	2·31	2·54	3·32
H_2O^-	0·05	0·10		0·23		0·63	0·60		0·04	0·04		0·04
TiO_2	2·05	1·70	3·13	0·73	0·05	0·94	1·29	1·60	1·45	1·92	3·38	1·77
MnO	0·39	—	0·26	0·21	0·09	0·08	0·14	0·09	0·11	0·45	0·32	0·06
P_2O_5	0·62	—	0·19	0·09	—	0·25	0·08	0·06	0·85	0·90	0·34	0·88
CO_2	3·18	1·28	—	0·13	—	2·21	tr.	—	0·00	6·15	—	0·00
Etc.	0·13	—	0·08	—	3·22	—	—	0·06	—	0·47	—	—
Total	99·73	100·72	100·71	100·82	99·45*	99·85	100·53	99·76	99·69	100·86	100·68	99·65

TABLE 2.—*Continued.*

	61	62	63	64	65	66	67	68	69	70	71	72
SiO_2	51·52	51·62	52·05	52·09	52·14	52·46	52·61	52·84	52·94	53·01	53·15	53·41
Al_2O_3	15·14	19·98	16·58	12·62	18·93	15·33	13·03	17·32	12·81	15·01	14·39	11·58
Fe_2O_3	8·00	7·34	1·31	0·05	7·42	4·09	3·90	3·12	3·76	7·42	1·28	0·97
FeO	2·02	2·32	5·19	9·52	2·00	6·13	8·48	5·29	9·29	0·92	9·33	9·90
MgO	7·22	2·87	4·65	7·54	4·36	4·69	5·10	8·68	3·65	3·55	4·74	2·59
CaO	3·84	5·68	5·67	9·90	3·60	5·98	7·26	0·99	6·22	4·68	7·04	7·81
Na_2O	5·44	3·66	6·42	3·28	5·10	5·62	5·60	5·32	5·25	3·77	4·58	4·90
K_2O	0·18	2·62	0·27	0·21	0·75	0·19	0·42	0·82	0·18	4·01	1·01	0·82
H_2O^+	4·07	—	3·09	1·97	4·05	3·81	1·65	4·28	2·33	2·15	2·02	3·29
H_2O^-	0·70	0·80	0·83	0·20			0·10	0·13	0·21	0·72	0·19	
TiO_2	2·00	—	0·99	1·16	1·08	0·94	0·72	1·19	2·54	1·48	1·50	3·13
MnO	0·22	0·18	0·07	0·20	0·15	0·18	0·19	0·08	0·21	0·06	0·14	0·18
P_2O_5	0·16	—	0·15	1·28	—	—	tr.	0·14	0·36	0·47	0·19	0·36
CO_2	tr.	—	2·70	—	0·23	—	0·05	0·00	0·00	3·37	0·10	1·19
Etc.	—	2·56	—	0·24	—	—	0·08	—	0·16	—	—	0·05
Total	100·51	99·63	99·97	100·26	99·81	99·42*	99·19	100·20	99·91	100·62	99·66	100·18*

	73	74	75	76	77	78	79	80	81	82	83	84
SiO_2	53·59	53·75	53·86	54·04	54·10	54·20	54·87	54·92	55·04	55·34	55·46	55·75
Al_2O_3	14·22	14·53	14·75	15·04	16·45	15·15	14·98	15·07	13·83	14·76	15·30	13·29
Fe_2O_3	2·03	7·95	3·94	7·79	4·04	7·05	1·65	0·16	2·19	8·83	6·06	0·88
FeO	9·66	0·79	5·90	1·53	6·49	1·60	8·89	9·23	7·39	0·41	3·71	8·46
MgO	3·58	2·84	4·17	3·94	3·69	3·05	3·33	7·44	4·78	2·49	3·89	1·80
CaO	6·18	6·11	7·17	4·08	6·16	6·41	4·06	2·06	7·08	5·53	4·24	6·85
Na_2O	5·52	3·84	5·36	3·74	4·97	3·78	5·73	2·98	5·90	3·60	2·58	4·07
K_2O	0·41	3·31	0·46	2·88	1·01	2·57	1·13	0·16	0·36	3·48	1·55	0·37
H_2O^+	1·49	1·41	2·53	2·48	1·01	1·37	2·39	5·65	0·77	0·83	5·30	2·95
H_2O^-	0·39	0·73	0·92	1·07	0·16	0·42	0·25	0·16		0·37		0·20
TiO_2	2·76	1·78	0·72	1·51	1·22	1·60	2·02	0·05	1·15	1·55	1·00	1·86
MnO	0·05	tr.	0·14	tr.	0·26	0·03	0·04	0·08	0·20	0·04	—	0·23
P_2O_5	0·34	0·49	0·16	0·59	0·26	0·44	0·47	—	0·08	0·53	—	0·19
CO_2	—	3·38	tr.	1·69	0·75	3·13	—	—	1·28	3·12	—	3·63
Etc.	—	—	0·07	—	—	—	—	3·62	0·01	—	—	0·17
Total	100·22	100·91	100·15	100·38	100·57*	100·80	99·81	101·58*	100·06	100·88	99·09	100·70

	85	86	87	88	89	90	91	92	93	94	95	96	97
SiO_2	55·86	56·13	56·84	57·04	57·66	58·48	62·92	63·58	49·65	46·01	51·22	50·83	45·78
Al_2O_3	15·17	14·71	14·95	13·31	15·90	15·07	14·33	13·42	16·00	15·21	13·66	14·07	14·64
Fe_2O_3	2·54	1·39	7·68	8·05	1·71	2·10	1·28	2·10	3·85	1·35	2·84	2·88	3·16
FeO	6·98	9·05	0·63	1·10	6·80	6·86	7·24	5·67	6·08	8·69	9·20	9·00	8·73
MgO	2·30	4·87	2·26	3·02	3·07	6·32	4·87	1·37	5·10	4·18	4·55	6·34	9·39
CaO	3·39	2·24	6·02	4·25	2·55	0·07	1·88	2·75	6·62	8·64	6·89	10·42	10·74
Na_2O	5·45	4·58	3·65	3·39	5·06	3·55	2·37	4·31	4·29	4·97	4·93	2·23	2·63
K_2O	2·05	2·80	2·68	3·09	2·81	0·08	0·49	2·93	1·28	0·34	0·75	0·82	0·95
H_2O^+	2·53	1·66	0·99	2·03	1·44	4·57	2·34	1·85	3·49	2·48	1·88	0·91	0·76
H_2O^-	1·21		0·25	0·71	0·21	0·23	0·16	0·30		—		—	—
TiO_2	1·60	2·21	1·71	1·51	1·94	0·64	1·21	0·99	1·57	2·21	3·32	2·03	2·63
MnO	0·19	0·16	0·06	tr.	0·01	0·27	0·16	0·14	0·15	0·33	0·25	0·18	0·20
P_2O_5	0·63	0·38	0·58	0·51	0·47	—	0·45	0·35	0·26	0·61	0·29	0·23	0·39
CO_2	tr.	—	2·51	2·16	—	—	0·18	0·03	1·63	4·98	0·94	—	—
Etc.	0·20	—	—	—	—	1·87	0·08	0·10	—	—	—	—	—
Total	100·10*	100·18	100·81	100·17	99·63	100·11*	99·96	99·89	—	—	—	—	—

excluded analyses published before about 1900. Rocks of probable spilitic character, but called diabases, greenstones, uralite porphyrites, traps, etc., are not listed. An analysis of the spilite from Nemingha, N.S.W. (Benson, 1915*b*), was omitted inadvertently. The average of these 92 spilites is given in column 93, and, to facilitate comparison, I have added Wells' (1923) average spilite (no. 94), Sundius' (1930) average spilite (no. 95), and Nockolds' (1954) average "normal tholeiitic basalt" (no. 96) and average "normal alkali basalt" (no. 97). In the average no. 93, values for TiO_2, MnO and P_2O_5 are doubtless low because these components have not been estimated in all cases; the corresponding values of Al_2O_3 and iron oxides will thus be high. Although CO_2 is not recorded in some analyses the totals suggest that it is not important in most of these cases.

In view of the fact that both Wells and Sundius had pre-conceived notions as to the composition of spilites and hence their averages are quite selective, it is at least intriguing to notice that all three average spilites are not strikingly dissimilar. However, one does not have to look through many of the 92 analysed spilites to realize that an extreme chemical variability is hidden in the average. In fact, silica varies over a range of about 26% (by weight), while the ranges of the other major constituents are roughly as follows: alumina 12%, ferric iron 9%, ferrous iron 13%, magnesia 12%, lime 18%, soda 6%, and potash 5%. The content of CO_2 exceeds 10% by weight in some cases, but in others carbonate material is absent. Of course, I realize that not all of the analysed rocks (1–92) would be accepted as spilites according to the chemical criteria of Wells and Sundius. It must be understood, however, that even within a single spilitic body there may be considerable variations in both mineralogy and composition. In pillowy spilites there is abundant evidence of chemical variations from core to rim and matrix of the pillows. Slavik (1928) and Vuagnat (1949*a*, *b*) offer examples in which the margins and matrices relative to the cores are extremely rich in iron, magnesia and water but poor in silica, lime and alkalis. In the "margined sacs" of the Builth spilites Nicholls (1959) finds rims richer in lime and poorer in silica and soda than the cores; the ratio of Na/K is much lower in the rims. The "chert-like" material between pillows of which an analysis is given by Reinhard and Wenk (1951) is certainly not like most cherts—it contains only 33·57% SiO_2, but has 21·49% Al_2O_3 and 20·46% CaO. Lime-rich "cherty" rocks also occurs at the margins of pillows at Nundle. A series of four samples collected over a distance of 6·5 cm. from core (A) to margin/matrix (D) in such a pillow is represented in Table 3. The dark, "fresh-looking" core is similar to the average spilite (93) and not greatly different from Benson's spilite from Nundle (34).

Compared with Nockolds' average basalts the average spilites are notable chiefly for their lower lime and higher alkali, water and carbon dioxide contents. The average spilites (93, 94, 95) also have less magnesia than Nockold's basalts. All of these components show wide variations in their distribution in spilites. The arbitrary limiting of spilite to rocks with normative feldspar containing less than 40% anorthite

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Key to Analyses in Table 2.

Amstutz (1954), nos. 23, 25, 68 ; Backlund (1930), no. 91 ; Bartrum (1936), no. 69 ; Battey (1956), nos. 73, 79, 85, 86, 89, 92 ; Benson (1913*c*), no. 34 ; Blyth (1935), no. 18 ; Duparc and Grosset (1916), no. 83 ; Duschatko and Poldervaart (1955), nos. 40, 45, 57, 60 ; Dziedzicowa (1958), nos. 70, 74, 76, 78, 82, 87, 88 ; Eskola (1925), nos. 51, 59, 72 ; Gardiner and Reynolds (1912), no. 50 ; Gilluly (1935), no. 71 ; Ginzberg (1934), nos. 21, 39 ; Grunau (1947), nos. 4, 48 ; Guppy and Sabine (1956), no. 44 ; Guppy and Thomas (1931), nos. 2, 3, 6, 22, 28, 31, 41, 49, 58 ; Kurshakova (1958), nos. 53, 66, 80, 90 ; Loewinson-Lessing and Diakonova-Savelieva (1933), nos. 1, 7, 13, 17, 33, 65 ; Nicholls (1959), nos. 38, 43, 54, 63 ; Niggli, de Quervain and Winterhalter (1930), no. 47 ; Pellizer (1954), nos. 12, 15, 16 ; Reed (1950), no. 75 ; Reed (1957), nos. 26, 42 ; Reinhard and Wenk (1951), nos. 11, 46, 55, 61 ; Richards and Bryan (1924), no. 77 ; Sargent (1917), nos. 8, 24 ; Scott (1951*a*), nos. 27, 35, 52, 67 ; Scott (1952), no. 36 ; Sirin (1937), no. 62 ; Slavik (1908), no. 37 ; Slavik (1928), no. 64 ; Sundius (1930), nos. 56, 81 ; Tomkeieff (1941), no. 32 ; Tomkeieff and Marshall (1940), no. 19 ; van Overeem (1948), nos. 5, 9, 10, 14, 20, 29, 30 ; Wells (1925), No. 84.

Average values : average of spilites nos. 1–92, no. 93 ; average spilite of Wells (1923), no. 94 ; average spilite of Sundius (1930), no. 95 ; average tholeiitic basalt of Nockolds (1954), no. 96 ; average alkali basalt of Nockolds (1954), no. 97.

(Note : **Totals marked with an asterisk are incorrectly quoted in the original work.**)

TABLE 3.

	A.	B.	C.	D.	
SiO_2	50·00	47·76	39·10	34·68	43·7
Al_2O_3	16·69	16·82	16·25	17·52	16·9
Fe_2O_3..	1·97	2·15	3·82	8·47	3·8
FeO	9·20	9·92	14·20	8·56	10·5
MgO	5·04	5·43	7·57	4·52	5·6
CaO	7·22	6·34	8·93	16·00	9·3
Na_2O	3·74	3·43	1·46	0·64	2·5
K_2O	1·10	1·74	1·16	0·55	1·1
H_2O^+	3·25	3·83	4·77	4·39	4·2
H_2O^-	0·14	0·19	0·26	0·29	
TiO_2	1·68	1·87	1·97	4·08	2·3
MnO	0·21	0·24	0·28	0·26	0·2
P_2O_5	0·26	0·30	0·26	0·47	0·3
CO_2	0·00	0·00	0·00	0·00	—
	100·50	100·02	100·03	100·43	—
S.G.	2·91	2·94	3·14	3·23	—

Serial samples across a pillow, from spilite, Left-hand Branch Creek, Nundle, N.S.W. Anal.: Avery and Anderson (alkalis redetermined by T.G.V.).

A, dark-grey core.

B, greenish-grey zone.

C, dark-grey zone.

D, greenish margin.

The figures in the last column represent the calculated bulk composition of the pillow, assuming a spherical shape.

(Sundius, 1930) would clearly exclude many parts of spilitic bodies. Gilluly (1935) demonstrated that the 40% limit has no real meaning; he also showed that the normative feldspars of albite diabases have a similar range to those of spilites. Many new data for spilites plotted in Figure 3 (*a*) confirm Gilluly's view on the arbitrary limit. It is quite clear that spilitic rocks rich in lime are not necessarily rich in CO_2. Even if we make allowance for calcite in the norm a similar wide spread is apparent (Fig. 3, *b*). There is, however, a greater range of normative orthoclase than that shown by Gilluly. Although most students of spilites have claimed that high soda and low potash are characteristic of all spilites, it is evident that potash spilites exist and furthermore that there is a complete chemical gradation between potassic and sodic types. As far

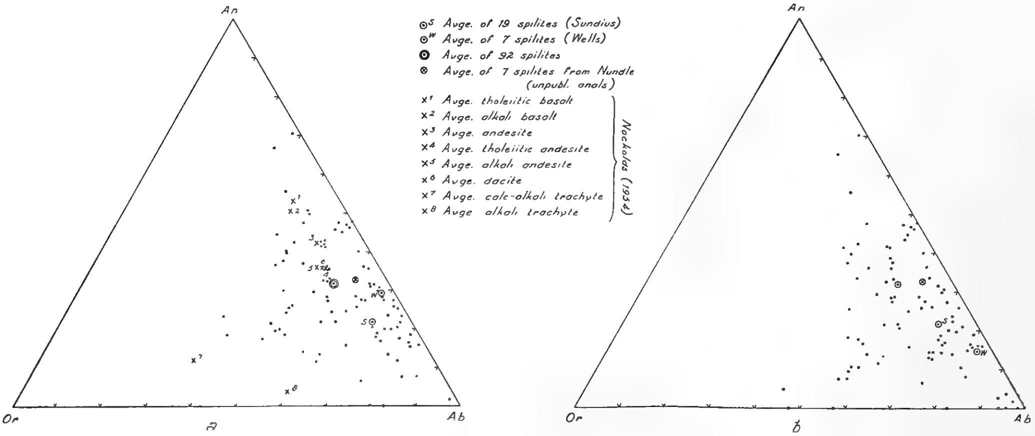

Figure 3.—Diagrams showing variation in normative Or-Ab-An for rocks called spilites (ref. Table 2). Various average compositions have been plotted for comparison. Fig. 3a represents normative feldspars calculated without regard to CO_2 content of the rock; in constructing Fig. 3b normative calcite was allotted before calculating the normative anorthite.

as the normative feldspars are concerned, there is clearly some overlap between normal basalts and spilites. Probably this overlap would be even greater if we could calculate bulk compositions of spilites. As a rough example, the normative feldspar appropriate to the bulk composition given in Table 3 is similar to the normative feldspars of average basalts. In this case, of course, the volume sampled is very small, but the occurrence of lime-rich patches, veins and cavity fillings is common and widespread in many spilitic bodies.

Sundius (1930) claimed that spilites have higher Fe/Mg ratios than basalts, but, as can be seen from Figure 4, there is a distinct similarity between Fe/Mg in tholeiitic basalts and in many rocks called spilites. Low ferric iron content, regarded by Wells (1923) as typical of spilites, is not general. Some groups of spilites, as, for example, those discussed by Dziedzicowa (1958), show consistently high values for ferric iron. The content of titania in the average spilites is not markedly different from that in the average basalts, though high titania was considered a characteristic of spilites by both Wells (1923) and Sundius (1930). In the analysed pillow from Nundle, titania is concentrated in the marginal zone. Perhaps titania, like lime, alkalis and iron and magnesia, is unevenly distributed in many spilites.

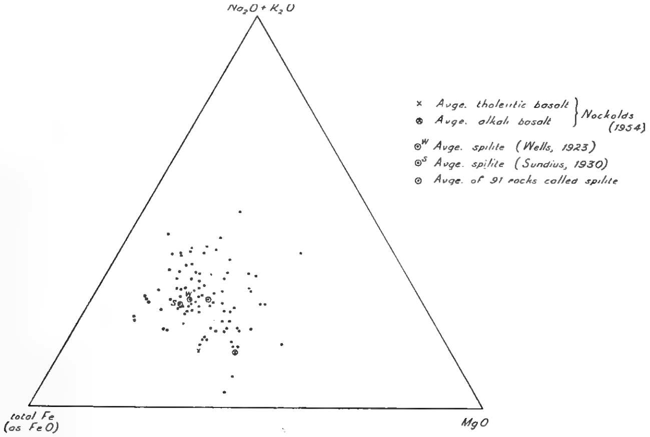

Figure 4.—Diagram showing variation in $Na_2O + K_2O$ – total Fe – MgO in rocks called spilites (ref. Table 2).

It seems to me that the most important chemical differences between basalts and spilites lie in the highly variable distribution of components in the latter. Sampling requires the closest attention in studies on spilites. As Amstutz (1958) has pointed out, most spilite analyses probably represent "fresh" samples, heterogeneous patchy material being ignored. Because of this sampling bias, the apparent differences between the "average" spilites and average basalts may be somewhat illusory. There is almost certainly a weighting of the average spilite in favour of the highly alkaline, lime-poor variants. Only combined water and, sometimes, carbon dioxide seem to be consistently more abundant in spilites than in basalts. One is certainly tempted to regard spilites as more sodic than normal basalts, but in view of the imperfect sampling I can only return a verdict of not proven. Perhaps some rocks called spilites are really hypersodic even in bulk, but I cannot believe that this is true of all rocks so named. It should be noted that the potassic spilites occur typically in epicontinental or continental associations; soda predominates in the alkali-rich parts of geosynclinal spilites.

ORIGIN OF SPILITES.

Controversy on the origin of spilitic rocks commenced even before Brongniart invented the name. We noted in the introduction that Lamanon had regarded the *variolite du Drac* as a volcanic rock, and for this view he was bitterly attacked by

Faujas de Saint Fond, among others. Lamanon later withdrew his paper and recanted. This same Faujas visited the toadstone localities in Derbyshire in 1784, and, recognizing the similarity between toadstones and *variolites du Drac*, concluded that none of these rocks was volcanic (Geikie, 1907). Whitehurst, who regarded the toadstones as volcanic rocks, seems to have been less influenced by Faujas' criticism than was Lamanon, and we find Whitehurst in 1786 stating that the toadstone was "as much a lava as that which flows from Hecla, Vesuvius, or Aetna". Subsequent work has shown the correctness of Whitehurst's view. Brongniart (1827), in his discussion on spilites, paid no attention to the question of genesis, but, as we have seen, it is likely that rocks of quite varied background were grouped together as spilites. Subsequently, the term was restricted more and more to rocks which we would now call igneous. Today, Perrin and Roubault, workers who have made a name for themselves through their advocacy of an extreme transformist view of granite, seem to be alone in regarding spilites (or, at least, one particular spilite) as the product of regional metamorphism acting on beds of quartzose dolomites (Perrin and Roubault, 1941). This view has been strongly attacked by den Tex (1950) and, I think, need not detain us here.

Although the great majority of modern workers agree that spilitic rocks are of igneous derivation and occur chiefly as effusive bodies, there is anything but agreement on the processes by which these rocks acquired their present characters. The theories proposed fall into three very broad groups. Spilites may be magmatic rocks which owe their present characters either to features inherent in the magma (e.g., richness in soda) or to special conditions of crystallization. According to these views the materials of spilites are derived from a magmatic source. Another view would attribute an important place to the influence of sea-water (or water in adjacent sediments) on still-molten magma. In this case some of the components may be derived from an extra-magmatic source. The third group of theories includes those suggestions that spilites are formed through the action of post-magmatic processes on basic igneous rocks. Van Overeem does not recognize rocks of the last group as true spilites, but I think we must consider the implications of post-magmatic action, especially as there is now a growing body of information on the alteration of rocks through diagenesis.

There is considerable evidence that most spilites are adjusted to conditions of low temperature and abundant water. These conditions may obtain in any of several contrasted environments, such as late magmatic (Wilshire, 1959), hydrothermal (Schwartz, 1939), low-grade metamorphic or diagenetic. As far as the origin of spilites is concerned, the important point is whether the adjustment to low temperature conditions is achieved through magmatic or post-magmatic processes. Eskola (1925) and Beskow (1929) were among the first to point out the similarity of spilite mineral assemblages and those of epimetamorphism. What little evidence is available on trace elements in spilites accords with the idea of low temperature adjustment. Both Scott (1951*a*) and Amstutz (1953) demonstrate higher Sc and Zr in spilites than in normal basalts; the accumulation of these elements suggests a low temperature environment. Despite the richness in Zr in the Swiss spilites zircon has not been recognized, and the only recorded case of zircon in spilites is that given by Duschatko and Poldervaart (1955). However, in this latter case, zircon, though commoner than in normal basalts, is of the same type as "basaltic" zircon.

As albite is a common phase in so many spilites the status of this mineral is especially significant. We have seen that Dewey and Flett regarded most spilitic albite as of replacement origin and, in fact, secondary albite has been regarded by some as essential in rocks called spilites. Turner (1948) claims that "the secondary origin of the albite [in spilites] can hardly be doubted". Many spilitic albites carry numerous inclusions of calcic minerals such as epidote-clinozoisite, and these are commonly considered as indicating an origin through replacement of a more calcic feldspar. In a few cases cores of labradorite or andesine surrounded by albite give clear evidence of original calcic feldspar. There are, however, also numerous examples in which the feldspars are free from inclusions and occur in environments at least locally deficient in lime. These albites have been interpreted as primary in origin (e.g., van Overeem, 1948; Amstutz, 1954). Clear albite is common in the spilites at Nundle and often occurs in sub-ophitic relation with fresh augite. Benson (1915*a*) regarded this albite as primary and his opinion has been widely quoted. Scott (1951*a*, *b*) and Battey (1956) have found albite crudely intergrown with fresh pyroxene and both consider the albite as primary. Probably no one doubts the primary nature of the clinopyroxene in spilites and it is argued from the sub-ophitic or intergrowth relations that the feldspar crystallized no later than the pyroxene. Certainly some feldspar did crystallize with the augite, but was it albite? Scott (1951*a*) claims that the albite-pyroxene intergrowths observed in the King Island spilites are eutectic in character analogous with the albite-diopside eutectic recognized by Bowen. This eutectic observed in an anhydrous system by Bowen carries about 97% An; the presence of water in the melt would, as Gilluly (1935) suggested, probably shift the eutectic even closer to the albite end. The intergrowths illustrated by Scott show no such excess of albite. In a later study, Scott (1954) stated that her conclusions on the King Island rocks do not hold generally for the Cambrian spilites of Tasmania, the albite being most commonly of secondary origin. Battey (1956) thinks that the fresh, often plumose augite, with $Mg > Fe$, in the North Auckland spilites was precipitated metastably "from a liquid in which high water content and consequent free diffusion has permitted the plagioclase to pass down the curve of continuous reaction to produce albite". Albite in the pyroxene-bearing spilites of Karelia is regarded by Eskola (1925) as of secondary origin. Most of the European spilites in which albite is interpreted as primary carry no pyroxene, but often contain considerable amounts of chlorite (van Overeem, 1948; Amstutz, 1954).

The low-temperature optics consistently found in spilitic albites indicate either a low temperature of formation or a complete adjustment during cooling from high temperatures. The latter is not likely in view of the common occurrence of glass in these rocks. However, as high-temperature pure albite is rarely found in any lavas, the low-albite in spilites may not be of itself specially critical. Petrographic experience indicates that low-albite may form directly, for example, in veins and cavities, and also as a replacement to an originally high-temperature more calcic feldspar. Karl (1954) supplies a good example of this latter in which the change was supposedly induced by slight metamorphism. In this process there is no indication of an inversion first to a low-temperature analogue of the primary calcic feldspar; low-albite replaces directly the earlier high feldspar with no observable intermediate steps. Features such as twinning may be inherited from the original feldspar. Donnay (1940), arguing from the French geometrical theory of twinning, on which ease of twinning is related to the obliquity of twin, predicted a systematic variation in the width of albite-twin lamellae with composition in the plagioclase series. Donnay's curve has now been revised by Gay (1956) using more accurate data, but the point remains that albite twinning should be much less frequent and hence the width of the lamellae greater in pure albite than in oligoclase. Obliquity increases again over the range An_{85-100}, but one may expect that for andesines and at least some labradorites the frequency of albite-twins would be greater than in low-albites. If this argument holds there should be systematic differences between the albite-twinning of primary albite and albite-twinning inherited from andesine or labradorite. The problem is essentially a statistical one and so far no one seems to have had the time and patience to tackle it. Again, Emmons (1943) claims that (001) twins are commoner in calcic than in sodic feldspars. If this can be established here is another possibility of distinguishing "inherited" twins from "primary" twins.

Amstutz (1954) has noted that the inclusion-free albites in patches and veins in his spilites are either untwinned or have few broad lamellae. Albites in the spilites at Nundle are often twinned and even some of the microlites of the groundmass may show one or two repeats. Fine albite-twinning in detrital feldspars of greywackes associated with the Nundle spilites is probably inherited. Most commonly these feldspars are now albite, but two calcite-rich greywackes in which the detrital feldspar is still recognizable as calcic andesine have been studied; the albite-twin frequency seems to be much the same in both albites and andesines. On the whole, I am inclined to regard the albites (except those in veins and cavities) of both spilites and greywackes at Nundle as secondary in origin. One of Benson's arguments for primary albite was that if the albite were secondary there should be signs of alteration in the associated pyroxene. But it is a matter of observation, unexplained as far as I know, that pyroxenes, doubtless metastable, may persist in hydrothermal environments, in sediments affected by diagenesis and in conditions of low-grade metamorphism (e.g., Vallance, 1953).

I do not think that we can be as definite about secondary albite in spilites as Turner (1948), but I must say that the claims of primary albite are not always very compelling. The mere absence of calcic inclusions and local deficiency in lime do not seem convincing criteria of primary origin. In almost every known spilite there are signs of local accumulations of lime. What is the source of this lime? Eskola, Vuoristo and Rankama (1937) have demonstrated experimentally that calcic feldspars are converted to albite, with the release of lime, in the presence of sodium carbonate solutions at moderate temperatures. Is there any comparable experimental support for the notion of primary albite in spilites?

The idea of a parental magma of special chemical character from which is derived a spilitic suite of rocks originated with Dewey and Flett (1911). These authors bestowed on this hypothetical magma the dignity of a place between the Atlantic and Pacific magma-types and claimed for it a characteristic geological occurrence—a spilitic province. Dewey and Flett regarded their spilitic magma as basic, but richer in soda, water and carbon dioxide than normal basaltic magma. Enrichment of late-stage solutions in soda and silica leads to the replacement of early calcic feldspars by albite (cf. Bailey and Grabham, 1909). Wells (1923) adopted this view of a spilitic magma and claimed in support of the idea that spilites were not associated with normal basalts. Not long after, Wells (1925) himself described an example of just such an association, and since that time it has been widely recognized. Sundius (1930) also "adopted" a spilitic magma, but in his view the peculiar composition determined the course of crystallization. Thus, through the inhibition of crystallization of olivine, the available lime is taken up in the ferromagnesian constituents, leaving albite to form as a primary constituent. According to Sundius (1930) there is no need to postulate autolysis and replacement of primary calcic feldspar even though earlier (Sundius, 1915) he had demonstrated the existence of labradorite relicts in the Kiruna spilitic greenstones. Backlund (1930) connected his spilites in Nowaya Zemlya with concentration of alkalis in what he calls an *Ursprungsmagma*, but it is not clear whether he regarded this as spilitic; his other writings suggest that he did not. Nicholls (1959) has recourse to a spilitic magma to account for the Builth spilites, and furthermore claims that metasomatic features are due to the action of related but immiscible liquid phases. There seems to me to be little evidence in support of a spilitic magma distinct from other basic magmas, and the known association of basalts and spilites is especially damaging to Dewey and Flett's claim. However, references are still made occasionally to spilite-keratophyre magma types (e.g., Semenenko, 1955), so the idea is not yet dead. The term spilite suite is still used, but nowadays this does not necessarily imply the existence of a spilitic magma.

The occurrence of adinoles at the margins of some spilitic bodies and the decrease in albitization away from the contacts indicate that these spilites, at any rate, held available soda at some stage during the cooling period. It should be remembered, however, that not all spilites are associated with adinoles. For example, there are no signs of adinoles in the fine sediments at Nundle. Benson (1915*a*) lists a sediment with 67·87% SiO_2, 1·10% Na_2O and 2·08% K_2O from the contact with a spilite; in some cases potash is even higher, as in this example also from a contact, 67·88% SiO_2, 0·81% Na_2O and 3·46% K_2O (unpubl. anal.).

Although some, perhaps many, spilites carried sodic solutions during the cooling, was this soda derived from the magma or from outside sources? Various answers have been suggested. Eskola (1925), for example, regarded the Karelian spilites as derived from normal calc-alkaline basalt magma and that retention of volatiles coupled with the effects of crystallization differentiation had led to the autolytic alteration of calcic feldspars. Chumakov (1940) seems to hold similar views. The intrusive spilites described by Tomkeieff and Marshall (1940) are supposed to have had their feldspars albitized through the influence of CO_2, the alkalis in these rocks being concentrated through the action of volatiles as carriers. Daly (1933) considered that the quantities of volatiles that could be retained within a magma were insufficient to achieve the mineral changes observed in spilites. According to Daly the magmatic volatiles were augmented by resurgent volatiles from deeper levels.

In recent years a number of European petrologists have outlined a scheme of hydromagmatic crystallization to account for spilites (Burri and Niggli, 1945; Vuagnat, 1946; van Overeem, 1948; Amstutz, 1954, 1958). According to this view spilites are derived from basaltic magma rich in volatiles, chiefly water, and these volatiles are retained during the cooling period. The high volatiles content is supposed to depress the freezing range, with the result that albite and, say, chlorite could crystallize as primary minerals. Niggli (1952) believed that accumulation of volatiles led to the development of spilitic material in the Keweenawan lavas. In this case there can be no doubt of early crystallization of olivine, pyroxene and calcic feldspar. Battey (1956) also appealed to a water-rich magma, but, as we have seen, the main assemblage in his spilites is albite-augite-chlorite, not albite-chlorite. Experimental work on hydrous systems does not offer much support for the hydromagmatic crystallization of spilites. In general, initial crystallization products in synthetic systems containing water appear to be anhydrous, though Yoder and Tilley (1956), in the preliminary work on the system natural tholeiite-water, have shown that abundant water, if retained, will lead to the development of amphibole-bearing assemblages. Crystallization in a water-rich environment might be expected also to lead to high Fe^{+++}/Fe^{++} ratios (cf. Kennedy, 1955). This ratio is extremely variable in spilitic rocks; Wells (1923) even claimed that spilites were notable for low Fe^{+++}/Fe^{++} values. The spilites analysed by Amstutz (1954) do, however, have considerable amounts of ferric iron and some of the Swiss spilites are quite rich in haematite. Hydromagmatic crystallization offers a possible explanation for some spilites, but I cannot believe that it is generally applicable.

Lehmann (1949, 1952*a*), who distinguishes between spilites (with secondary albite and chlorite) and weilburgites, envisages a process of what he calls "allopegmagenesis" to account for the Lahn weilburgites. He regards albite and chlorite in these rocks as primary, and the rocks themselves are supposed to have originated through the volatiles from an ascending diabasic magma acting on an earlier group of keratophyres. These views have been strongly criticized by Hentschel (1952*a*, *b*, 1953), who regards weilburgites as spilitic and the albite and chlorite as secondary products.

Some workers have been impressed by the common occurrence of spilites in submarine environments and attribute to sea-water or to water in wet sediments an important chemical role in the development of spilites. Beskow (1929) believed that albitization of calcic feldspar and the conversion of ferromagnesian minerals to chlorite as observed in spilitic rocks in Lapland were due to the action of sea-water heated during the extrusion of basaltic magma. Some of the soda involved in the albitization was thus of marine origin. Park (1946) accepts the idea of sea-water diffusion involving an exchange of Na for Ca. Gilluly (1935) emphasizes with Daly the influence of wet sediments on magma. In the spilites studied by Gilluly albitization of original feldspar seems to have occurred after complete consolidation and may have been related to the action of resurgent water or to the action of albite-rich residual solutions derived from a hypothetical trondhjemitic magma regarded as the source of abundant quartz-keratophyres. Barth (1936) has a rather cryptic reference to spilite as "formed by stewing of solid rocks in low-temperature liquids". Rittman (1958) and Szádeczky-Kardoss (1958) have both recently appealed to high water-pressures in deep-sea environments as a means of retaining magmatic water. Szádeczky-Kardoss claims that under these circumstances chlorite appears instead of augite, etc., and albite instead of calcic feldspar. This author considers that the formation of albite is aided by "transvaporization" of sea-water and states that this is the process of spilite formation investigated by Amstutz. It certainly cannot apply to Amstutz's (1954) Verrucano spilites which are of epicontinental type. Rittman's theory involves the retention of water, but "carbon dioxide and the other volcanic gases (HCl, H_2S, H_2, etc.) and gas transferred substances ($FeCl_3$, $MnCl_2$, $SiCl_4$, etc.) escape from the lava and form with sea-water pneumatolytic and hydrothermal solutions immediately at the roof of the outflowing lava". Rittmann believes that the chemically active solutions remain in contact with the lava in deep water and bring about reactions of the type andesine + augite + water + CO_2 = albite + epidote + actinolite + kaolinite + silica + calcite which he regards as a spilite reaction. Probably the greatest single difficulty in these deep-sea theories is that the formation of spilites is clearly not dependent on an abyssal environment. The sea-water diffusion theories are not of general application because some spilitic lavas are associated with non-marine environments (e.g., Dziedzicowa, 1958) and others may have been subaerial. Furthermore, there are now several records of non-spilitic submarine lavas. The pillow lavas from the mid-Atlantic ridge (Shand, 1949) appear to be normal basaltic types with olivine and calcic feldspar. The spilitic intrusion studied by Duschatko and Poldervaart (1955) contains sulphate minerals which may indicate addition from gypsum beds, but no case can be made there for the derivation of soda from the immediate environment.

So far we have considered mainly examples of spilite formation in the presence of volatiles at least partly juvenile in character. But the suggestions of Daly and Gilluly on the importance of resurgent waters may involve post-consolidational alteration. Gilluly, in fact, gives a convincing example of such late alteration in the Oregon spilites. It is an impressive fact that spilitic rocks are often associated with tuffs and greywackes (Tyrrell, 1933). Pettijohn and Bastron (1959) state that "the close association of many graywackes with spilitic rocks suggests that the sodium problem [in greywackes] is related to the origin of spilites". These sediments are often albite-bearing and may show many signs of extensive post-depositional mineral alteration, due to processes of diagenesis or low-grade metamorphism. It is an equally impressive fact that the post-depositional mineral assemblages of these sediments are often similar to those of the associated spilites. There is often clear evidence of growth of minerals such as albite, chlorite, epidote, prehnite, pumpellyite and zeolites in sediments after deposition. Coombs *et al.* (1959) offer examples from New Zealand. As this alteration is so extensive within a sedimentary pile it is clearly too much to expect it to result exclusively from the action of magmatic volatiles. Probably most of the fluid available for reaction and as a medium for the transfer of other components is connate in origin. The pore-water in geosynclinal sediments is often dismissed as sea-water, but it is likely that this water varies considerably in composition, the variation probably reflecting diagenetic or metamorphic changes in the rock (White, 1957). Controls such as pH, P_{load} and P_{H_2O} will have important influences on post-depositional mineral reactions in sediments. The work of Coombs in New Zealand has clearly demonstrated systematic changes in mineralogy with depth. Recently, Stoiber and Davidson (1959) have recognized systematic changes with depth in the amygdule minerals in basic lavas in Michigan. The Tamworth Group in which spilites occur at Nundle was probably overlain by a cover of the order of 40,000 feet of Devonian, Carboniferous and Permian sediments. Dr. K. A. W. Crook (pers. comm.) has found diagenetic mineral sequences in these rocks. Calcic zeolites of the types found in the New Zealand examples (Coombs *et al.*, 1959) have been observed by Dr. Crook in the rocks above the Tamworth Group, but are rare in the spilites and greywackes of the Tamworth Group itself.

There must be a continuous sequence from diagenesis to low-grade metamorphism and most of the mineral facies of spilites are akin to those of the Zeolite Facies and Greenschist Facies, appropriate to these environments. Quite clearly, diagenesis cannot be invoked to account for intrusive spilites such as those described by Duschatko and Poldervaart (1955). I think, however, that post-depositional diagenetic alteration offers possibilities as an explanation of the mineral changes in many geosynclinal spilites and greywackes. One great deficiency in the literature is the all too common omission of details concerning the mineralogy of sediments associated with spilites. The occurrence of rocks containing calcic feldspars associated with spilites is difficult to explain on the diagenetic theory. While on the subject of post-depositional alteration it is interesting to recall that Termier (1898) proposed a mechanism involving circulating ground-water in the zone of weathering to account for the spilites at Pelvoux. Dziedzicowa's (1958) spilites had earlier been regarded as weathering products.

Many spilites have been involved in deformative movements which have converted the rocks to greenschists. As a result some people (e.g., Sundius, 1915; Fairbairn, 1934) have regarded spilites as merely regionally metamorphosed basalts. As, however, there are numerous examples of undeformed spilites with similar mineral assemblages, I cannot believe that regional deformation is in any way essential to the formation of these rocks. I think there would be fairly general agreement with Rittmann's (1958) view that low-grade regional metamorphism of spilites is reflected mainly in changes in fabric, not in mineralogy.

I cannot see how any single hypothesis can account for all the occurrences of spilitic rocks. It is clear in some cases that volatiles have concentrated in the magma, leading possibly to direct crystallization of "spilite" minerals or to replacement of earlier anhydrous phases. In other cases an equally good argument can be made for post-consolidational changes. It is important to recognize that these processes are convergent as far as mineral products are concerned. In all of these processes the fluids available enter into mineral reactions and also serve as carriers. The heterogeneity of spilitic bodies, with some parts rich in soda and poor in lime, other parts rich in lime and poor in soda, and so on, is surely related to the transfer of materials in solution.

Two main spilite associations have to be explained. We have seen that in geosynclinal regions spilites may occur in close proximity to ultrabasic bodies—the ophiolite association—or with keratophyres and other more acid rocks. Both of these associations are too common to be purely accidental, although, in the case of the occurrence of ultrabasic bodies with spilites there may be rather variable time relations between the two rock types. For this latter reason Turner and Verhoogen (1951) regard spilites and serpentinites as belonging to different geosynclinal associations. European petrographers (e.g., Gees, 1956) incline to the view that all the ophiolites are derived from ultrabasic magma through gravity differentiations. This view raises the problem of the nature of ultrabasic "magma" and whether crystal sinking is possible in such a medium—a fascinating problem which I cannot pursue here. However, I find it difficult to reconcile differentiation from ultrabasic magma with the observations of Vuagnat and others that diabases are the most abundant ophiolitic rocks in the Pennine Alps. Van Bemmelen (1950) suggests that the ophiolite association represents "a geochemical culmination of cafemic constituents in front of acidification and migmatization of the crustal base", in other words, a "basic front".

The spilite-keratophyre association almost certainly involves differentiation from a basic magma. In view of the lack of evidence of a parental spilite magma it seems most reasonable to postulate the spilite-keratophyre group as derived from basaltic magma. It is instructive to compare spilite-keratophyre association with commonly accepted differentiation sequences. Figure 5 shows diagrammatically relations between SiO_2 and the ratios $CaO/CaO + Na_2O + K_2O$ and $Na_2O/Na_2O + K_2O$. The examples from California, taken as typical of a basalt-andesite-rhyolite sequence, shows a significantly different variation from that in the suite from Ascension and St. Helena. Examples of analyses of spilite-keratophyre suites are unfortunately rare, and those that have been studied may be imperfectly sampled. A great deal of chemical information is available on the rocks of the Lahn region, but, in view of the doubt about the significance of weilburgites, I have avoided this suite. The spilite association from Crimea is not completely satisfactory because Loewinson-Lessing and Diakonova-Savelieva (1933) suggest that this suite belongs to a group formed through mixing of acid and basic magmas. I have used this Crimean suite simply because I know of no other more suitable example offering a comparable number of analyses. It should be at once evident that there is a greater scatter of points in the spilite-keratophyre diagram than in the diagrams for normal differentiation. Spilites and albite dolerites from Nundle display more regular variations than the Crimean spilites, but the Nundle suite still shows definite departure in the Na_2O/Na_2O+K_2O ratio from those of the Pacific and Atlantic suites. There is even a suggestion of an increase in soda relative to total alkalis with increase in SiO_2 at Nundle; this is hardly the usual pattern in differentiation sequences. I must emphasize, however, that the Nundle area is still incompletely sampled. The Keewatin lavas, though

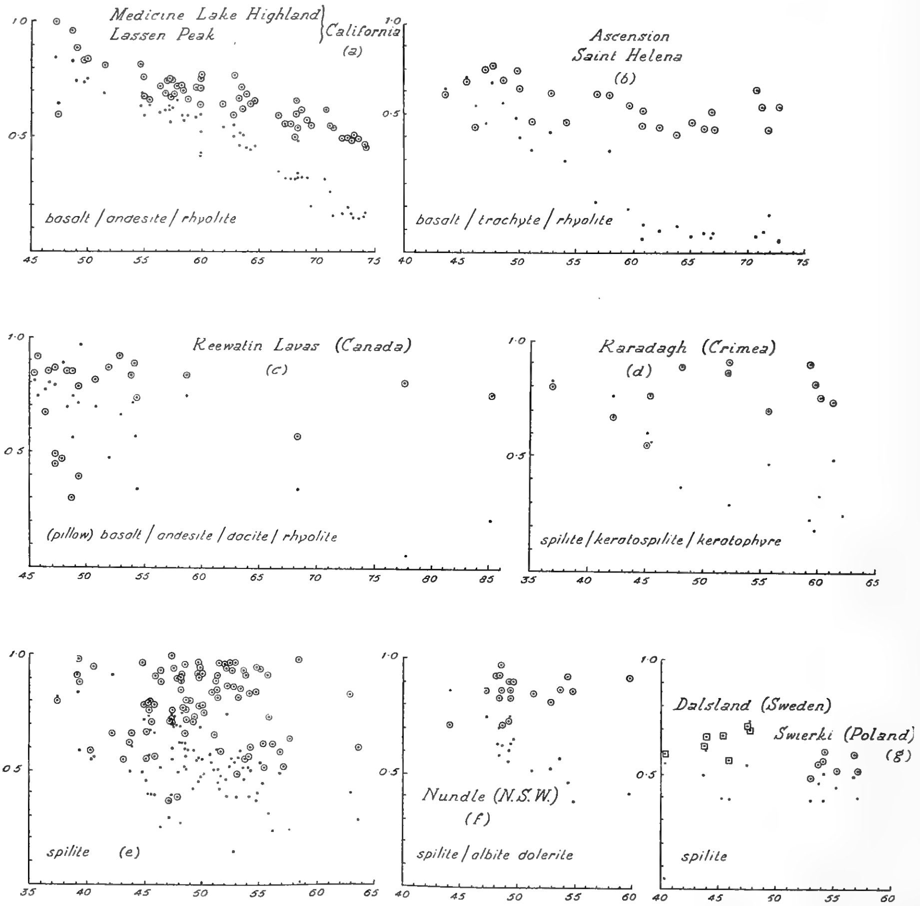

Figure 5.—Variation diagrams showing relations between typical calc-alkaline (a) and alkaline (b) suites and spilitic associations. In each case the horizontal scale represents SiO_2 (wt. %) and the vertical scale represents the ratios Na_2O/Na_2O+K_2O (enclosed spots) and $CaO/CaO+Na_2O+K_2O$ (spots). References for (a)—Anderson (1941) and Williams (1932), for (b)—Daly (1925, 1927), for (c) Satterly (1941) and Wilson (1938), for (d)—Loewinson-Lessing and Diakonova-Savelieva (1933), for (e)—Table 2, for (f)—unpublished analyses, for (g)—Dziedzicowa (1958) and Van Overeem (1948).

not regarded as spilitic by Canadian geologists, also show a wide scatter. Many of these lavas contain sodic felspar and signs of alteration of primary minerals are common. The variations in the Keewatin basalt-andesite-rhyolite association are certainly different from those in the more recent Californian suite.

Spilites and keratophyres are doubtless related genetically, but the high soda to total alkali relation in the more acid types sampled and the departure from regular serial variation in lime and alkalis seen in Figure 5 are unusual in differentiation series. Are these features superimposed on the main differentiations? Are spilites and keratophyres essentially basaltic and andesitic rocks in which there has been re-distribution of material and adjustment to low temperature, hydrous conditions? Such re-distribution might occur under the influence of any of several processes, late-magmatic, hydrothermal, or diagenetic/metamorphic. A suggestion along these lines, interpreting spilite as a modified basalt, was put forward by R. A. Daly years ago. I think the idea has a great deal to recommend it. Perhaps the main reason why spilitic rocks are so common in geosynclinal associations is because these environments offer such considerable opportunities for post-consolidational alteration.

In conclusion, I wish to thank my friends Mr. R. A. Binns (Cambridge), Prof. Dr. E. den Tex (Leiden) and Dr. V. A. Eyles (Oxford) for help in obtaining information on works not available in Australia. My thanks are also due to Miss G. Allpress, our Assistant Secretary, who very kindly collected the material for the first part of my address, and to my wife for patience and for typing a refractory manuscript. Acknowledgement is made of a grant from the University of Sydney to defray the cost of the analyses quoted in Table 3.

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THE SUBGENUS *OCHLEROTATUS* IN THE AUSTRALIAN REGION (DIPTERA: CULICIDAE).

III. Review of the Victorian Species of Perkinsi and Cunabulanus Sections with Descriptions of Two New Species.

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(Seven Text-figures.)

[Read 30th March, 1960.]

Synopsis.

Both sexes and larvae of *Aëdes continentalis*, n. sp., and *Aëdes waterhousei*, n. sp., are described. The male and larvae of *Aëdes luteifemur* Edwards and *Aëdes nivalis* Edwards, the larvae of *Aëdes cunabulanus* Edwards and *Aëdes andersoni* Edwards are described for the first time. The pupae of all species are figured. The notes on *Aëdes camptorhynchus* (Thomson) are given. An account is given of the biology and distribution of all species. The relationship of reviewed species is discussed.

The present paper is one of a series on the subgenus *Ochlerotatus* initiated by E. N. Marks (1957, 1958). In that first paper Marks proposed a subdivision of the Australian species of the subgenus into nine sections on the structure of the male terminalia. Southern species of the Perkinsi and Cunabulanus Sections will be reviewed here.

Edwards (1932) stated that "most of the species of the subgenus *Ochlerotatus* inhabit temporary ground pools and are single brooded". Marks (1957) indicated that the larval and pupal periods are usually short and that the adults appear suddenly in large numbers and are a pest for a limited period only. Studies on the biology of Victorian species of this subgenus have revealed that these conclusions cannot be applied to most Victorian species. The appearance of adults depends on the time at which breeding places filled by rainfalls, character of pools and their situation. Development of larvae in shallow pools exposed to the sun proceeds much faster than in deeper pools shaded by trees. These factors prolong the duration of adult occurrence in nature. An apparent disappearance of adults often means not that they have died out but that they have changed their habits. Thus *Aë. andersoni* in the Grampians and *Aë. waterhousei*, which are day biting mosquitoes during the spring, bite only after sunset during the summer and early autumn.

Moreover, unseasonal, heavy summer rainfall can fill breeding places and produce a second generation of spring species in the summer. IV stage larvae and pupae of *Aë. waterhousei* have been recorded in back water pools in stream bed in late March at Steiglitz, Victoria. At Bogong High Plains larvae of all stages and pupae have been collected in early December (G. W. Douglas) and all stages except youngest larvae were present in permanent pools in mid-February. *Aë. camptorhynchus* breeds all the year round.

Larvae of *Aë. contintentalis* and *Aë. andersoni* have not been collected during the summer, but biting adults of the first species have been recorded at Carpendeit in February and of the second species at Cape Otway and at the Grampians in March. It is hard to believe that these mosquitoes belonged to a spring generation; they were not rubbed and appeared to be recently emerged.

All the usual breeding places have been completely dry during the summer and it seems that they possibly continue to breed in some places which are difficult to locate. In South Australia, E. W. L. Lines (Marks, 1957) found that flooded rabbit

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burrows are an important breeding place of several species of mosquitoes. N. V. Dobrotworsky (1954) expressed the opinion (confirmed later) that some species of *Theobaldia* would be found to breed in subterranean waters in the tunnels of the land crayfish (*Engaeus* spp.). Thus the possibility is not excluded that above-mentioned species of *Aëdes* are able to breed in such places near creeks during the summer.

Biologically, the species reviewed in this paper have some common features: (1) The adults are most abundant during the spring; they are derived from larvae which have developed during the winter. (2) The eggs laid by that spring generation, on soil amongst decayed vegetation of dry or drying out pools, are able to survive the summer drought. (3) The eggs hatch after the breeding places are filled by rain water. (4) It is likely that all species given favourable conditions are able to produce one or more summer generations. (5) All species except *camptorhynchus* are confined to woodland areas with an average annual rainfall at least 16–18 inches.

The study of the morphological traits of the male terminalia as well as of the life histories revealed that a form of *cunabulanus* from the mainland is distinct, particularly on larval characters, from Tasmanian *cunabulanus*. This new form from the mainland is regarded as a distinct species which, on larval characters, is closer to *andersoni* than to *cunabulanus* and named *Aë. contintentalis*, n. sp. *Aë. nivalis* appears to be a complex of several forms. One of these which is readily distinguished, particularly on the male characters, will be described below as *Aë. waterhousei*, n. sp. The form *andersoni*, which is common in the Grampians, and distinguished by the absence of a patch of broad scales in front of the wing roots, will be treated as a form with undecided taxonomic status.

AËDES LUTEIFEMUR Edwards.

Aëdes luteifemur Edwards, 1926, *Bull. Ent. Res.*, 17: 112.

Distinctive Characters. Adults: Scutum uniformly clothed with goldish scales, with admixture of some black ones. Hind femora ochreous, with more or fewer dark scales towards apex. Wing dark-scaled, becoming pale distally, particularly on C and R. Female tergites unbanded, IV–VII mottled with creamy scales. Sternites clothed with whitish scales, with some admixture of ochreous scales. Male terminalia: Coxite with numerous long setae along inner edge. Apical lobe of coxite prominent; basal lobe shelf-like, having on its margin one short stout seta and row of about 13 long setae, about 7 of them recurved. Larva: Head seta 5, 3–5-branched; 6, 2–4-branched. Prothoracic seta 1, 1–2-branched; 2 and 6, single; 3, 2–3-branched; 4 and 5, 2-branched. Lateral comb of 20–23 fringed scales with long central tooth. Siphon index 2·9–3·4.

Description of Adult. Male. Head: Vertex clothed with curved and forked creamy scales becoming dark towards neck. Small elongate patch of narrow curved bronzy scales close to posterior margin of eyes. Broad flat white scales laterally. Proboscis and palps black-scaled. Palps longer than proboscis (without labella) by half length of 5th segment. Thorax: Integument brown. Scutum uniformly clothed with goldish scales, with some admixture of black ones. Scutellum with pale narrow curved scales and strong goldish bristles, a few of them may be dark. Anterior pronotum with narrow pale scales, and pale and dark bristles. Posterior pronotum with small patch of elongate white scales below, a mixture of elongate dark and narrow curved pale scales medially, and narrow curved pale scales above. Post-spiracular area with patch of narrow curved and elongate pale scales. Two lower mesepimeral bristles. Legs: Fore and mid femora mottled with pale scales anteriorly, pale posteriorly; hind femur pale on basal three-quarters, black apically with mottling of pale scales. Knee spots small. All tibiæ black anteriorly, and more or less pale posteriorly. Tarsi black, unbanded, with light mottling on 1st segment of fore and hind legs; a few pale scales at base of 2nd segment of hind legs. Claws of all legs with tooth. Wing length 4·6–5·2 mm. Cell R_2 about 1·2 times its stem. Wing scales dark brown, except those towards apex on C and R, which are paler. Abdomen: Tergites black-scaled, with some mottling of ochreous scales on VII and VIII, and white lateral spots. Sternites white-scaled, becoming ochreous towards apex of abdomen; segments with elongate black median patch, and admixture of black and ochreous scales apically. Terminalia (Fig. 1, *a*, *b*, *c*): Coxite dark-scaled sternally and laterally, with a few pale scales at base, with numerous strong setae; dense long setae along inner edge of coxite. Tergally coxite bears short fine setae along its inner aspect, laterally and apically with long and strong setae. Apical lobe prominent with 10–15 setae. Basal lobe prominent, shelf-like, having on its margin one short stout seta and row of about 13 long setae, about 7 of them recurved apically; several long setae and numerous fine short setae on its upper surface. Style about as long as coxite, curved, with 2–3 fine preapical setae; terminal appendage almost straight. Harpago stout with a few short setae at base; appendage widening rapidly near half length and tapering towards tip. Paraproct with single tooth. Lobes of IXth tergite with 5–7 short stout setae.

Female. Female differs from male as follows: Palps about one-seventh length of proboscis, black-scaled with some pale scales. Proboscis more or less mottled. Forked scales on vertex mostly black, with only a few pale scales in middle. Black scales on scutum more numerous, particularly in fossa. Narrow curved scales in front of wing roots may become white. Most bristles on scutellum dark. Posterior pronotum with small patch of elongate and narrow curved white scales below, a few narrow curved pale scales above along border with scutum, and black scales medially. Usually 4 lower mesepimeral bristles. Wing length 4·6–5·9 mm. Cell R_2 2·2–2·4 times its stem. Number of pale scales along C and R variable. Legs: Hind femur pale on basal half, becomes ochreous towards apex, and always with admixture of some black scales towards apex, particularly on dorsal side. Some specimens have black stripe on apical one-third of femur. May be some pale scales at base of 2nd and 3rd segments of tarsi. Abdomen unbended, purplish-black scaled with increasing admixture of ochreous scales, usually from segment 4 or 5. Some specimens have admixture of ochreous scales on all tergites, but others have only on tergites 6 and 7. Sternites clothed with whitish scales, with admixture of some ochreous scales in middle and at apical angles of segments, segment 7 usually ochreous-scaled.

Description based on specimens from the following localities: Otway, Carpendeit, Baxter, Maroondah, Yellingbo, Lower Tarwin, Wilson's Promontory, Victoria.

The specimens from Tasmania have an integument much lighter than mainland specimens. The upright forked scales on vertex are mostly creamy; the golden scales on the scutum are pale and in some specimens almost white. The apical part of the hind femur is ochreous with only a few scattered black scales dorsally.

The specimens from Flinders I. are intermediate in some traits (integument, colour of forked scales on vertex, number of black scales on hind femur).

Larva (Fig. 1, *f*, *g*, *h*, *i*). Head, siphon and saddle light brown. Head about three-fifths as long as broad. Antennae slightly more than half length of head, with scattered spicules; seta 1 arising about mid-length of antenna, 7–9-branched. Head seta 4, tiny, 5–6-branched; 5, 3–5-branched; 6, 2–4-branched; 7, 6–12-branched; 8, single or 3-branched; 9, 2–3-branched. Mentum with 13–14 lateral teeth on each side. Thorax: Prothoracic seta 1, 1–2-branched; 2 and 6, single; 3, 2–3-branched; 4 and 5, 2-branched; 7, 3-branched. Abdomen: VIIIth segment: Lateral comb patch of 20–23 fringed scales, central tooth about twice as long as nearest lateral one. Seta 1, 5–8-branched; 2, single, may be 2-branched; 3, 8–11-branched; 4, single; 5, 6–9-branched. Siphon tapering towards apex; index 2·9–3·4, mean 3·1. Pecten of 21–24 spines with 3–4 denticles at base, distal one usually the largest. Seta 1 arising about halfway along siphon, 6–9-branched, slightly plumose. Anal segment: Saddle covering dorsal three-quarters of segment, it covered with short arched rows of fine spines; a small separate sclerotized plate lies near lower proximal angle of saddle. Seta 1, single; 2, 5–7-branched; 3, single; 4 (ventral brush), of 15–16 tufts, usually one precratal, but may be two. Ventral pair of anal papillae slightly shorter than dorsal one, all pointed, less than half length of saddle.

Pupa. Details shown in Figure 1, *j*, *k*.

Biology. Aë. luteifemur, which is one of the most common spring species, breeds in clean rain water pools more or less exposed to the sun. Pools may be with or

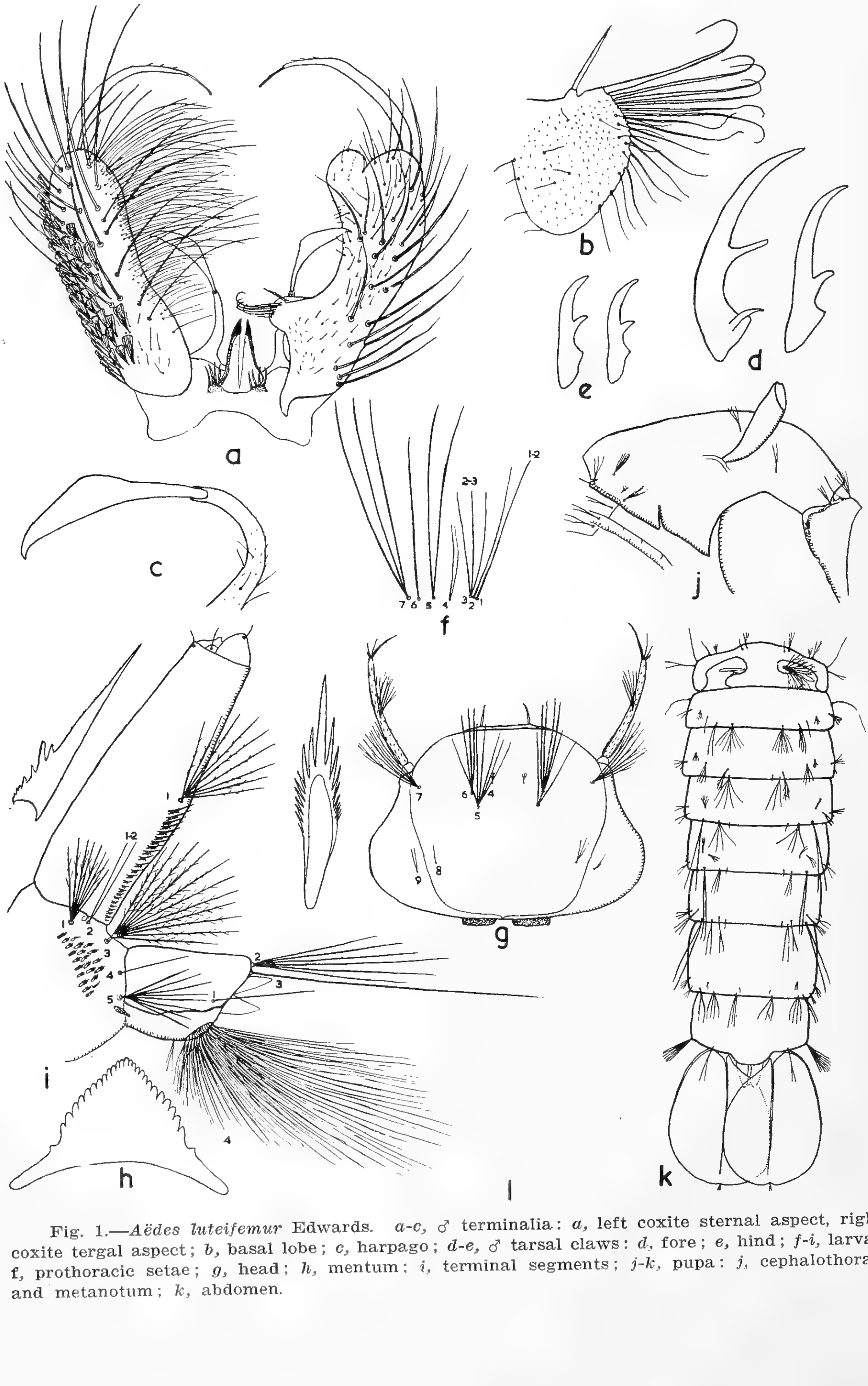

Fig. 1.—*Aëdes luteifemur* Edwards. *a-c*, ♂ terminalia: *a*, left coxite sternal aspect, right coxite tergal aspect; *b*, basal lobe; *c*, harpago; *d-e*, ♂ tarsal claws: *d*, fore; *e*, hind; *f-i*, larva: f, prothoracic setae; *g*, head; *h*, mentum; *i*, terminal segments; *j-k*, pupa: *j*, cephalothorax and metanotum; *k*, abdomen.

without vegetation and from a few inches to 2–3 feet deep, and often having decayed leaves on the bottom. The breeding places are usually confined to sparse woodlands; in more heavily timbered country this species is confined to cleared patches where it breeds in pits made by uprooted trees. The eggs hatch immediately after the breeding places become filled by rain water. The adults usually appear in September and have been collected as late as 5th March. A second, summer generation can develop in favourable conditions. Larvae have been associated with *alboannulatus, queenslandis, waterhousei, calcariae, flavifrons, purpuriventris.*

Biting habits. It is a day biting mosquito attacking man, rabbits and birds (hen). Its biting activities are restricted mainly to the vicinity of the breeding places.

Distribution. It is confined to woodlands, mainly in plain or low hills country, and has not been collected at altitudes greater than 2,000 feet. Specimens have been examined from the following localities: VICTORIA: Cabbage Tree Creek, Foster, Fish Creek, Wilson's Promontory, Tarwin Lower, Cranborne, Mornington Peninsula, Baxter, Maroondah, Healesville, Yellingbo, Woori Yallock, Ringwood, Anglesea, Cape Otway, Gorae West, Timboon, Drik Drik, Ballan, Lyonville, Grampians, Carpendeit (N. V. Dobrotworsky); Lady Barron, Flinders I. (F. N. Ratcliffe and D. L. McIntosh); TASMANIA: Lake St. Clair (S. G. Anderson).

AËDES WATERHOUSEI, n. sp.

Types. The type series was bred from larvae and pupae collected at Wattle Glen, Victoria: Holotype male and allotype female 8.9.55, nine paratype males and nine paratype females 25.4.54, 3. and 8.9.55, 5.1.55, 26.9.57 and 3.11.58. The holotype, two paratype males, the allotype and nine paratype females have their associated larval and pupal skins. The holotype male, allotype female, four paratype males and four paratype females are in the collections of the National Museum, Melbourne. One paratype male and one paratype female are in each of the following collections: C.S.I.R.O., Division of Entomology, Canberra; School of Public Health and Tropical Medicine, Sydney; University of Queensland, Brisbane; British Museum (Natural History), London; U.S. National Museum, Washington.

This species is named after Mr. E. J. Waterhouse, C.S.I.R.O., Wildlife Survey Section, whose extensive collections and studies of the breeding places in the Armidale area of N.S.W. have contributed much to an understanding of the taxonomic status of the *nivalis* complex.

Distinctive Characters. Male: Hind femur pale on basal three-quarters. Tergites black-scaled, with white basal bands. Coxite with large number of long setae directed mesially. Basal lobe of coxite shelf-like, having on margin one short stout seta and row of 11–13 long setae, 7–8 of them recurved. Female: Scutal scales mesially, particularly between dorso-central bristles, narrow, straighter, bronze. Tergites 2–3 with basal white bands convex posteriorly. Tarsi unbanded. Larva: Head seta 6, usually 2-branched. Prothoracic seta 1, 2-branched; 2, 4 and 6, single; 3, 2–4-branched; 5, 2–3-branched; 7, 3-branched. Spines from lateral comb fringed at base; central tooth 3–4 times longer than longest lateral one. Siphon index 2·6–3·0. Anal papillae narrow, about as long as length of saddle.

Holotype Male. Head: Vertex clothed with curved and forked creamy scales; elongate patch of narrow curved bronzy scales close to posterior margin of eyes. Broad white scales laterally with central patch of dark scales. Palps slightly longer than proboscis (including labella), black-scaled; hairs on apex of segments 3 and 4, long, dark. Proboscis black-scaled. Thorax: Integument dark brown. Scutal scales narrow curved. Those scales mesially between dorso-central bristles, inner half of fossa and lateral areas, narrower, straighter, dark bronze. Outer part of fossa, margin of lateral area, and area round prescutellar bare area, clothed with larger pale scales. Scutellum with narrow curved pale scales. Anterior pronotum with narrow curved pale scales, pale and dark bristles. Posterior pronotum with a few elongate pale scales below, curved and elongate dark scales medially, and curved pale scales above. Post-spiracular area with patch of elongate and narrow curved white scales and pale bristles. 2–3 lower mesepimeral bristles. Legs: Fore and mid femora dark above, and mottled with white scales, basal three-quarters pale below. Hind femora pale on basal three-quarters, dark-scaled on dorsal one-quarter, with some mottling anteriorly. All tibiae dark-scaled, with some pale scales. Tarsi unbanded. Wing length 4·5 mm., black-scaled. Cell R_2 1·1 times its stem. Abdomen: Tergites dark-brown-scaled. Basal white bands broken in middle but joining white lateral spots. Venter white-scaled with black elongate central patch and apical lateral patches. Terminalia (Fig. 2, *a*, *b*, *c*): Coxite dark-scaled sternally and laterally, with a few pale scales at base, with numerous long setae directed mesially, and a number of strong, long setae scattered along distal one-third, 5–6 being particularly strong and long. Tergally coxite bears a few small setae on its basal half or two-thirds, long setae laterally and distally. Apical lobe prominent with several fine setae. Basal lobe shelf-like, with several fine setae on its upper surface, having on its margin one short stout seta, and row of 11–13 long setae, 7–8 of them recurved apically. Style slender, curved tapering on distal third, with 3 preapical setae; appendage slender, almost straight. Harpago with a few moderately strong setae, appendage blade-like, expanding gradually at mid-length and then tapering to curved tip. Paraproct with single tooth. Lobes of IXth tergite with 4–7 strong short setae.

Allotype Female. Differs from the male as follows: Head: Patch of narrow curved bronzy scales close to posterior margin of eyes larger than in male. Palps one-quarter length of proboscis, black-scaled with a few pale scales. Five lower mesepimeral bristles. Wing length 5·5 mm. Cell R_2 1·9 times its stem. Legs with conspicuous knee spots. Tibiae paler underneath. First segment of all tarsi with pale scales basally. Tergite 1, with pale scales; 2–6, with basal white bands convex posteriorly. Peak of triangular band on segment 6 almost touching apical border. Black median patches on sternites as long as half length of segment, apical lateral black spots small.

Paratype Females. The chief variations shown in a series of 9 females are: Some have two narrow lines of goldish scales along acrostichal bristles and along borders of lateral area of scutum. The mottling of black apical part of hind femora is variable. Wing length 5·0–5·5 mm. Basal bands on tergites may be reduced to small triangular patches. Some specimens have an irregular mesial patch of creamy scales on tergites 2–6; others have two such patches mesially on tergites 3–4.

Larva (Fig. 2, *d*, *e*, *f*, *g*). Head, siphon and saddle dark brown. Head about three-quarters as long as broad. Antenna about half length of head, spiculated; basal quarter light brown, distal three-quarters darker. Seta 1, 6–8-branched. Head seta 4, tiny, 3–5-branched; 5, usually 3-branched, rarely 4; 6, usually 2-branched, rarely 3; 7, 5–8-branched; 8, usually single, may be 2-branched; 9, 2-branched. Mentum with small central tooth and 11–12 lateral teeth on each side. Thorax: Prothoracic seta 1, 2-branched; 2, 4 and 6 single; 3, usually 3-branched, rarely 2 or 4; 5, 2–3-branched; 7, 3-branched. Abdomen: VIIIth segment: Lateral comb patch of 20–29 spines, fringed at base; central tooth 2–3 times longer than longest lateral tooth. Seta 1, 4–6-branched; 2 and 4, single; 3, 7–11-branched; 5, 4–6-branched; seta 1, 3 and 4 plumose. Siphon almost cylindrical up to distal spine of pecten, then tapering towards apex; index 2·6–3·0, mean 2·8. Pecten on basal half of siphon, of 21–30 spines, mean 25; spines at base with 4–5 teeth. Seta 1, 7–9-branched. Anal segment: Saddle covering dorsal three-quarters of segment and covered with short arched rows of fine spines; a small separate sclerotized plate lies near lower proximal angle of saddle. Seta 1, single, about as long as saddle; 2, 4–7-branched; 3, single; 4 (ventral brush), of 18–19 tufts, may be one precratal tuft. Anal papillae narrow, about as long as length of saddle.

Pupa. Details shown in Figure 2, *h*, *i*.

Biology. In New South Wales larvae have been collected in the Armidale area (E. J. Waterhouse) at heights of 2,800–4,700 feet from August until the end of October. They were breeding in pools with cloudy water, with or without vegetation, usually exposed to the sun. Usually the pools were shallow, but some were up to three feet deep. The breeding sites were situated mostly in the open, but sometimes amongst white gums or along gullies near the edge of forests.

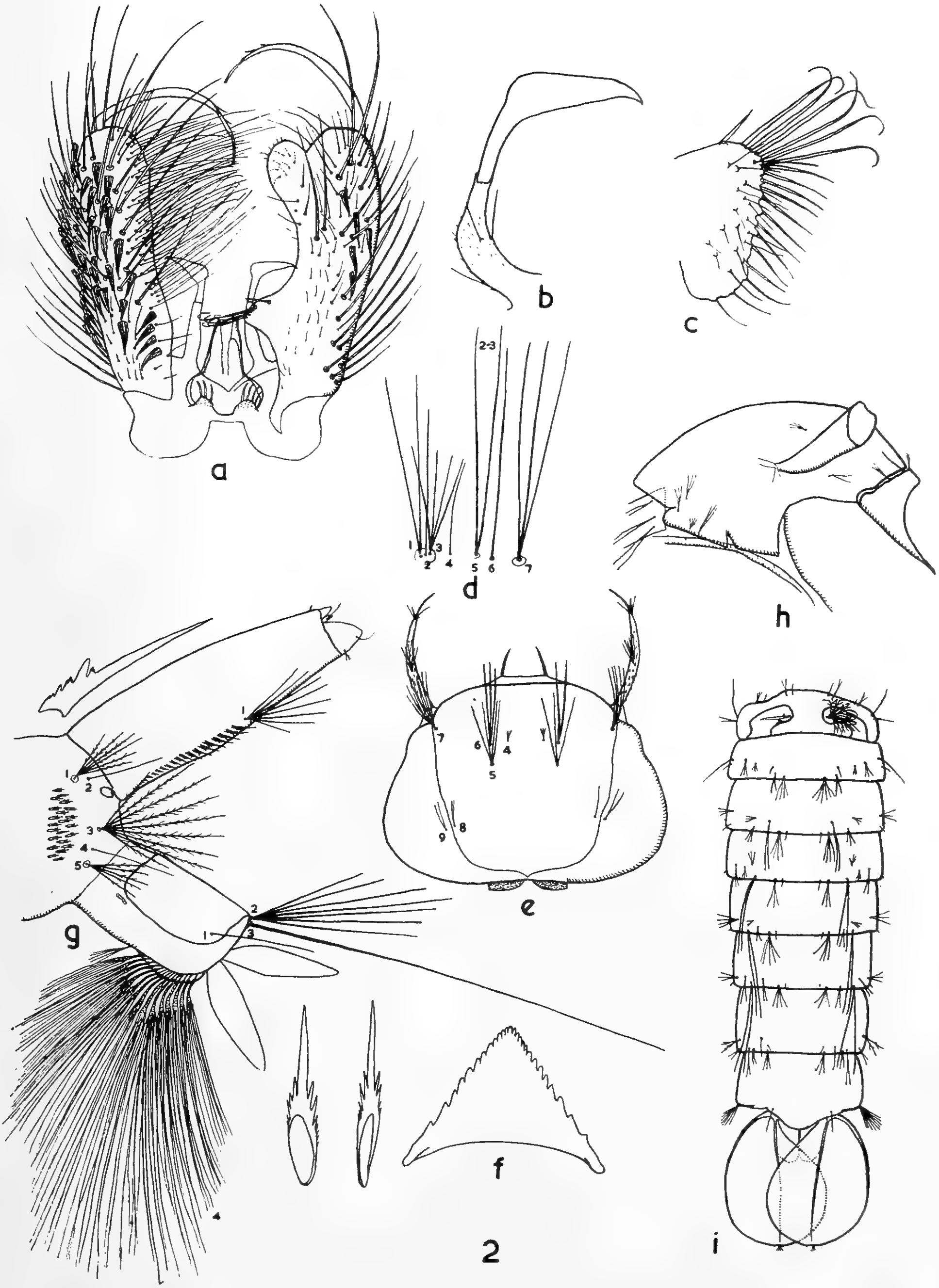

Fig. 2.—*Aëdes waterhousei*, n. sp. *a-c*, ♂ terminalia: *a*, left coxite sternal aspect, right coxite tergal aspect; *b*, harpago; *c*, basal lobe; *d-g*, larva: *d*, prothoracic setae; *e*, head; *f*, mentum; *g*, terminal segments; *h-i*, pupa: *h*, cephalothorax and metanotum; *i*, abdomen.

In Victoria this species breeds in elevated country at altitudes up to 2,500 feet, but also spreads down to flat woodland country; it has been collected north-west of Horsham (G. W. Douglas). Although *waterhousei* is confined to woodland it avoids completely shaded pools in dense forests. Shallow valleys or plains with sparse bush are also favoured breeding sites of this species. The larvae have frequently been found in pools 1–3 feet deep with clear or cloudy water. In most places *waterhousei* has only one generation per year. Larvae hatch immediately after adequate autumn-winter rains, and usually complete their development during September-October. An additional summer generation is possible when heavy summer rains fill breeding places. At Steiglitz fourth stage larvae and pupae have been collected in backwater pools in creek beds late in March.

In New South Wales *Aë. waterhousei* was associated with larvae of *Aë. nivalis, alboannulatus, sagax, milsoni*; in Victoria with *Aë. queenslandis, alboannulatus, luteifemur, inconspicua* and *Aë.* (*Pseudoskusea*) sp.

Time of appearance of adults depends on weather conditions and may occur as early as August. September is the more usual time, and adults then remain numerous until November. In New South Wales biting adults have been recorded at 3,300 feet in March (Armidale, E. J. Waterhouse). In Victoria this species has also been recorded biting in the autumn, but only after sunset, at Grampians early in March.

Biting Habits. Aë. waterhousei is a day biting species which is very numerous near its breeding places. During hot dry weather it bites only after sunset.

Distribution. Distribution of *Aë. waterhousei* sometimes overlaps that of *Aë. nivalis*, but it does not occur at such high altitudes as the latter species; it is apparently absent from Barrington Tops, Mt. Kosciusko and Bogong High Plains. On the other hand *waterhousei* occurs at lower altitudes and has a much wider distribution. It seems that this species is not common either in South Australia or Tasmania. Specimens have been examined from the following localities: N.S.W.: Colo Vale (A. K. O'Gower), W. Uralla, "Robert" Uralla, Ben Lomond (E. J. Waterhouse), Urana (G. W. Douglas); A.C.T.: Condor Creek (J. F. Hill); VICTORIA: Tubbut (E. Bass), Warrandyte, Christmas Hills, Ringwood, Wattle Glen, Steiglitz, Euroa, Ballan, Lyonville, Grampians, Stawell, Cavendish, Armstrong, Ararat, Barkley (N. V. Dobrotworsky), Boto, Maryvale (G. W. Douglas); S.A.: Mt. Torrens (E. W. L. Lines), Belair Nat. Pk. (G. F. Gross); TASMANIA: Hobart (G. H. Hardy).

AËDES NIVALIS Edwards.

Culex australis, Theobald, 1911 (not Erichson, 1842), *Mon. Cul.* II: 91. *Aëdes nivalis* Edwards, 1926, *Bull. Ent. Res.*, 17: 112.

Distinctive Characters. Adults: Male with hairs but no scales on tergites, except for lateral patches of white scales. Terminalia: Coxite with numerous long setae along inner edge directed mesially; tergally with 5 or 6 long strong setae arranged in a row directed to base of apical lobe. Basal lobe shelf-like, having on margin one short stout seta, one long stout recurved seta and 4–6 finer setae, 3 or 4 of them with recurved tips. Female: Scutum clothed with narrow golden scales. Hind femora pale on basal two-thirds, black apically; tarsi unbanded. Tergites black-scaled with basal bands almost straight. Larva: Head seta 5 and 6, usually 3-branched. Prothoracic setae: 1, 2-branched; 2 and 6, single; 3, 2–5-branched; 4, single or 2-branched; 5, 2–3-branched. Lateral comb patch of 18–27 spines fringed at base; central tooth usually 3–4 times longer than longest lateral one. Siphon index 2·6–3·6. Pecten of 20–26 spines. Anal papillae narrow, longer than saddle. Larva sometimes cannot be distinguished from that of *waterhousei*.

Description of Adult. Male. Head: Vertex clothed with curved and forked creamy scales, latter becoming black towards neck. Broad flat white scales laterally with central patch of dark scales. Elongate patch of narrow curved bronzy scales close to posterior margin of eyes. Palps as long as proboscis including labella, black-scaled. Proboscis black-scaled. Thorax: Integument dark reddish-brown. Scutal scales narrow curved golden, but broader and paler in front of wing roots and around prescutellar bare area; a few small black scales scattered on scutum. Scutellum with curved narrow pale-golden scales. Anterior pronotum with narrow curved pale-golden scales and bristles, latter becoming black dorsally. Posterior pronotum with patch of elongate white scales below, narrow curved goldish and black scales medially, and pale goldish scales above. Post-spiracular area with patch of broad, and narrow curved white scales and a few bristles. 3–4 lower mesepimeral bristles. Legs: Fore and mid femora dark above with some mottling, pale for three-quarters length below. Hind femur pale on basal two-thirds, black apically with a few scattered white scales. Wing length 4·3–5·6 mm., black-scaled. Cell R_2 1·1 times its stem. Abdomen: Tergites black, hairy, without dark scales, with only lateral patches of white scales. Venter white-scaled with large median black patch and black apical border to segments. Terminalia (Fig. 3, *a*, *b*, *c*): Coxite dark-scaled laterally and sternally. Sternally coxite bears numerous long setae directed mesially, several strong long setae scattered along coxite, 5 or 6 most distal of them strongest and longest. Tergally coxite bears numerous small setae on its basal two-thirds, long setae laterally and distally, and level with apical lobe, a row of 5–6 long strong setae. Apical lobe large with several fine setae. Basal lobe shelf-like, upper surface bears several fine setae having on margin one short stout seta, one long stout recurved seta and 4–6 finer setae, 3–4 of them with recurved tips. Style slender curved, tapering on distal one-third with 2–3 preapical setae and numerous minute setae below; appendage slender, slightly curved. Harpago stout curved, with a few moderately strong setae on basal half; appendage blade-like, expanding gradually towards mid-length and then tapering towards curved tip. Paraproct with single tooth. Lobes of IXth tergite with 3–6 short strong setae.

Female. Female differs from the male as follows: Palps one-fifth length of proboscis, black-scaled, with a few pale scales. Posterior pronotum may be clothed mainly with pale scales and have only a few black scales medially. 4–5 lower mesepimeral bristles. Wing length 4·0–6·0 mm. Cell R_2 1·8–2·0 times its stem. Legs with conspicuous knee spots. Tergites black-scaled; segments 1–2, with patch of white scales; 3–4, with incomplete basal band; 6–7, with band joining lateral patches. Segments 3–7 may have complete basal bands. Sternites with central and apical lateral patches of black scales.

Larva (Fig. 3, *d*, *e*, *f*, *g*, *h*, *i*). Head, siphon and saddle dark brown. Head about four-fifths as long as broad. Antenna about half length of head, spiculated, basal one-quarter light brown, distal three-quarters dark, almost black, may be lighter towards tip. Seta 1, 5–6-branched. Head seta 4, tiny, 2–5-branched; 5, usually 3-branched, rarely 4-branched; 6, usually 3-branched, rarely 2- or 4-branched; 7, 5–9-branched; 8, single; 9, usually 2-branched, rarely single. Mentum with small central tooth and 11–13 lateral teeth on each side. Thorax: Prothoracic seta 1, 2-branched, rarely 3-branched; 2 and 6, single; 3, 3–4-branched, may be 2- or 5-branched on one side; 4, usually single, rarely 2-branched; 5, 2–3-branched; 7, 3-branched. Abdomen: VIIIth segment: Lateral comb patch of 18–27 slender spines fringed at base. Central tooth 3–4 times as long as longest lateral tooth. Seta 1, 4–7-branched; 2 and 4, single; 3, 8–11-branched; 5, 8–7-branched. Seta 1 and 3 plumose. Siphon almost cylindrical from base up to seta 1, then tapering towards apex; index 2·6–3·6, mean 3·0. Pecten extending about half of length of siphon, with 20–26 spines, each with 3–4 small and one larger denticles at base. Seta 1, 6–8-branched. Anal segment: Saddle covering dorsal half of segment; surface with fine spines arranged in short arched rows. Small separate chitinized plate near lower proximal angle of saddle. Seta 1, single; 2, 5–8-branched; 3, single; 4 (ventral brush), of 16–17 tufts, one sometimes precratal. Anal papillae narrow, longer than saddle.

Description of adults and larva based on specimens collected at Marysville, Victoria (type locality).

Pupa. Details shown in Figure 3, *k*, *l*.

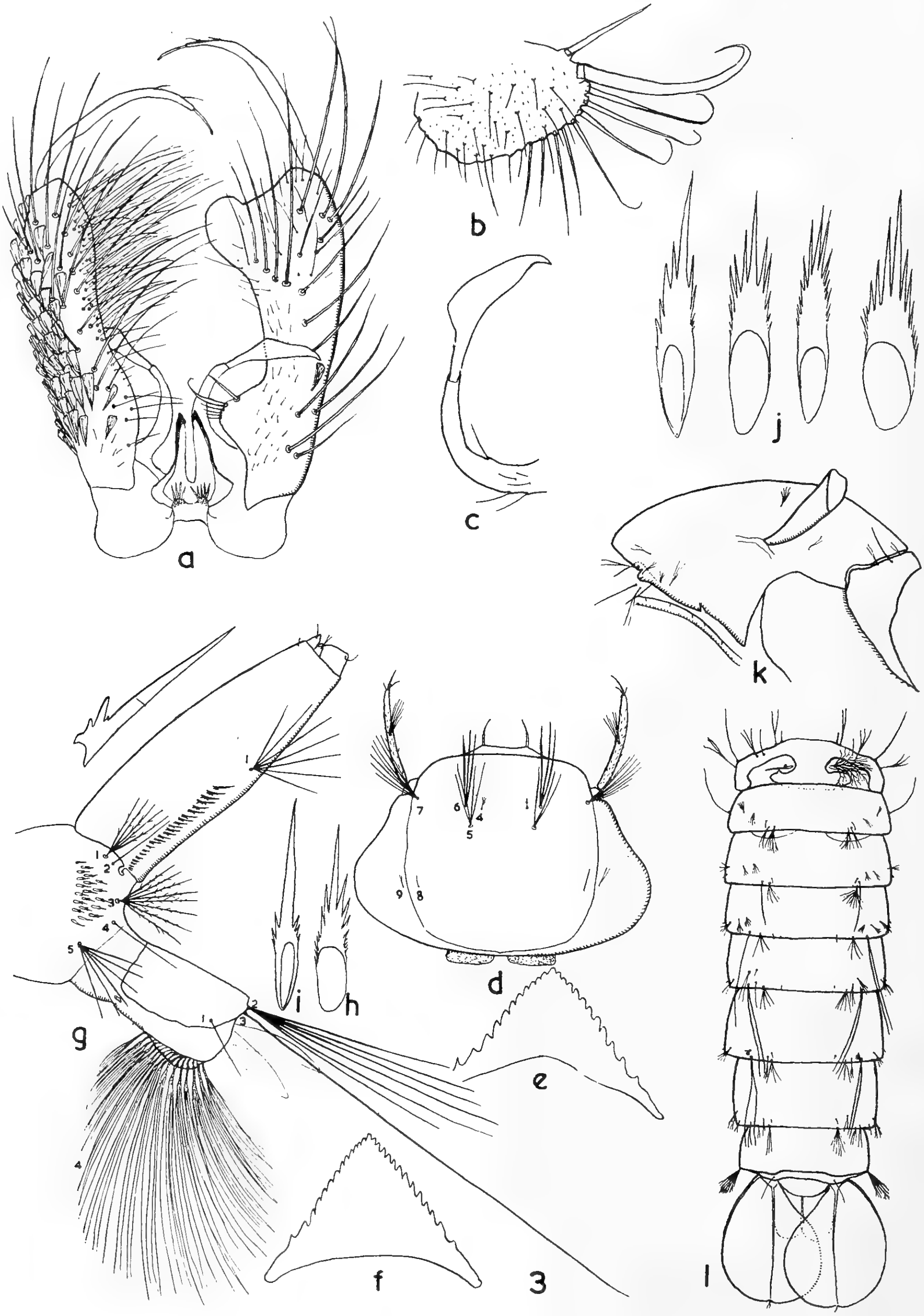

Fig. 3.—*Aëdes nivalis* Edwards. *a-c*, ♂ terminalia: *a*, left coxite sternal aspect, right coxite tergal aspect; *b*, basal lobe; *c*, harpago; *d-j*, larva: *d*, head; *e*, mentum of larva from Marysville; *f*, mentum of larva from Lyonville; *g*, terminal segments; *h-j*, lateral comb teeth: *h*, from Marysville; *i*, from Lyonville; *j*, from Bogong; *k-l*, pupa: *k*, cephalothorax and metanotum; *l*, abdomen.

Bogong form of AËDES NIVALIS.

Specimens of *Aë. nivalis* from Bogong High Plains agree in general with *nivalis* from the type locality, but are smaller (wing length of the males 4·2–5·2 mm., the females 4·1–5·0 mm.) and darker. There are some differences in morphological traits of the larva: prothoracic seta 1 has 3–8 branches, with mean of 5 branches, whereas in larvae from other populations it has only 3–4 branches. The scales of the lateral comb are highly variable; they may have a single central tooth three times longer than the nearest lateral one or three long central teeth almost equal in size (Fig. 3, *j*).

Biology. Aë. nivalis is confined mainly to elevated country and rarely descends to the plains. In New South Wales it has been recorded at Barrington Tops at 5,000 feet (I. M. Mackerras, 1927), Mt. Kosciusko 6,000 feet (L. E. Cooling, 1924) and was recently collected in the Armidale area (E. J. Waterhouse) at 3,300–4,800 feet. Here in 1955 larvae were found during August and September in pools usually exposed to the sun, with or without vegetation, mainly in water cloudy with colloidal clay suspension. Adults were collected until March. In Victoria it breeds usually at altitudes higher than 2,000 feet, mainly in shallow pools with decayed leaves, but also in deeper ones 2–3 feet deep. The pools are usually exposed to the sun or to dispersed light; only once have larvae been collected from a shaded pool. Water in pools was clear or cloudy. Although *nivalis* is associated with woodland, it avoids dense forests with deep shade and is confined to the sparse patches of bush or clearings. The Bogong form breeds on High Plains at altitudes 5,300–5,400 feet in pools 1–2 feet deep exposed to the sun.

It seems likely that in most localities *nivalis* has only one generation a year, because the breeding places remain dry during summer months, but the Bogong form breeds continuously in permanent pools during the summer, and passes winter in the larval stage under ice. Laboratory experiments have shown that larvae survive in iced water at 0°C., but die at –4°C., in solid ice.

At higher altitudes, e.g. Marysville (3,000–3,200 feet), the larvae did not complete their development before the end of November, and in the Mt. Buller area (4,000 feet) larvae have been collected late in December. At lower altitudes (Lyonville) larval development usually is completed not later than the end of October.

In New South Wales *Aë. nivalis* larvae were associated with *Aë. waterhousei* and *alboannulatus*; in Victoria also with *queenslandis* and at Lyonville sometimes with *flavifrons*, *purpuriventris*, *calcariae* and *T. inconspicua*.

Distribution. Aë. nivalis is distributed along the Great Dividing Range from the north of New South Wales (Ben Lomond) to the Grampians in Victoria. It reaches the highest altitudes at Mount Kosciusko (6,000 feet). It has also been recorded in Tasmania. Specimens from the following localities have been examined: N.S.W.: Barrington Tops 16.1.34 (I. M. Mackerras?); "Walsh" Ben Lomond 12.9.55, Ben Lomond 3.3.56 (E. J. Waterhouse); Colo Vale 16.10.56 (W. Wirth); 20.11.57 (J. C. Towitsh); Mt. Kosciusko 31.12.33 (I. M. Mackerras); Ebor 16.10.50. VICTORIA: Bogong High Plains 6.12.56 (G. W. Douglas); 13.2.58 (N. V. Dobrotworsky); Mt. Buller area 19.12.58, Marysville 14.11.57, 25.11.58, Trentham 27.10.57, Ballan 11.10.56, Lyonville 14.12.54, 19.10.55, 19.11.55, 13.9.56, Mt. Victory (Grampians) 26.9.58 (N. V. Dobrotworsky).

AËDES CAMPTORHYNCHUS (Thomson).

Culex camptorhynchus Thomson, 1868, Eugenies Resa, Dipt. 443. *Culex labeculosus* Coquillett, 1906, *Ent. News*, 16: 116. *Culicelsa westralis* Strickland, 1911, *Entom.*, 44: 131. *Culicada inornata* Strickland, 1911, *Entom.*, 44: 201. *Culicada annulifer* Taylor, 1913, *Trans. Ent. Soc. London*, 693. *Culicada victoriensis* Taylor, 1914, PROC. LINN. SOC. N.S.W., 39: 400. *Culicada nigra* Taylor, 1914, *Trans. Ent. Soc.*, 688.

Distinctive Characters. Adults: Wing dark-scaled. Femora, tibiae and first tarsal segment mottled with white scales. Tarsi banded. 2–3 lower mesepimeral bristles. Tergites with white basal bands; female with convex basal bands. Male terminalia: Coxite with prominent apical lobe and moderate basal lobe. Basal lobe having on margin one short stout seta, one long stout recurved seta and 6–11 shorter and finer straight setae. Larva: Head seta 5, 3–4-branched; 6, 2–3-branched. Prothoracic setae: 1, 2-branched; 2, 4, 5 and 6, single; 3, 2–4-branched; 7, 2–4-branched. Comb of 24–33 fringed scales. Siphon index 2·0–2·3. Anal papillae very small rounded.

Description of Adult. Male. Head: Vertex usually clothed with narrow curved and forked pale scales; latter may be dark laterally and towards neck. Lateral scales broad white except for dark patch. Proboscis entirely black-scaled or with a few pale scales. Palps as long as proboscis, dark-scaled, with white scales at base of segments 2, 4 and 5. Antenna with long pale lustrous hairs. Thorax: Integument dark brown. Scutum uniformly clothed with narrow curved dark golden scales or light golden in some specimens. One or two pairs of whitish patches on scutum about half-way from front edge. Posterior pronotum with patch of moderately broad white scales below, narrow dark scales medially and above; in some specimens broad white scales tend to replace dark ones. Post-spiracular area with patch of broad scales. 2–3 lower mesepimeral bristles. Legs: Femora, tibiae and 1st tarsal segments mottled. White basal bands on tarsal segments 2 and 3 of fore leg, 2, 3 and 4 of mid leg and 2–5 of hind leg. All claws with tooth (Fig. 4, *c*, *d*). Wing length 4·0–5·0 mm. Cell R_2 about 1·5 length of its stem. Abdomen: Tergites black-scaled, segment 2 with patch of white scales, 3–7 with basal white bands. Sternites white-scaled with central and lateral apical patches of black scales. Terminalia (Fig. 4, *a*, *b*): Sternally coxite bears numerous long mesially directed setae. Apical lobe prominent with several moderately long setae; basal lobe moderate, having on margin one short stout seta, one long stout recurved seta and 6–11 short, finer straight setae; upper side of lobe usually with numerous moderately long setae. Appendage of harpago narrow on basal two-thirds then sharply expanding and then tapering towards tip.

Female. Differs from male as follows: Elongate patches of narrow bronzy scales close to posterior margin of eyes. Torus dark mesially with a few pale scales and black bristles. Palps one-fifth length of proboscis, mottled. Proboscis extensively mottled, often almost completely pale-scaled. 3–4 lower mesepimeral bristles. White bands on 2–5 tarsal segments of all legs. Wing length 3·4–5·2 mm. Cell R_2 about 2·5 its stem. Usually patches of white scales on tergites 1–2, and convex bands on tergites 3–6, but these bands may be either narrow and almost straight or triangular, sometimes with apex reaching posterior margin of tergites. Patch of black scales on sternites may be reduced to a few scales.

Larva (Fig. 4, *e*, *f*, *g*). Head seta 4, tiny, 5–7-branched; 5, 3–4-branched; 6 and 9, 2–3-branched; 7, 8–9-branched; 9, single or 2-branched. Mentum with small central tooth and 9–10 lateral teeth on each side. Prothoracic setae: 1, 2-branched; 2, 4, 5 and 6, single; 3 and 7, 2–4-branched. Abdomen: VIIIth segment: Lateral comb patch of 24–33 fringed scales; scales without long central tooth. Seta 1, 4–5-branched; 2 and 4, single; 3, 7–8-branched; 5, 5–6-branched. Siphon with index 2·0–2·3; pecten of 22–24 spines, each with 3–4 denticles at base; seta 1, 7–8-branched. Anal segment: Saddle covering about half of segment; seta 1 and 3, single; 2, 6–7-branched; 4, of 18–19 tufts, usually 2 of them precratal. Anal papillae very small rounded.

Biology. Aë. camptorhynchus breeds mainly in brackish swamps in open country, but it can be easily carried by winds into areas where brackish water is absent. In such conditions *camptorhynchus* breeds, more or less successfully, in freshwater swamps. This has been recorded in the Melbourne area (N. E. Kent, 1953), and at Violet Town (N. V. Dobrotworsky), more than 80 miles from the nearest brackish swamps; E. J. Britten (1958) frequently collected larvae of this species in fresh water in Western Australia.

In Victoria *Aë. camptorhynchus* remains active throughout the year. All larval stages, pupae and the emergence of adults have been observed on many occasions during the winter.

Biting Habits. It is an extremely vicious mosquito, which attacks during the day and particularly after sunset. It has been recorded as biting man, horses, cows and birds (ducks, hens).

Distribution. It is common in south-eastern, southern and south-western parts of Australia, and Tasmania. In Victoria it is not restricted to the coastal areas, but is permanently established inland where brackish waters occur. Thus in the Mildura area (about 225 miles from coast) *camptorhynchus* is a very common species.

Aëdes cunabulanus Edwards.

Aëdes cunabulanus Edwards, 1923-24, *Bull. Ent. Res.*, 14: 378.

Distinctive Characters. Adult. Proboscis black-scaled. Scutum uniformly clothed with goldish narrow curved scales. Hind femora mottled. Male terminalia: Coxite without long dense mesially directed setae. Basal lobe of coxite shelf-like, having on its margin one short stout seta, 5–8 long setae with recurved tips, remainder straight and finer. Larva: Head seta 5, 4–5-branched; 6, 3–4-branched. Prothoracic setae: 1, 2–3-branched; 2 and 6, single; 3, 2–4-branched; 4, 5 and 7, 2-branched. Lateral comb patch of 28–32 fringed scales without long central tooth. Siphon index 2·9–3·2; pecten of 16–23 spines. Surface of dorso-distal part of saddle with fine spines arranged in arched rows.

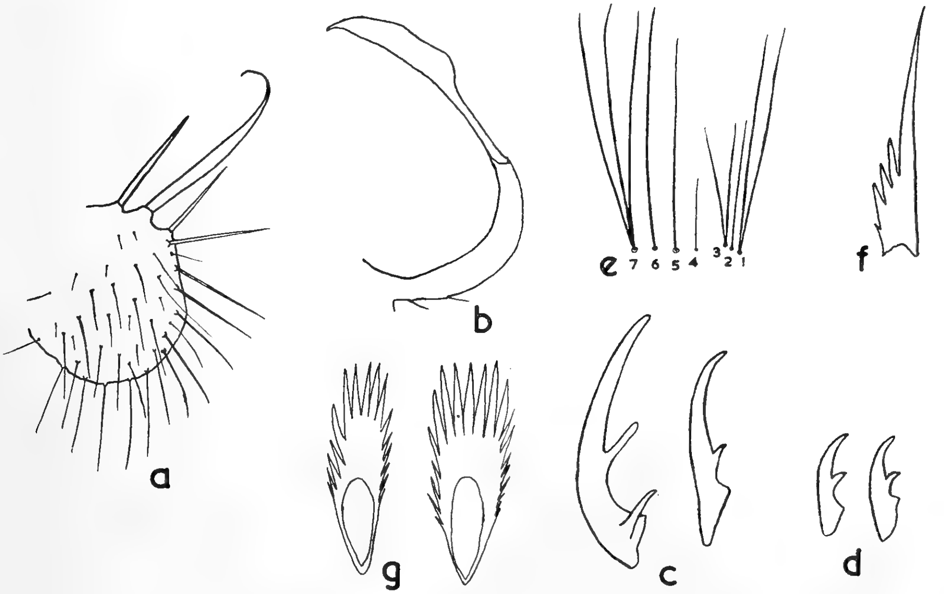

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Fig. 4.—*Aëdes camptorhynchus* (Thomson). *a-b*, ♂ terminalia: *a*, basal lobe; *b*, harpago; *c-d*, ♂ tarsal claws: *c*, fore; *d*, hind; *e-g*, larva: *e*, prothoracic setae; *f*, pecten tooth; *g*, lateral comb teeth.

Description of Adult. Male. Head: Vertex clothed with narrow curved and forked creamy scales, the latter becoming dark laterally and towards neck; lateral broad flat scales white with patch of black scales. Proboscis black-scaled. Palps black-scaled, slightly longer than proboscis without labella. Torus ochreous, black on medial aspect with a few black hairs and scales. Thorax: Integument reddish. Scutum uniformly clothed with narrow curved goldish scales, with a few dark bronze scales on fossa. Scutellum with narrow pale curved scales. Anterior pronotum with elongate white scales, pale and dark bristles. Posterior pronotum with elongate white scales below, elongate and narrow curved pale or goldish scales above. Single lower mesepimeral bristle. Legs: All femora mottled. Tibiae black anteriorly and with pale longitudinal stripe posteriorly; mid tibia slightly mottled. Tarsi black, unbanded; 1st tarsal segment of hind legs mottled. Wing length 4·1–5·6 mm. Cell R_2 about 1·7 times its stem. Abdomen: Tergites black-scaled with white basal bands joining lateral spots. Sternites white-scaled, with median and apical lateral black patches on 2–7 sternites. Terminalia (Fig. 5, *a*, *b*, *c*): Coxite dark-scaled laterally and sternally with numerous long and short setae, only a few of the longer ones directed mesially. Apical lobe prominent with a few short setae. Basal lobe shelf-like, having on its margin one short stout seta, 5–8 long setae with recurved tips, remainder straight and finer. Style slender curved tapering, with 2–3 preapical setae; appendage slender almost straight. Harpago stout curved, with a few scattered setae; appendage narrow. Lobes of IXth tergite prominent with 3–5 short strong setae.

Female. Differs from male as follows: Palps one-fifth length of proboscis. Wing length 4·9–5·7 mm. Cell R_2 2·4–2·6 times its stem. Legs: Femora mottled, knee spots small, whitish. Tibia black with a few pale scales, which may form a line. Abdomen: 1st tergite with patch of dark and pale scales, 2–6 usually with incomplete bands, but bands on 4–6 may join lateral spots.

Larva (Fig. 5, *f*, *g*, *h*, *i*). Head siphon and saddle brown. Head four-fifths as long as broad. Antennae about three-fifths length of head, with scattered spicules; seta 1 arising at about mid length, 7–9-branched. Head seta 4, tiny, 3–4-branched; 5, usually 4- sometimes 5-branched; 6, 3–4-branched; 7, 8–9-branched; 8 and 9, single or 2-branched. Mentum with small central tooth and 11–12 lateral teeth on each side. Thorax: Prothoracic seta 1, 2–3-branched; 2 and 6, single; 3, 3–4-branched; 4, 5 and 7, 2-branched. Abdomen: VIIIth segment: Lateral comb patch of 28–32 scales; scales without odd long central tooth, usually with 2 or 3 equal in length. Seta 1, 4–7-branched; 2, 2-branched; 3, 9–14-branched; 4, single; 5, 4–7-branched. Setae 1 and 3 plumose. Siphon tapering beyond seta 1, index 2·9–3·2, mean 3·0. Pecten extending about two-fifths length of siphon of 16–23 spines; distal spines with 3–4 denticles at base. Seta 1, 7-branched. Anal segment: Saddle covering dorsal half, or slightly less, of segment, surface with fine spines arranged in arched rows. A small separate sclerotized plate near lower proximal angle of saddle. Setae 1 and 3, single; 2, 7–8-branched; 4 (ventral brush), of 15–16 tufts, 1 or 2 precratal. Anal papillae equal, pointed, slightly less than length of saddle.

Pupae. Details shown in figure 5, *j*, *k*.

Biology. Larvae of *Aë. cunabulanus* have been collected at Moth Creek, Port Davey District (E. N. Marks) and this is an abstract of Dr. Marks' observations:

"3rd and 4th instar larvae (mostly 4th) and pupae (there were a few pupal skins) were numerous in several prospect holes on 27.1.54. The holes were about 5′ × 2′ 6″–3′ and 3–4′ deep with 1′ 6″–2′ water in them; with sides of peaty soil and some overhanging sedges growing on ground surface. Some pools were more shaded than others. (There was no breeding in similar holes but with quartzite gravel lower sides and bottom). At one pool, several apparently gravid adults were disturbed on the upper part of the sides of the hole. It appeared that they might be seeking an oviposition site about 8–12 in. above the present water level. The pools are said to be usually practically full of water and never dry. Of these adults from the pool side, 2 were put in tubes over cotton wool. One was moribund and had laid 82 eggs by 9.15 next morning. The second had laid approximately 158 eggs on 28.1.54.

"The pools were re-examined on 7.2.54, 4 or 5 inches of rain having fallen since the earlier collection. There were still some 4th instar larvae and pupae and numerous 2nd instar larvae (presumably hatched from eggs submerged by the rise in waterlevel)."

The adults have been frequently collected during November-February (Edwards), 1926.

Distribution. Apparently it is a very common species in Tasmania, but only a single specimen, a female, has been collected on the mainland (Wilson's Promontory, 9.5.53, G. W. Douglas). Specimens from the following Tasmanian localities have been examined: Mt. Arthur, 28.12.15 (F. M. Littler), Gormanston, 28.1.48 (Key, Carne & Kerr); Moth Creek, 27.1.54 (E. N. Marks); Mt. Field Nat. Pk., 6.2.55 (T. E. Woodward).

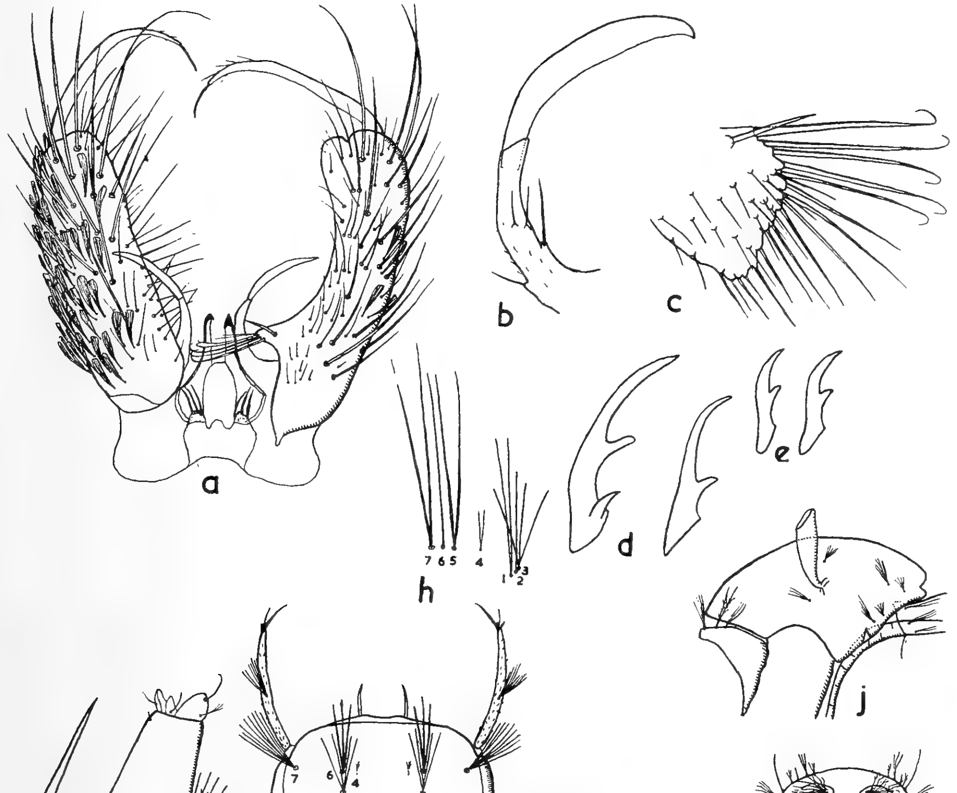

Fig. 5.—*Aëdes cunabulanus* Edwards. *a-c*, ♂ terminalia: *a*, left coxite sternal aspect, right coxite tergal aspect; *b*, harpago; *c*, basal lobe; *d-e*, tarsal claws: *d*, fore; *e*, hind; *f-i*, larva: *f*, head; *g*, mentum; *h*, prothoracic setae; *i*, terminal segments; *j-k*, pupa: *j*, cephalothorax and metanotum; *k*, abdomen.

AËDES ANDERSONI Edwards.

Andersonia tasmaniensis, Strickland, 1911, *Entom.*, 44: 250. *Aëdes andersoni* Edwards, 1926, *Bull. Ent. Res.*, 17: 112.

Distinctive Characters. Adult: Scutum with median area of small dark bronze scales broadening on posterior half and contrasting with broad margin of creamy scales. In front of wing roots large patch of broad white scales (typical form) or long narrow pale scales in place of it (Grampians form). Hind femora mottled. Male terminalia: Coxite without long dense mesially-directed setae. Basal lobe shelf-like having on its margin one short stout seta, one long stout seta with recurved tip, 10–14 long finer setae with recurved tips, remainder finer. Larva: Head seta 5, 3–5-branched; 6, 2–4-branched. Prothoracic setae: 1, 2 and 6, single; 3, 4 and 5, 2-branched; 7, 2–3-branched. Lateral comb patch of 24–33 fringed scales, central tooth twice as long as two nearest lateral ones. Siphon index 3·2–4·0. Pecten of 24–37 close-set strong spines.

Description of Adult. Male. Head: Vertex clothed with curved and forked creamy scales, lateral scales broad white. Torus dark. Palps as long as proboscis, excluding labella, dark-scaled. Proboscis black-scaled. Thorax: Integument dark brown. Scutal scales narrow curved; broad median stripe of small dark bronze scales between dorsocentral bristles broadening on posterior half in direction of wing roots; a very narrow stripe of goldish or creamy scales along acrostrichal bristles. Broad lateral border of larger white or creamy scales in fossa, extending back towards wing roots. Large patch of broad white scales in front of wing roots. Scutellum with narrow curved creamy scales. Anterior pronotum with elongate and broad pale scales and dark bristles. Posterior pronotum with narrow curved and broader elongate dark and a few pale scales. Post-spiracular area with broad and elongate white scales and pale bristles. 4–6 lower mesepimeral bristles. Legs: All femora mottled. Fore and mid tibiae black anteriorly, with a few white scales, white-scaled posteriorly. Hind tibia black anteriorly with wide, white streak, pale posteriorly, except for black apex. Tarsi dark, unbanded; first segment of fore and mid legs with a few pale scales, first segment of hind tarsi mottled on basal three-quarters. All tarsal claws toothed. Wing length 4·6–5·5 mm. Cell R_2 1·4 times its stem. Abdomen: Tergites black-scaled, with white lateral patches. First tergite with median patch of pale scales, second with basal patch. Venter white-scaled with small central and larger apical lateral black patches. Terminalia (Fig. 6, *a*, *b*, *c*): Coxite dark-scaled laterally and sternally, with numerous long and short setae; only a few moderately long setae directed mesially. Apical and basal lobe prominent. Apical lobe with a few short setae. Basal lobe shelf-like with several moderately long setae on its upper surface and having on its margin one short stout seta, one long stout seta with recurved tip, 10–14 long finer setae with recurved tips, remainder finer. Style slender curved, tapering on distal third with 3 preapical setae; appendage slender almost straight. Harpago stout curved with slightly developed thumb near base of appendage, and a few scattered setae; appendage lanceolate as long as harpago. Lobes of IXth tergite with 3–7 short strong setae.

Female. Differs from male as follows: Head: Elongate patches of narrow bronzy scales close to posterior margin of eyes. Upright scales become dark laterally and towards neck. Lateral flat white scales with round dark patch medially. Torus with a few elongate pale scales above and black hairs mesially. Palps one-fifth length of proboscis, black-scaled, sometimes with a few pale scales. Thorax: Posterior pronotum with narrow curved white scales below, sometimes with some broader elongate scales; narrow curved and elongate, dark, almost black scales medially; narrow curved creamy scales above. Mottling on femora variable. Wing length 5·6–5·8 mm. Cell R_2 2·0–2·3 times its stem. Abdomen: Patch of scales on first tergite may be pale or dark; basal pale patch of second tergite may not be present.

Variability. The specimens from Tasmania, Flinders I., Wilson's Promontory and Lower Tarwin, Victoria, do not show much variation in colour; a patch of broad white scales in front of the wing roots is always present. Specimens from south-western

Victoria show a great deal of variation in colour and in size of the patch of broad white scales; many specimens have narrow curved scales in place of the broad ones. They also show greater variability in the mottling of the hind femur. Usually the basal half can be described as white with black mottling, the distal half as black with white mottling.

Larva (Fig. 6, *d, f, e, g*). Head, siphon and saddle light brown. Head three-fifths as long as broad. Antennae almost half length of head, with scattered spicules; seta 1 arising at about mid length, 5–6-branched. Head seta 4, tiny, 2–4-branched; 5, 3–5-branched, usually 4-branched; 6, usually 3-branched, rarely 2- or 4-branched; 7, 5–7-branched; 8, single; 9, 1–2-branched. Mentum with a median and 11–12 lateral teeth on each side. Thorax: Prothoracic setae: 1, 2 and 6, single; 3, 4 and 5, 2-branched; 7, 2–3-branched. Abdomen: VIIIth segment: Lateral comb a patch of 24–33 fringed scales, central tooth twice as long as two nearest lateral ones. Seta 1, 5–6-branched; 2, 2–3-branched; 3, 9–10-branched; 4, 2-branched; 5, 7–8-branched; seta 3 plumose, all others simple. Siphon tapering towards apex; index 3·2–4·0, mean 3·7. Pecten on basal half of siphon of 24–37 (mean 31) close-set, strong dark spines paler towards tip. Seta 1 arising at three-fifths length from base, 4–9-branched, plumose. Anal segment: Saddle covering dorsal half of segment, with coarse denticles on surface of dorso-distal part. Small elongate sclerotized plate lies near lower proximal angle of saddle. Seta 1 single, about as long as saddle; 2, 9–11-branched; 3, single; 4 (ventral brush), of 18–19 tufts, 2 of them usually precratal. Anal papillae equal, pointed, less than half length of saddle.

Pupa (Fig. 6, *h, j*). The pupa of *andersoni* possesses two main features which distinguish it from the pupae of the other six species reviewed in this paper, viz.: The trumpet has a row of short setae along the posterior side and seta 5 of abdominal segments 4, 5 and 6 is single.

Grampians form of AËDES ANDERSONI Edwards.

Specimens of *Aë. andersoni* from Grampians, Victoria, agree in general with *andersoni* from Wilson's Promontory, but have no patch of broad white scales in front of wing roots. In addition this form differs as follows: Posterior pronotum with white elongate scales below, narrow curved and elongate pale-goldish scales medially and narrow curved pale scales above. May be goldish scales along acrostrichal bristles on scutum. Cell R_2 of female wing 2·5–2·8 times its stem. Pale scales on tibiæ arranged in longitudinal stripe. First segment of tarsi of all legs mottled with pale scales, particularly those of hind legs, which almost entirely pale. 2–4 lower mesepimeral bristles. Tergites 2 and 3 with trace of basal band.

Biology. Breeding places of *Aë. andersoni* are confined to sparse woodland and particularly to tea-tree scrub. Larvae have been found in clean shallow road-side ditches and excavations as well as in pools of different sizes. At Wilson's Promontory, it usually breeds in peat swamps in which the water is dark coloured by decayed moss. The adults appear as early as September and continue their biting activity through to autumn; biting females have been collected in March. Larvae of *andersoni* are associated with *luteifemur*, *continentalis*, *alboannulatus*, and sometimes with *flavifrons* and *Aë.* (*Pseudoskusea*) sp.

Biting Habits. It is a day-biting mosquito that attacks men, rabbits and birds (hens).

Distribution. The typical form of *Aë. andersoni* occurs in a coastal belt of Victoria about 20–30 miles wide and is very common on Flinders I. and in Tasmania. The form, described above as the "Grampians form", is known from three isolated localities: the Grampians (N. V. Dobrotworsky) and Bright (K. Meyers), both in Victoria, and Kiandra (I. M. Mackerras and H. J. Willings) in New South Wales. Specimens have been examined from the following localities: VICTORIA: Wilson's Promontory, Tarwin Lower, Colac, Carpendeit, Cape Otway, Homerton, Gorae West, Timboon (N. V. Dobrotworsky). FLINDERS I.: Lady Barron and Razorback (F. N. Ratcliffe, J. H. Callaby and D. L. McIntosh). TASMANIA: Boystown Res. (I. C. R. Rowley); Port Davey (E. N. Marks); Mt. Field Nat. Pk., Lake St. Clair (T. E. Woodward).

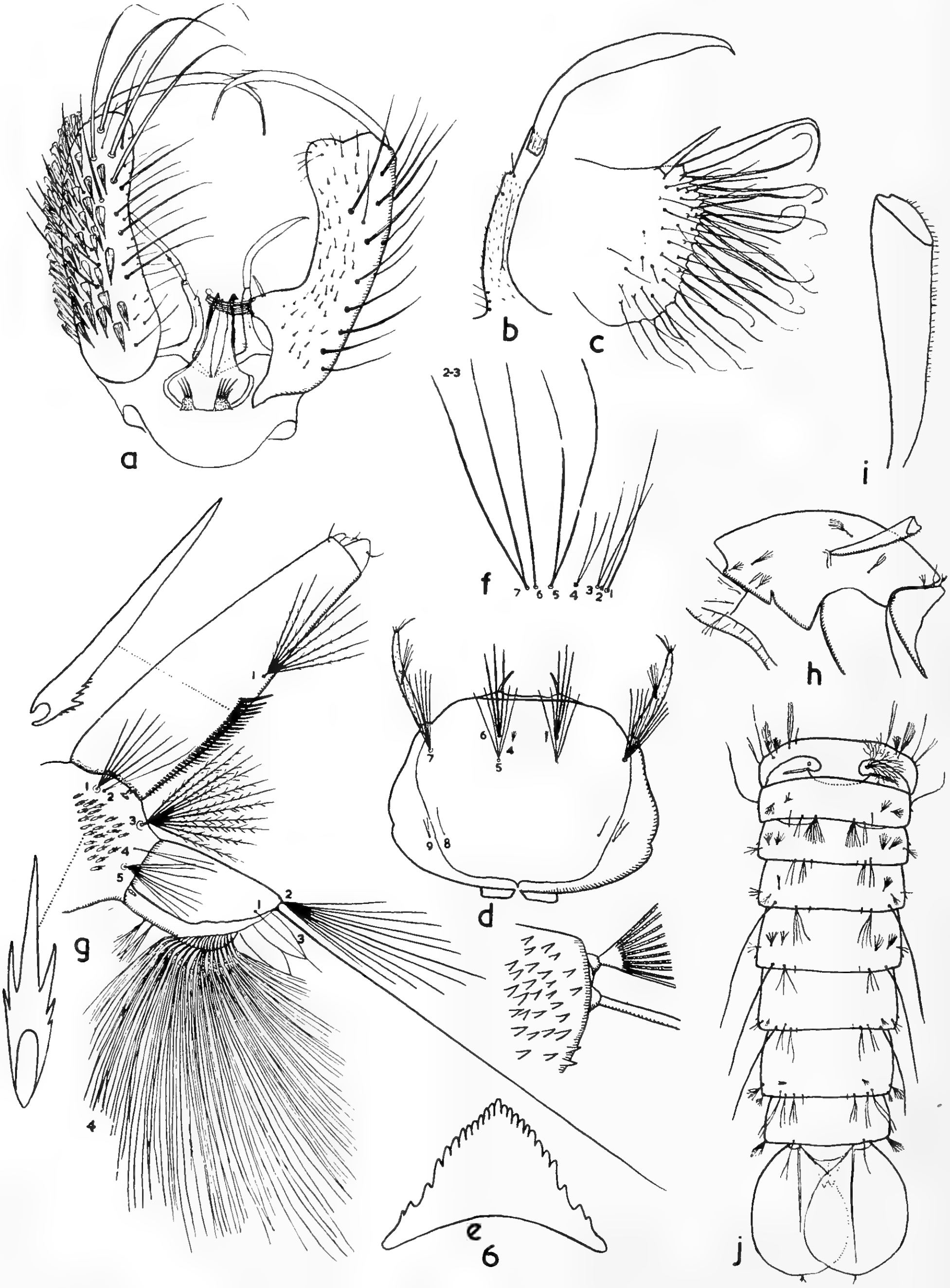

Fig. 6.—*Aëdes andersoni* Edwards. *a-c*, ♂ terminalia; *a*, left coxite sternal aspect, right coxite tergal aspect; *b*, harpago; *c*, basal lobe; *d-g*, larva: *d*, head; *e*, mentum; *f*, prothoracic setae; *g*, terminal segments; *h-j*, pupa: *h*, cephalothorax and metanotum; *i*, trumpet; *j*, abdomen.

Discussion. Of the two forms of *andersoni*, the typical one alone is found in Tasmania, Flinders I., and the coastal parts of southern Gippsland (Wilson's Promontory—Tarwin Lower). The Grampians form, alone, in three isolated areas on the Dividing Range. However, a mixed population of both forms and also intermediates (which have only a few broad white scales in front of the wing roots) occurs in the Western District south of the 38th latitudes. This mixed population appears to be isolated from the Gippsland population and from the Grampians population.

AËDES CONTINENTALIS, n. sp.

Types. The type series were bred from larvae and pupae collected at Carpendeit, Victoria, 24.9.58. One paratype male and three paratype females have their associated larval and pupal skins. The holotype male, allotype female, four paratype males and four paratype females are in the collections of the National Museum, Melbourne. One paratype male and one paratype female are in each of the following collections: C.S.I.R.O., Division of Entomology, Canberra; School of Public Health and Tropical Medicine, Sydney; University of Queensland, Brisbane; British Museum (Natural History), London; U.S. National Museum, Washington.

Distinctive Characters. Adults: Proboscis mottled on basal half. Scutum uniformly clothed with narrow curved golden scales. All femora mottled. First segment of tarsi of all legs mottled. Male terminalia: Coxite without dense long hairs directed medially. Basal lobe shelf-like, having on its margin 2 or 1 short spine-like setae and 12–14 long setae, most of them recurved. Larva: Head seta 5, 3–4-branched; 6, 3-branched. Prothoracic setae 1 and 2, single; 3, 2-branched; 4, 5 and 6, single; 7, 2–3-branched. Siphon index 4·0–5·0. Pecten of 25–35 strong closely set spines. Spines on surface of saddle coarse and irregular on dorso-distal part. Anal papillae equal, broad, about one-third length of saddle.

Holotype Male. Head: Vertex clothed with narrow curved and forked creamy scales. Lateral scales broad flat creamy. Proboscis mottled with creamy scales on basal half. Palps mainly dark-scaled, segments 2 and 3 with creamy scales at base, 4 and 5 with a few pale scales at base. Palps slightly longer than proboscis with labella. Thorax: Integument brown. Scutum uniformly clothed with narrow curved golden scales, becoming paler around bare area. No bronze scales on fossa. Scutellum with narrow curved pale scales. Anterior pronotum with dorsal patch of narrow curved goldish scales, broader scales medially, and black and pale strong bristles. Posterior pronotum with small patch of curved pale scales below, elongate dark and pale scales medially, narrow curved pale scales above. Post-spiracular area with patch of mainly narrow and a few broader, pale scales. 3–4 lower mesepimeral bristles. Legs: All femora mottled anteriorly and pale-scaled posteriorly. Knee spots inconspicuous. Fore and mid tibiae mottled anteriorly, hind tibia black dorsally with some mottling near apex. Tarsi black-scaled, unbanded, with first segment of all legs and base of 2nd segment of hind legs mottled. All claws with tooth. Wing length 5·2 mm. Cell R_2 1·2 length of its stem. Knob of halters pale-scaled. Abdomen: Tergites black-scaled; first segment with a few pale and dark scales; 2–7 with white basal bands joining lateral spots. Sternites white-scaled with median and apical lateral, black spots on 2–7 segments. Terminalia (Fig. 7, *a*, *b*, *c*): Coxite dark-scaled sternally and laterally with some white scales at base; strong setae apically and several moderately long, and some short setae along inner edge of coxite; tergally with numerous short fine setae along inner aspect, long and strong setae laterally. Apical lobe prominent, with a few fine setae. Basal lobe shelf-like, having on its margin 2 short spine-like setae and 12–14 long setae, most of them recurved; upper surface with several fine setae. Style about half length of coxite, curved, with 3–4 short fine preapical setae; terminal appendage slightly curved. Harpago stout, with a few short setae near base; appendage widening gradually toward half length and then tapering gradually towards tip. Paraproct with single tooth. Lobes of IXth tergite with 3–5 short, stout setae.

Paratype Males. The chief variations shown in a series of 9 males are: The length of the wing varies from 4·7 to 5·3 mm. In some specimens the proboscis is less mottled and the palps have fewer pale scales than in the holotype. Some specimens have only 2 lower mesepimeral bristles. Degree of mottling of legs varies only slightly. The tergal bands may be greatly reduced and sometimes absent. The black patches on the sternites may be expanded, reducing the white-scaled area to two lateral longitudinal patches. Basal lobe of coxite may have only one short stout seta instead of two.

Allotype Female. Differs from holotype male as follows: Forked scales on vertex become black laterally and towards neck. Proboscis extensively mottled on basal three-quarters. Palps one-fifth length of proboscis, mottled with creamy scales. Torus ochreous, dark in medial aspect, with a few black hairs and pale scales. Posterior pronotum medially black-scaled. Scales on post-spiracular area mostly narrow. Three strong lower mesepimeral bristles. First two tarsal segments extensively mottled with creamy scales; base of third segment with some pale scales. Claws on all legs toothed. Wing length 4·7 mm. Cell R_2 1·8 times its stem. Knobs of halters pale-scaled with some black scales below. Basal bands complete only on tergites 4 and 5, reduced on 2nd to a few pale scales, and on 3rd and 6th to a median patch of pale scales.

Paratype Females. The chief variations shown in a series of 9 females are: Length of wing varies from 4·5 to 5·0 mm. In some specimens the tergal bands are reduced to a few pale scales. Sternites 3 and 4 may be mottled.

Larva (Fig. 7, *f*, *h*, *g*, *i*). Head, siphon and saddle light brown. Head about two-thirds as long as broad. Antenna almost half length of head; seta 1, arising at about midlength, 4–5-branched. Head seta 4, small, 2–4-branched; 5, usually 3-, may be 4-branched; 6, 3-branched; 7, 5–7-branched; 8 and 9, single or 2-branched. Mentum with small median and 11–12 lateral teeth. Thorax: Prothoracic setae: 1 and 2, single; 3, 2-branched; 4, 5 and 6, single; 7, 2- may be 3-branched. Abdomen: VIIIth segment: lateral comb patch of 24–32 fringed scales, central tooth twice as long as two nearest lateral, or longer. Seta 1, 5–6-branched; 2 and 4, single; 3, 6–11-branched; 5, 4–6-branched. Seta 1, slightly fringed; 3, fringed; other simple. Siphon tapering towards apex, index 4·0–5·0, mean 4·5. Pecten on basal half of siphon of 25–35 strong closely set, dark spines with pale tips and 4–5 denticles at base. Seta 1 arising slightly beyond mid length of siphon, 5–7-branched. Anal segment: Saddle covering dorsal three-quarters of segment, surface with coarse irregular denticles on dorso-distal part; small separate elongate sclerotized plate lies near lower proximal angle of saddle. Seta 1 and 3, single; seta 2, 5–7-branched; 4 (ventral brush), of 16–19 tufts, 2–4 of them precratal. Anal papillae equal, broad, about one-third length of saddle.

Pupa. Details shown in figure 7, *j*, *k*.

Biology. *Aë. continentalis* have been found breeding in rain-water pools and small swamps with grassy edges, exposed to the sun. Fourth stage larvae have been collected as early as September. The larvae have been found associated with larvae of *Aë. andersoni*, *luteifemur*, *alboannulatus*, *queenslandis* and *C. fergusoni* (at Maroondah). The adults have been collected during November-February. It is not a very common species and during the past few years has been numerous only at Maroondah.

Biting Habits. It is a day-biting mosquito.

Distribution. The distribution is similar to that of *andersoni*, but it has not been collected farther than 40 miles from the coast. Its range extends to East Gippsland, South Australia and Flinders I., but apparently it is absent from Tasmania. Specimens have been examined from the following localities: VICTORIA: Cabbage Tree Creek, Wilson's Promontory, Tarwin Lower, Maroondah, Yellingbo, Carpendeit, Hamerton, Gorae West (N. V. Dobrotworsky), Colac (F. G. Tighe); S.A.: Shallbank, Lake Bonney Millicent, Robe, Narrabarra (E. W. L. Lines); FLINDERS I.: Razor Back (J. H. Calaby and D. L. McIntosh), Lady Barron (F. N. Ratcliffe).

CLASSIFICATION.

Of the seven species considered here, three, namely, *cunabulanus*, *andersoni* and *continentalis*, belong to the Cunabulanus Section as defined by Marks (1957).

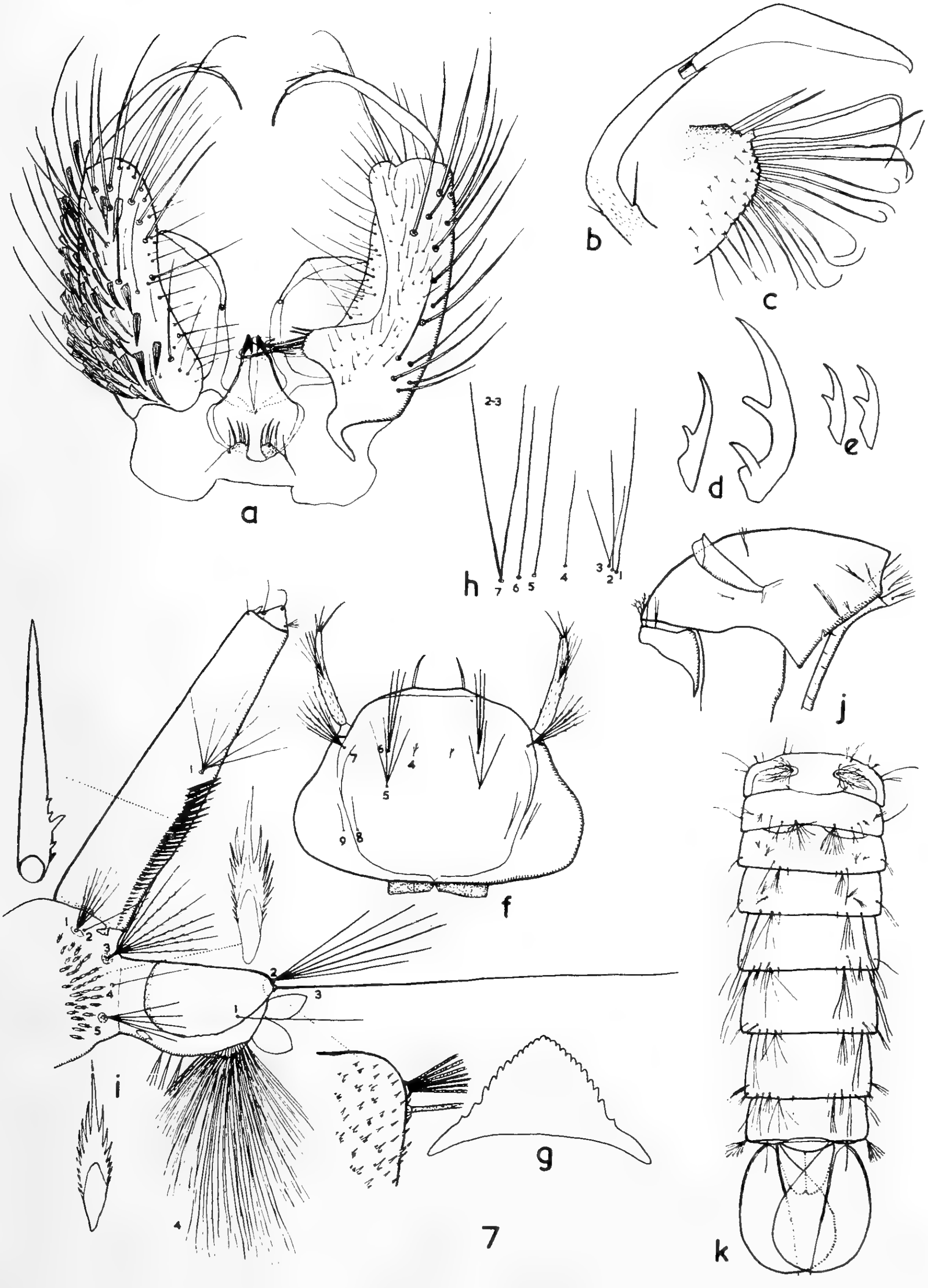

Fig. 7.—*Aëdes continentalis,* n. sp. *a-c,* ♂ terminalia: *a,* left coxite sternal aspect, right coxite tergal aspect; *b,* harpago; *c,* basal lobe; *d-e,* ♂ tarsal claws: *d,* fore; *e,* hind; *f-i,* larva: *f,* head; *g,* mentum; *h,* prothoracic setae; *i,* terminal segments; *j-k,* pupa: *j,* cephalothorax and metanotum; *k,* abdomen.

Of the remaining four species, *camptorhynchus* and *nivalis* were placed by Marks in the Camptorhynchus Section, while *luteifemur* and *waterhousei* would fall into the Perkinsi Section. However, their separation into two sections does not seem to be justified.

The main character for distinguishing between members of the Camptorhynchus and Perkinsi Sections, as defined by Marks, is the structure of the marginal setae on the basal lobe of the coxite: in Camptorhynchus Section there is a single long strong recurved seta; in the Perkinsi Section there are several such setae. However, in respect of this feature the four species listed above form a series: *camptorhynchus* with one strong recurved seta, *nivalis* with one similar seta followed by four long fine setae with recurved tips, *luteifemur* with the first seta more slender and the following setae only slightly finer than first, and *waterhousei* with 5–6 equally strong recurved setae.

The larvae of these species do not have any traits which would support a division into two sections, and for these reasons it is proposed to unite the Camptorhynchus Section and Perkinsi Section under the name Perkinsi Section.

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REVISION OF THE GENUS *ACROTRICHE* R.BR. (EPACRIDACEAE).

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Armidale, New South Wales.

(Eighty-two Text-figures.)

[Read 30th March, 1960.]

Synopsis.

A key for the determination of twelve species of *Acrotriche* including two new species, *A. rigida* and *A. halmaturina,* is given. These species are distributed throughout Australia, along the coast and adjacent ranges from Queensland to Tasmania and south-west Western Australia, the greatest density of species being in the south-eastern corner of South Australia.

The taxonomic history, variations and economic importance of this Australian genus are briefly discussed.

Introduction.

General.

The genus *Acrotriche* was described by Robert Brown (1810). He included *Styphelia cordata* which had previously been described by Labillardière (1804). Since then the number of species accepted as valid has varied from botanist to botanist. A total of sixteen species has been described, two of which, *Acrotriche aristata* and *A. latifolia,* have since been reduced to synonymy under *Leucopogon cuspidatus* and *L. cordifolius* respectively. Ten of the described species are recognized by the writer as distinct taxonomic groups; the remaining four species (*A. ovalifolia, A. subcordata, A. manglesii, A. ramiflora*) have been reduced to synonymy. In addition two new groups have been accorded specific rank.

The generic name is derived from a combination of two Greek words, *akron* and *thrix, triklos,* referring to the chief characteristic of the genus: an erect tuft of hairs near the apex of the corolla-lobes. These hairs easily distinguish *Acrotriche* from the two closely allied genera, *Leucopogon* R.Br., whose corolla-lobes are bearded, and *Monotoca* R.Br., where the corolla-lobes are naked.

The genus is distributed throughout Australia along the coast and adjacent ranges from Queensland to Tasmania and Western Australia, the greatest density of species being in the south-eastern corner of South Australia. Within this range the habitat varies from areas of high to low rainfall; the plants are usually on poor soils.

Acrotriche appears to be unimportant economically, though the fruits of *A. depressa* are used for making jams and jellies by those sufficiently energetic to collect them. It has been reported from some areas that *A. serrulata* is often eaten by sheep, but whether this is under normal or drought conditions is unknown. The author considers that the typical heath characteristics of the leaves of most species would provide a natural deterrent to their being eaten.

Nomenclature.

No type material, other than photographs, has been available, with the exception of the two new species. The comparison of type photographs with the written description has been the basis of name determination; these photographs have been lodged at the National Herbarium, Sydney. The following type definitions have been used in this paper: A *holotype* is that single specimen or other element used as a basis for the description by the author and/or designated by him as the nomenclatural type or a specimen interpreted by the author as belonging to the taxon described by himself. A *paratype* is a specimen cited with the original description other than the holotype or isotype(s). *Topotype*: A specimen from a type locality agreeing with the type. *Lectotype*: A specimen or other element selected from the original material to serve as nomenclatural type when the holotype was not designated at the time of publication or for so long as it is missing.

Evaluation of Taxonomic Characters.

The taxonomic value of morphological characters varies from character to character. An assessment of this value is made below.

(*a*) *Vegetative Characters.*

Habit.—The variation in habit may be used to distinguish certain species, e.g., *A. aggregata* and *A. prostrata*, yet in others it is of slight or no value, e.g., *A. serrulata* and *A. affinis*, where the habit is very similar.

Leaves.—The leaves have again (Paterson, 1957) proved to be the most effective character for diagnosis. No two species have identical leaves, although at first some may appear identical; however, upon closer observation differences are apparent. Where infraspecific variation in leaf shape occurs, it does not influence interspecific differences. Leaf pubescence in connection with thickness of leaf and leaf margins is important. The number of veins does not appear, in general, to be of specific importance, but rather to be proportional to the width of the particular leaf.

(*b*) *Floral Characters.*

Inflorescence.—The position and length of the spike, together with the number of flowers on the spike, can in some cases be characteristic of a species, e.g., *A. fasciculiflora*, but its real value lies in breaking up the genus into groups.

Floral Bracteoles and Sepals.—Of slight value when considered alone. Usually when the bracteoles and calyx of different species vary in shape and degree of pubescence, there are also other and more objective characters present.

Corolla.—Variation in colour of the corolla-tube can be a guide in some cases. The manner in which the hairs at the throat are borne, whether on a cushion of tissue or not, assists in breaking up the genus into smaller groups.

Stamens.—Size, shape and colour show insufficient variation between the species to be used in identification.

Ovary.—Anatomically, the structure of the ovary distinguishes each species. Morphologically, the ovary is important; the degree of pubescence and the number of loculi when used collectively enable a rough determination to be made. Where doubt exists after leaf comparison, the ovary may be used for confirmation.

Style and Stigma.—The variation which exists is of no value in identification.

Fruit.—The shape, colour, degree of pubescence, together with the general structure of the mesocarp, may be used to distinguish each species. The fruits show the most distinctive characters of the generative parts.

Specimens Examined.—More than 100 specimens have been examined since February, 1958, and it is from these specimens in conjunction with written descriptions that the data in this paper have been compiled. Previously some 500 had been examined, but unfortunately these were lost when the Botany Department of the University of New England, Armidale, was destroyed by fire. All species have been redescribed and the specimens examined are all cited under the appropriate species. The abbreviations used for their location follow "Index Herbariorum Part I, Ed. 4" with the exception of the following: INGRAM, Collection of C. K. Ingram, Bathurst; MELU, University of Melbourne, Melbourne; NSWU, University of New South Wales, Sydney.

TAXONOMY.

Generic Description.

ACROTRICHE R.Br., *Prodromus*, 547 (1810), Epacridaceae.

Synonymy: *Froebelia* Regel, *Gartnfl.*, i: 164, t.18 (1852).

Low shrubs, intricately branched. *Leaves* crowded, shortly petiolate, rigid. *Flowers* small in sessile or shortly pedunculate clusters or spikes, axillary or on the old wood below the leaves; each flower sessile within a small subtending bract and two bracteoles.

Calyx 5-parted, imbricate. *Sepals* ovate-lanceolate, obtuse. *Corolla*-tube funnel-shaped or bulbous, usually exceeding the calyx; lobes valvate in bud, spreading with a tuft of hairs on the inside near the tip; the hairs closing the throat may arise direct from the epidermal cells or from a scale or cushion. *Stamens* short filaments inserted at summit of corolla-tube between the bundles of hairs; anthers dorsifixed, enclosed at first, later hanging down on the outside between the lobes. *Ovary* 2–10-celled with a single anatropous ovule in each cell, a short nectary envelopes the proximal half. *Style* with a small terminal stigma. *Fruit* drupe, globular or depressed, mesocarp in some species slightly pulpy, endocarp hard. Twelve species, all Australian.

Lectotype: *Acrotriche divaricata* R.Br.

Key to the Species.

A. Flowers in clusters or in short spikes.
B. Leaves pungent pointed.
C. Leaves flat, margins not recurved.
D. Leaves with microscopic hairs on lower surface; ovary usually 6-10-celled .... 2. *A. aggregata.*
DD. Leaves with undersurfaces smooth or with very small protuberances; ovary usually 5-celled .... 1. *A. divaricata.*
CC. Leaves shallow or deeply grooved and/or margins recurved.
E. Shrubs with adventitious roots, usually less than 6″ in height .... 6. *A. prostrata.*
EE. Shrubs without adventitious roots, usually greater than 6″ in height.
F. Leaves ovate-lanceolate .... 7. *A. patula.*
FF. Leaves linear-lanceolate or lanceolate.
G. Leaf margins recurved.
H. Leaves lanceolate, 5-12 × 2-5 mm. Flowers in globular clusters on the stem at the ground .... 11. *A. halmaturina.*
HH. Leaves linear-lanceolate, 7·5-11 × 1-1·5 mm. Flowers in spikes on old wood .... 5. *A. rigida.*
GG. Leaf margins not recurved.
J. Leaves with deep grooves between the veins, thick, rigid, lanceolate, 3-8 × 0·7-2 mm. .... 4. *A. affinis.*
JJ. Leaves with shallow wide grooves between the veins, thinner, not rigid, linear-lanceolate, 4-10 × 0·6-2 mm. .... 3. *A. serrulata.*
BB. Leaves with blunt callous point not pungent .... 8. *A. cordata*
AA. Flowers in long open spikes.
K. Leaves under 2·5-3 mm. long .... 9. *A. depressa.*
KK. Leaves more than 6-11 mm. long.
L. Flower spikes scattered along old wood, 8-10 mm. long, with 6-10 flowers each. Leaves 1·2 mm. broad, scabrous above with microscopic hairs between the veins below .... 10. *A. ramiflora.*
LL. Flower spikes densely crowded near the base of the stem, 10-17 mm. long, with 8-16 flowers each. Leaves 2-4 mm. broad, with long hairs on both sides, with some microscopic hairs between the lower veins .... 12. *A. fasciculiflora.*

Specific Descriptions.

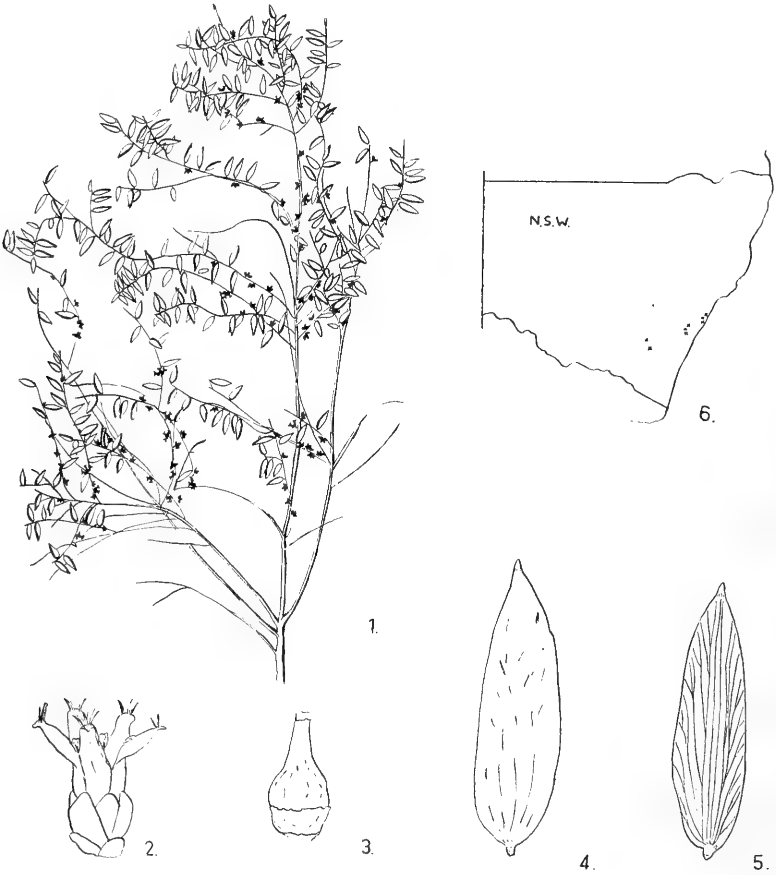
1. ACROTRICHE DIVARICATA R.Br., *Prod.* 547 (1810). (Text-figs 1–6.)

Synonymy: *Styphelia divaricata* (R.Br.) Spreng., *Syst.*, i: 658 (1824); (R.Br.) F. Muell., *Fragm. Phytog.*, vi: 44 (1867).

Erect much-branched shrub, 1–1·5 m. high, young branches usually shortly hirsute. *Leaves* lanceolate, spreading, flat, 8–13 mm. long, 2–3 mm. broad, with a pungent mucronate tip; margins smooth; both surfaces glabrous or lower with very small protuberances. *Inflorescence*: Flowers green, 3–5 in axillary spikes or clusters. *Bracteoles* keel-shaped, 0·5 mm. high. *Sepals* glabrous, ovate-lanceolate obtuse, 1·5 mm. long, 1 mm. broad. *Corolla* tube 2 mm. long, a darker green than the lobes; lobes 1 mm. long, spreading; single row of hairs at the neck arising directly from the epidermal cells. *Stamens*: Anthers orange, oblong, 0·5 mm. long. *Ovary* reddish, globular, glabrous, 4–5-celled, 1 mm. diameter, 1 mm. long; nectary slightly lobed, 0·5 mm. high. *Style* conical, 0·5 mm. long; flattish stigma. *Fruit* reddish.

Range: New South Wales, mainly in the Blue Mountains along the banks of gullies, and westward to the Australian Capital Territory.

Specimens Examined.—New South Wales: Newcastle, "small flowers under branches", 23.7.1901, R. H. Cambage (SYD); Wamberal, 1940, J. McLuckie (SYD); Ourimbah, A. H. K. Petrie (MELU); Patonga, "leaves flat, pungent-pointed. Rigid shrub. Flowers on old wood in clusters. Plant hairy (new branches)", 5.3.1947, C. K. Ingram (NE, NSW); Sassafras Gully, Springwood, "much branched shrub, 3-4 feet", 9.1.1958, B. R. Paterson (BRI, NE, NSW, NSWU, SYD); Springwood, "edge of gullies", 8.8.1958, A. McCusker (AD, ADW, BRI, HO, INGRAM, MEL, MELU, NE, NSW, NSWU, PERTH, SYD); Head of Cedar Creek, Kowmung, Yerranderie, "200 feet, devonian quartzite", 7.6.1909, R. H. Cambage (SYD); Canberra, 9.1928, E. B. Williamson (MEL); Top of Tidbinbilla, Queanbeyan, 5115 feet, 7.11.1911, R. H. Cambage (SYD).



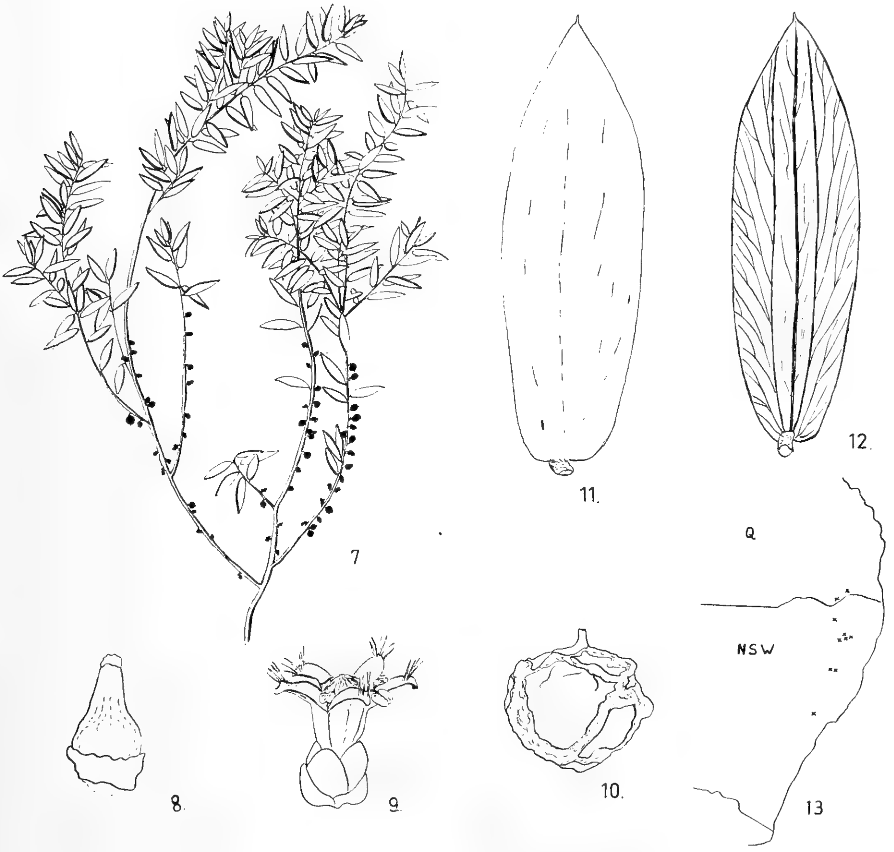
Figs 1-6.—*Acrotriche divaricata.* 1, Habit × 0·25; 2, flower × 5·5; 3, pistil × 9·5; 4, upper surface of the leaf × 2·5; 5, lower surface of the leaf × 2·5; 6, distribution.

This species is usually found amongst the hills and valleys of the Great Dividing Range in the area from Newcastle to the Southern Alps. The plants occupying the southern portion of this area appear to resemble more closely the allied species *A. aggregata* than those in the north. This resemblance is found in the leaves which tend to be broader in relation to their length; they also tend to bear small protuberances on the lower surface between the veins, giving a paler appearance to this surface in relation to the upper.

2. Acrotriche aggregata R.Br., *Prod.*, 547 (1810). (Text-figs 7–13.)

Synonymy: *Styphelia aggregata* (R.Br.) Spreng., *Syst.*, i: 657 (1824); (R.Br.) F. Muell., *Fragm. Phytog.*, vi: 44 (1867).

An erect spreading shrub 0·6–3 m. high, with young stems lightly pubescent. *Leaves* lanceolate, flat, spreading, 10–19 mm. long, 3–6 mm. broad, with mucronate pungent tip; margins smooth or may be slightly serrated towards the summit; upper surface glabrous, lower surface with numerous small microscopic hairs giving a whitish appearance. *Inflorescence*: Flowers pale green, 4–7 in axillary spikes or clusters. *Bracteoles* keel-shaped, 0·5 mm. long. *Sepals* ovate, glabrous, 1 mm. long; hairs at the tips of the lobes and at throat white; the latter arise directly from the epidermal cells.



Figs 7-13.—*Acrotriche aggregata.* 7, Habit × 0·25; 8, pistil × 9·5; 9, flower × 5·5; 10, fruit × 5·5; 11, upper surface of the leaf × 2·5; 12, lower surface of the leaf × 2·5; 13, distribution.

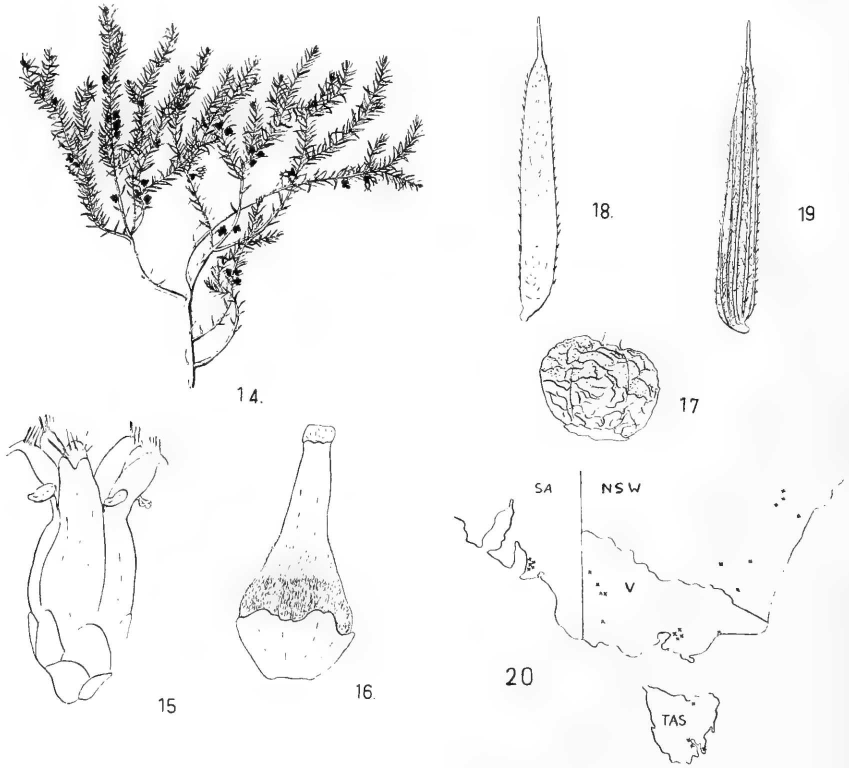
Stamens: Anthers orange, orbicular, 0·5 mm. long. *Ovary* glabrous, slightly lobed, 1 mm. diameter, 1 mm. long, 6–10-celled, green except for a red band at the base of style which extends in both directions as ovary matures; nectary green slightly lobed. *Style* semi-conical, 0·5 mm. long; globose stigma. *Fruit* red, fleshy mesocarp depressed-globular, 3–6 mm. diameter, 2–5 mm. long.

Range: Usually found in the Rainforest or wet sclerophyll forests of Queensland and New South Wales.

Specimens Examined.—QUEENSLAND: Wilson's Downfall, 3.9.1911, R. H. Cambage (SYD); Wallangarra, 1900, (SYD). NEW SOUTH WALES: Timbarra, New England, C. Stuart (MEL); Dorrigo State Forest, "red loam", 26.2.1958, B. R. Paterson (ADU, ADW, BRI, INGRAM, MEL, NSW); 12 miles west of Dorrigo on Ebor road, "red loam, red fleshy drupe, shrub 4-6 feet", 27.2.1958, B. R. Paterson (AD, BRI, HO, INGRAM, MEL, NE, NSW, NSWU, PERTH, SYD); Deervale near Dorrigo, 20.7.1958, J. L. Charley (MELU, NSW); Big Hill, Styx River, "low diffuse shrub 2-6 feet", 23.5.1958, B. R. Paterson, (BRI, NE, NSW), Mt. Wilson, 25.11.1955, W. J. Gregson (SYD).

Specimens of *A. aggregata* attain the maximum height for *Acrotriche*, and when found in rainforests it forms a tall shrub. Unlike the majority of the species, *A. aggregata* prefers areas with a relatively high rainfall, and is distributed along the coast and eastern scarp of the Range from Central Queensland to Central New South Wales (Figure 13). Throughout this area the species shows great uniformity. Vegetatively *A. aggregata* resembles *Leucopogon lanceolatus* R.Br. with which it often grows. These two species may be distinguished vegetatively as follows:

A. Upper surface flat without grooves .... *A. aggregata.*
AA. Upper surface with three small parallel grooves corresponding to the major veins .... *Leucopogon lanceolatus.*



Figs 14-20.—*Acrotriche serrulata.* 14, Habit × 0·25; 15, flower × 5·5; 16, pistil × 9·5; 17, fruit × 5·5; 18, upper surface of the leaf × 2·5; 19, lower surface of the leaf × 2·5; 20, distribution.

3. ACROTRICHE SERRULATA (Labill.) R.Br., *Prod.*, 547 (1810). (Text-figs 14–20.)

Synonymy: *Styphelia serrulata* Labill., *Nov. Holl. Pl. Spec.*, i: 45, t.62 (1804).

A low prostrate or diffuse shrub forming a mat 0·3–0·9 m. diameter, and 0·15–0·6 m. high; young branches pubescent. *Leaves* linear-lanceolate, spreading, flat, 4–10 mm. long, 0·6–2 mm. broad, with a 1 mm. long, mucronate, pungent point; margins serrated, ciliate; upper and lower surfaces with long scattered hairs; 3–5 prominent veins on the lower surface. *Inflorescence*: Flowers green, in axillary spikes or clusters with 5–8 flowers. *Bracteoles* keel-shaped, 1 mm. long. *Sepals* broadly lanceolate, obtuse, 2–3 mm. long, 1·5 mm. broad, glabrous or with ciliation at the apex, reddish tinge at summit. *Corolla* pale green, tube inflated, 4–5 mm. long, lobes spreading, 1–1·5 mm. long; short hairs at throat borne on spongy cushions. *Stamens*: Anthers orange, 1 mm. long, filaments reddish. *Ovary* globular, slightly lobed, 5–7-celled, 1–1·5 mm. diameter, 1–1·5 mm. long; proximal half covered by a lobed nectary 0·5 mm. long, distal half ciliate. *Style* linear, 1·5–2·5 mm. long, base of style bears microscopic hairs; lobed stigma. *Fruit* greyish-green, slightly lobed, globular, bearing numerous short hairs, 3–4 mm. diameter, 2–3 mm. long.

Range: From southern New South Wales through Victoria in South Australia and Tasmania.

Specimens Examined.—New South Wales: Hargreaves, "ground berries very much like the Tasmanian form; N.S.W. forms generally more ciliate and have broader and stiffer leaves", 1.8.1911, R. H. Cambage (SYD); Cudgegong River, 15 miles east of Rylstone, "near dam", prostrate, 11.1.1953, H. S. McKee (SYD); Bathurst, "Rocky Hill", 12.1822, C. Northpom (MEL); Colong, "shale", 20.5.1933, H. C. Davis (SYD); Tharwa-Queanbeyan, "granite", 6.11.1911, R. H. Cambage (SYD); Tumbarumba, "semi-prostrate shrub, pinky-greenish flowers", 13.9.1947, E. J. McBarron (SYD); The Glen, Tumbarumba, "prostrate shrub open forest", 10.11.1949, E. J. McBarron (NSWU); the base of Mt. Kosciusko, 10.1887, F. v. Mueller (MEL). Victoria: Sources of the Brodribb River, 11.1887, E. Merrah (MEL); Ovens River, 1891, W. Gates (MEL); Springfield Road, Mitcham, "growing beneath *Eucalyptus* sp. and shrubs, podsol, shrub about 6 inches high", 7.9.1955, T. B. Muir (MELU); Frankston, 24.8.1949, R. E. Winkworth (MELU); Port Phillip, R. Brown (MELU); Delatite River, 3.1853, F. v. Mueller (MEL); northern end of Grampians, "shrub about 6 inches high", 3.9.1955, T. B. Muir (MEL); near the Pinnacle, Grampians, "shrub about 3 feet high, flowers green, in Heathland on sandstone", 10.8.1958, B. G. Briggs (MEL, NSW); Mitchell's Journey No. 275, "on the Glenelg near Chetwynd", 5.8.1836, (MEL); Wimmera, 7.8.1892, J. M. Reader (MEL); Yenda, N.W. District, 9.1905, W. Callister, (MEL); Tallandorn, H. B. Williamson (MEL); Austral felix, F. v. Mueller (MEL). Tasmania: Punchbowl, Launceston, 9.1921, H. M. Rupp (MELU); Port Arthur, 1892, J. Bufton (MEL); Mt. Nelson, Hobart, 17.1.1928, E. H. Ising (AD 95813093); Knocklofty, Hobart, 9.1920, H. M. R. Rupp. South Australia: Near Mt. Gawler, 15.10.1958, J. B. Cleland (AD 95911052); Chain of Ponds, "hillside compact shrub, 6 inches high", 23.8.1958, B. R. Paterson (AD, BRI, HO, MEL, MELU, NSW, PERTH); Tea Tree Gully, Adelaide, "9 inches forming a dense mat 2-3 feet in diameter", 27.8.1958, B. R. Paterson (N.S.W.); Morialta Falls, between bottom of third fall and top of second fall, 20.10.1956, Hj. Eichler 13080 (AD 95815003, NE); Gandy's Gully in foothills, about 8 Km. east of Adelaide, 16.7.1938, E. H. Ising (AD 95813090); Mt. Lofty, 7.8.1926, E. H. Ising (AD 95815023); Mt. Lofty, "hillside, compact shrub 6 inches", 24.8.1958, B. R. Paterson (BRI, MEL, NE, NSW, NSWU); Mt. Lofty, 3.9.1916, E. H. Ising (AD 95813094); Stirling East, near school, "in natural shrub", 17.8.1957, Hj. Eichler 13907 (AD 95813067, NE); National Park, Belair, near Pine Oval, 16.9.1958, Hj. Eichler 14931 (AD, NE); Mt. Lofty Range, South Reserve, Myponga, 22.11.1957, J. B. Cleland (AD 95846005); Mylor, "9 inches high, forming a dense mat, 2-3 feet in diameter", 26.8.1958, B. R. Paterson (HO, SYD); Macclesfield, 26.8.1958, B. R. Paterson (AD, BRI, MELU, NSWU, SYD); Strathalbyn, "forming a dense mat, 9 inches high, 2-3 feet in diameter", 26.8.1958, B. R. Paterson (AD, ADW, HO, INGRAM, NE, PERTH).

This species has the widest distribution within the genus, but within its range the degree of variation is small and concerns the amount of pubescence of the leaves. In some plants the mature leaves are comparatively "hairy" while in others they are almost glabrous, but in all cases the young leaves bear numerous long thin hairs.

The large inflated corolla-tube of *A. serrulata* is half-filled with honey, resulting in a heavy, slightly unpleasant smell. Ants are attracted to this plant by this large quantity of honey (common name in some areas "Ant's Delight"). The accepted common name is "Green Groundberry".

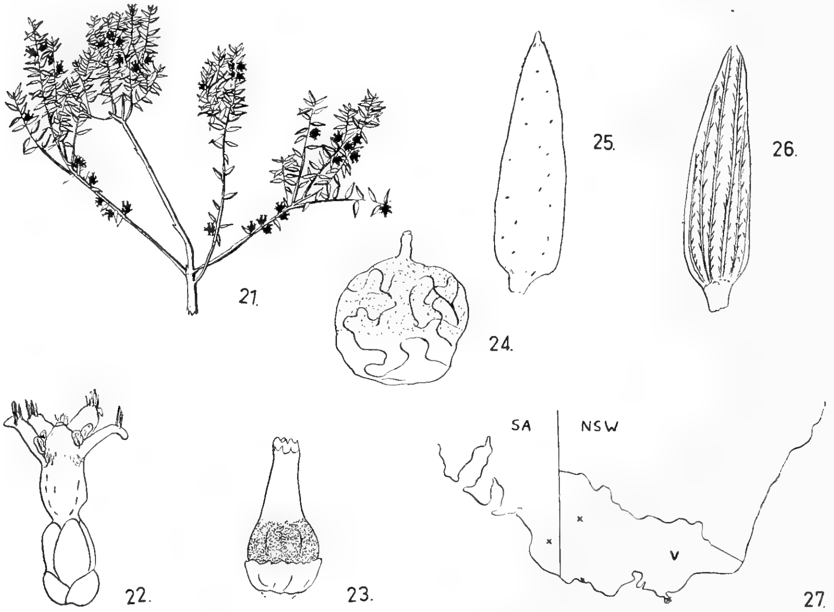
4. Acrotriche affinis DC., *Prod.*, vii: 757 (1839). (Text-figs 21–27.)

Much branched shrub, 0·3–0·5 m. high, forming an erect mat. *Leaves* lanceolate, thick, rigid, 3–8 mm. long, 0·7–2 mm. broad, spreading, with a mucronate pungent tip 0·5 mm. long; margins slightly serrated; upper surface shiny, lower surface deeply grooved with numerous small microscopic hairs together with several long thin hairs in the grooves. *Inflorescence*: Flowers green, 7–8, spikes axillary. *Bracteoles* keel-shaped, 1 mm. long. *Sepals* subcordate, pinkish tinge at apex, glabrous, 2 mm. long, 1·5 mm. broad. *Corolla* green, tube 2·5 mm. long, lobes 1·3 mm. long; hairs at throat arising from large spongy cushions almost completely enclosing the throat. *Stamens*: Anthers orange, 0·5 mm. high. *Ovary* slightly angled, 1 mm. diameter, 1 mm. long, 4–6-celled, short scattered hairs on distal half, proximal half covered by a lobed nectary 0·4 mm. long. *Style* slightly conical, 1 mm. long, semi-translucent stigma. *Fruit* globular, 4 mm. diameter, 2·5 mm. long, covered by very short microscopic hairs.

Range: South-eastern South Australia and Victoria, particularly in mallee communities.

Specimens Examined.—VICTORIA: Near Forester's Spring, Dinyarrack North, "under *Melaleuca wilsonii* bushes in depressions between mallee sand-hills", 9.9.1949, J. H. Willis (MEL); Hopkins Mouth, 3.1900, H. B. Williamson (MEL); Wilson's Promontory, 12.5.1853, F. v. Mueller (MEL). SOUTH AUSTRALIA: Meningie, near Lake Albert, 9.11.1958, J. B. Cleland (AD 95911051).

This species is limited to poor sandy soils in Victoria and south-eastern South Australia. *A. affinis* is closely related to *A. serrulata*, with which it has often been united. Bentham (1868) considered that these two species were "probably the same". Mueller (1867) and Rodway (1903) combined them. Black (1952) on the other hand kept *A. affinis* separate from *A. serrulata*, but he commented "these 2 species would perhaps be better united". The author considers the two species to be distinct taxa. This distinction lies chiefly in the leaves which in *A. affinis* are shorter, thicker and quite rigid with deep grooves between the veins, whereas in *A. serrulata* they are neither rigid nor deeply grooved. Further evidence of the distinction of these two species is provided by anatomical characteristics of the leaves and ovaries, which will be presented in a later paper.



Figs 21-27.—*Acrotriche affinis*. 21, Habit × 0·25; 22, flower × 5·5; 23, pistil × 9·5; 24, fruit × 5·5; 25, upper surface of the leaf × 2·5; 26, lower surface of the leaf × 2·5; 27, distribution.

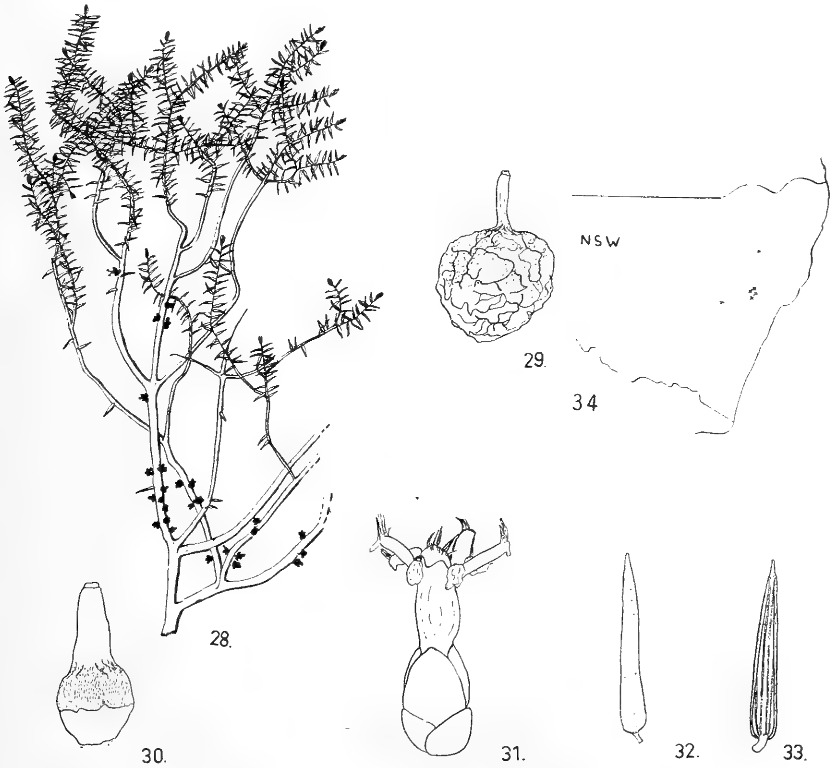
The corolla-tubes of this rigid plant are only slightly inflated compared with those of *A. serrulata*.

5. ACROTRICHE RIGIDA, n. sp. (Text-figs 28–34.)

Holotype: Lee's Pinch, Goulburn River, "growing in intricately branched and matted clumps. Up to 6 feet in diameter and 4 feet high, branching from the base in many stems. Leaves pungent and easily detached. Readily adhering to clothing, etc., hence avoided by animals. Growing on sandstone hillside (south aspect) in association with *Angophora intermedia* and *Acacia linearifolia*"; 15.11.1958 C. K. Ingram (NSW). *Paratypes*: *Loc. cit.* (AD, BRI, HO, K, MEL, NSW, PERTH).

Frutex rigidus, in massas spissas et confertissimas usque ad 1·8 m. per medium et 1·2 m. altas collectus. *Folia* lineari-lanceolata, rigida, stirpi ex quo expandunt opposita, 7·5–11 mm. longa, 1–1·5 mm. lata, acumine attenuato, mucronato 1 mm. longo;

marginibus valde recurvatis, in parte superiore scabra; inter venas in parte inferiore alte striata unde oriuntur capilli multi minutissimique. *Flores* virides, spiculis flores 5–7 numero ferentibus e ramis adultis enascentes. *Bracteolae* carinae similes, 1 mm. longae. *Sepal* is acumina rosacea, obtusa, 2 mm. longa, 1·5 mm. lata, marginibus superioribus quasi fimbriis adornatis. *Corollae*-tubus 2·5 mm. longus, lobis 1 mm. longis, capillis in gula quasi e pulvinis orientibus. *Stamina* antheris orbicularibus 0·8 mm. longis, in brevibus, filamentis positis. *Ovarium* non multum lobatum, 1 mm. per medium, 1 mm. altum, in 4–5 partes divisum; dimidio proximo nectario subviridi tecto; dimidio distanti breves, leviter coloratos capillos ferente. *Stylus* rectus, 1·5 mm. longus, capillis compluribus minutissimis usque ad basim. *Drupa* albida et subviridis, depresse globularis, per medium 3 mm., 2–2·5 mm. alta, multos, parvos, albos capillos ferens.

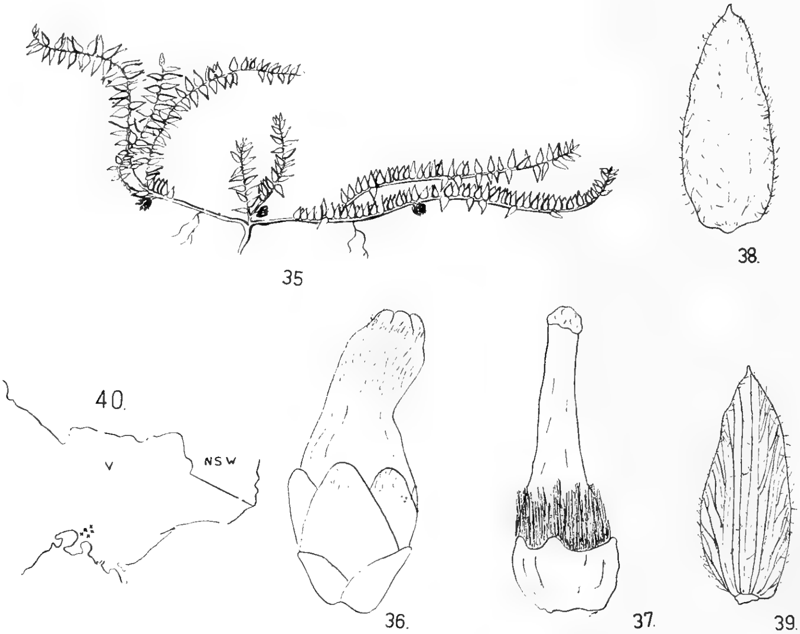


Figs 28-34.—*Acrotriche rigida*. 28, Habit × 0·25; 29, fruit × 5·5; 30, pistil × 9·5; 31, flower × 5·5; 32, upper surface of the leaf × 2·5; 33, lower surface of the leaf × 2·5; 34, distribution.

A rigid shrub forming clumps up to 1·8 m. in diameter and 1·2 m. high. *Leaves* linear lanceolate, rigid, spreading at right angles to the stem, 7·5–11 mm. long, 1–1·5 mm. broad, attenuate mucronate tip 1 mm. long; margins much recurved; upper surface scabrous; numerous microscopic hairs are borne in the deep grooves between the veins. *Inflorescence*: Flowers green, in 5–7 flowered spikes on the old wood. *Bracteoles* keel-shaped, 1 mm. long. *Sepals* tips pinkish, obtuse, 2 mm. long, 1·5 mm. broad, margins of upper edges fringed. *Corolla* tube 2·5 mm. long, lobes 1 mm. long; hairs at throat arising from cushion-like structures. *Stamens*: Anthers orbicular, 0·8 mm. long, on short filaments. *Ovary* slightly lobed, 1 mm. diameter, 1 mm. long, 4–5-celled, the proximal half covered by a pale green nectary; the distal half bears short pale coloured hairs. *Style* linear, 1·5 mm. long, with a few microscopic hairs towards the base. *Fruit* creamy-green, depressed-globular, 3 mm. diameter, 2–2·5 mm. long, bearing numerous small white hairs.

Habitat: Ridges with sandstone or granite formation.

Range: Central Western Slopes of New South Wales; individual areas appear to be localized.



Figs 35-40.—*Acrotriche prostrata*. 35, Habit × 0·25; 36, mature bud × 5·5; 37, pistil × 9·5; 38, upper surface of the leaf × 2·5; 39, lower surface of the leaf × 2·5; 40, distribution.

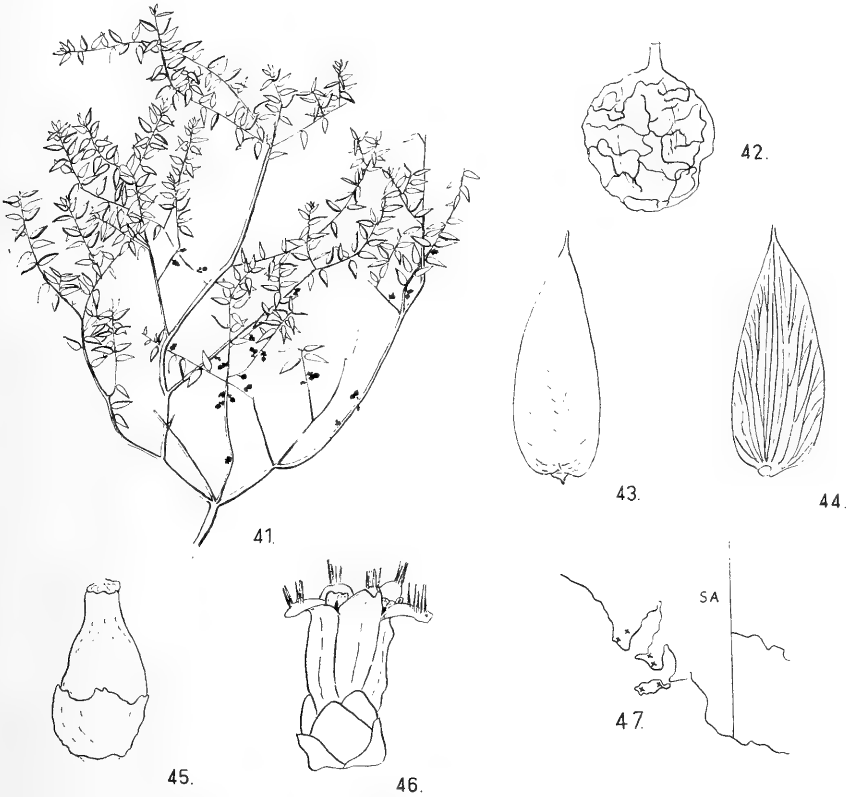
Specimens Examined.—NEW SOUTH WALES: Warrumbungle National Park, 10.1958, F. K. Hersey, (NSW 46141); foot of Breadknife, Warrumbungle Mtns., "common, spreading to 2 feet", 24.5.1959, C. K. Ingram and W. J. Hayes (NE, NSW); Baerami, 14.5.1911, R. H. Cambage (SYD); Lee's Pinch, Wollar, "altitude 1100 ft, 2-3 ft high, bushy habit. Growing on top of ridge, sandstone formation", 10.8.1950, L. A. S. Johnson and E. F. Constable (NSW 18840, NE); Wollar, via Mudgee, "green flowers in clusters on old wood. Leaves spreading scarcely paler underneath", 11.8.1950, L. Johnson and E. Constable (INGRAM, NE); Lee's Pinch, Goulburn River, 5.10.1952, C. K. Ingram (INGRAM); Harvey Range State Forest, Trewilga, "compact undershrub 2-3 ft., fruits creamy-green. Common, granite", 2.10.1951, E. F. Constable (NE, NSW 17344).

This group has previously been regarded as belonging to *A. serrulata*. However, its specific nature is realized when the general habit of the plant and the internal and external structures of the leaf and fruit are considered (Paterson, M.Sc. thesis 1959, NE). The localization of this plant to small areas is probably due to clearing, since in protected areas, such as the Harvey Range State Forest, Constable (NE, NSW 17344) has recorded it as common.

6. ACROTRICHE PROSTRATA F. Muell., in *Trans. Vict. Inst.*, 40 (1855). (Text-figs 35–40.)

A trailing shrub, with weak prostrate pubescent branches, which are adpressed to the ground and bear adventitious roots. *Leaves* narrow to broadly lanceolate, thin, spreading, ciliate, 7·5–15 mm. long, 2–8 mm. broad, attenuate mucronate tip 1 mm. long; margins slightly recurved, ciliate; lower surface scarcely paler than upper surface. *Inflorescence*: Flowers 7–10 in clusters on lower side of stem, outer flowers curved. *Bracteoles* keel-shaped, 1 mm. long. *Sepals* lanceolate, 3 mm. long, 1·5 mm. broad, membranous, with several long hairs near the apex. *Corolla* greenish, tube inflated, 4 mm. long, long hairs on back of lobes; and at the throat long scattered hairs arise from a slight swelling. *Stamens*: Anthers oblong, 0·8 mm. long on short filaments. *Ovary* lobed, 1–1·5 mm. diameter, 0·8–1 mm. long, 5-celled; long thin hairs on distal half, proximal half covered by a lobed nectary 0·5 mm. long. *Style* slightly conical, 2 mm. long; globose stigma. *Fruit* not seen by the writer, or described by previous writers.

Range: Southern and eastern Victoria.



Figs 41-47.—*Acrotriche patula.* 41, Habit × 0·25; 42, fruit × 5·5; 43, upper surface of the leaf × 2·5; 44, lower surface of the leaf × 2·5; 45, pistil × 9·5; 46, flower, × 5·5; 47, distribution.

Specimens Examined.—VICTORIA: Dandenong Ranges, 7.1900, C. Walker (MEL); Dandenong Ranges, 1.1853, F. v. Mueller (MEL); Delatite River, 3.1853, F. v. Mueller (MEL); Montrose, P. St John (MEL): Beaconsfield, 21.4.1902, P. R. H. St. John (MEL); Emerald, 1903, J. P. McLennan (MEL); Old Beerae Rd., 12.2.1956, S. Ducker (MELU).

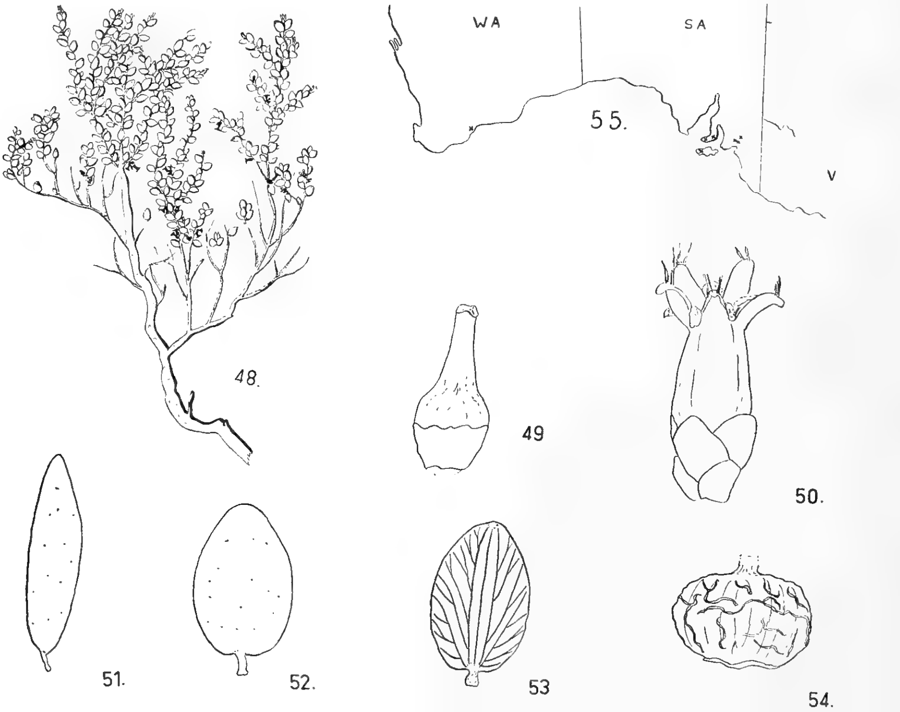
A small localized species which is remarkable in being the only member of the genus to have adventitious roots growing from the frail stems which are adpressed to the ground.

In 1855, when Mueller described this species, he remarked that "the nearest affinity is to *A. ramiflora*, and it produces likewise edible fruits". The author is of the opinion that Mueller was referring to *A. fasciculiflora* (Regel.) Benth., and not to *A. ramiflora* R.Br. (*Fragm. Phytog.*, vi: 44). Yet later (1867) Mueller combined *A. prostrata* with *A. serrulata* under the name *Styphelia serrulata*, but all subsequent workers have regarded these two species as distinct. With respect to the arrangement of the flower spike and the structure of the individual flower, this species most closely resembles *A. halmaturina*, but in habit and leaf structure *A. prostrata* is distinct.

7. ACROTRICHE PATULA R.Br., *Prod.*, 547 (1810). (Text-figs. 41-47.)

Synonymy: *Styphelia patula* (R.Br.) Spreng., *Syst.*, i: 657 (1824). *Styphelia patula* (R.Br.) F. Muell., *Fragm. Phytog.*, vi: 44 (1867).

Rigid, divaricately branched shrub forming dense clumps up to 0·6 m. diameter, and 0·4–0·6 m. high; young stems lightly pubescent. *Leaves* ovate-lanceolate, rigid, concave above, 6–12 mm. long, 2·3–5 mm. broad, with attenuate mucronate pungent tips; margins slightly serrated towards the apex; upper surface glabrous, shiny; lower surface discoloured. *Inflorescence*: Flowers pale green, in axillary spikes or clusters with 6–9 flowers. *Bracteoles* keel-shaped, glabrous, or microscopically pubescent, 0·6 mm. long, 1·2 mm. broad. *Corolla* green with a white streak extending from the throat to halfway down the corolla-tube along the lines of fusion; tube 2·3 mm. long, lobes 1 mm. long, with reflexed hairs at apex of lobes tending to form a line linking them with the hairs at throat, the latter arise directly from the epidermal cells. *Stamens*: Anthers orbicular, orange-brown, 0·7 mm. long. *Ovary* glabrous, angled, 1 mm. diameter, 1·2 mm. long, 5–8-celled, lobed nectary covering proximal half 0·5 mm. long. *Style* short, linear to conical; flat stigma. *Fruit* green, glabrous, depressed-globular. 2–3 mm. diameter.



Figs 48-55.—*Acrotriche cordata.* 48, Habit × 0·25 ; 49, pistil × 9·5 ; 50, flower × 5·5 ; 51, 52 upper surface of two leaves to show shape variation × 2·5 ; 53, lower surface of the leaf × 2·5 ; 54, fruit × 5·5 ; 55, distribution.

Range: Southern coast of South Australia and Kangaroo Is.

Specimens Examined.—SOUTH AUSTRALIA: Marino, 6.3.1926, E. H. Ising (AD 95815024) ; near Daly Head-Warooka Road about 8 Km. east of crossing with Corny Point-Stenhouse Bay Road, 30.9.1957, Hj. Eichler 14157, 14158, (AD95813074, NE, AD95813067, NE) ; between Corny Point and Cape Spencer, 26.9.1957, Hj. Eichler 13970 (AD 95750040, NE) ; south of Mt. Damper, about 15 Km. N.E. of Minnipa 23.9.1957, J. B. Cleland (AD 95846001) ; on cliffs (300 feet high) within 100 yards of edge, west of Lake Hamilton, Eyre Peninsula, "calcarious sandy soil, low rigid shrub to 3 feet high", 27.2.1959, H. B. S. Womersley (AD 95912001) ; Kingscote, K.I., "1-2 feet high, 2 feet diameter", 18.8.1958, B. R. Paterson (BRI, INGRAM, SYD) ; American River, "dense much branched shrub, 1-2 feet high, 2 feet diameter, green fruits pale green flowers", 18.8.1958, B. R. Paterson (AD, HO, MEL, NE, NSW, NSWU, PERTH) ; West Bay, in Flinders Chase, K.I., 12.4.1958, J. B. Cleland, (AD 95817048).

A. patula shows only slight variation between its different populations.

8. ACROTRICHE CORDATA (Labill.) R.Br., *Prod.*, 548 (1810). (Text-figs 48–55.)

Synonymy: *Styphelia cordata* Labill. *Nov. Holl. Pl. Spec.*, i: 46, t.63 (1804). *Acrotriche ovalifolia* R.Br., *Prod.*, 548 (1810). *Styphelia ovalifolia* (R.Br.) Spreng., *Syst.*, i: 656 (1824). *Acrotriche subcordata* DC., *Prod.*, vii: 757 (1839). *Acrotriche ovalifolia* var. ? *oblongifolia* Benth., *Fl. Austral.*, iv: 228 (1868).

Erect spreading shrub 0·1–0·2 m. high; young branches lightly pubescent. Leaves ovate to oblong, thick, flat or nearly so, 5–12 mm. long, 2–5 mm. broad; margins smooth; upper surface glabrous, shiny; lower surface with three prominent veins which form a blunt callous point at the apex; a few small protuberances between the veins. *Inflorescence*: Flowers green, in axillary 3–6-flowered spikes. *Bracteoles* keel-shaped, glabrous, 1 mm. long. *Sepals* ovate, glabrous, obtuse, 1·5 mm. long, 1·3 mm. broad. *Corolla* green, tube may be slightly inflated, 2·5 mm. long, lobes 1·5 mm. long, spreading; numerous short hairs at the throat arising from a cushion. *Stamens*: Anthers orange, orbicular, 0·5 mm. long on short filaments. *Ovary* glabrous, green, 1 mm. diameter, 1 mm. long, 4–5-celled; lobes nectary covering proximal half 0·5 mm. long. *Style* short, thick, conical, 1 mm. long; obtuse stigma. *Fruit* globular-depressed, pale green, 2–3 mm. diameter, 1·5–2 mm. long.

Range: Usually coastal areas of southern Western Australia, South Australia and south-western Victoria.

Specimens Examined.—SOUTH AUSTRALIA: Bangham, about 35 Km. south-east of Bordertown, 5.1931, J. B. Cleland (AD 95911061); Bangham, 29.5.1931, J. B. Cleland (AD 95911063); scrub between Bordertown and Naracoorte, 13.3.1931, J. B. Cleland (AD 95911060); Meningie, near Lake Albert, 9.11.1958, J. B. Cleland (AD 95911054); Chauncey's Line, about 15 Km. south-west of Murray Bridge, 26.9.1953, J. B. Cleland (AD 95911059); Chauncey's Line Mallee, 7 miles east of Hartley, 10.12.1938, E. H. Ising (AD 95813096); Coonalpyn, 5.1911, Herb. J. B. Cleland (AD 95911057); Encounter Bay, Goolwa, 27.8.1935, J. B. Cleland (AD 95911064); near Maitland, 19.5.1928, J. B. Cleland (AD 95911056, AD 95911066); seacoast about 4 Km. south of Corny Point, 27.9.1957, Hj. Eichler 14056 (AD 95751088, NE); Port Lincoln, 28.6.1952, F. Mills (AD 95726001); Kirton Point Reserve, Port Lincoln, 12.10.1958, D. J. E. Whibley 367 (AD, NE); Rocky River, K.I., 2.2.1940, J. B. Cleland (AD 95911058); Rocky River, K.I., 6.3.1925, J. B. Cleland (AD 95911062); Rocky River, K.I., 4.3.1929, J. B. Cleland (AD 95911065); road to Cape de Couedic, K.I., 4.12.1934, J. B. Cleland (AD 95911067); West Bay, in Flinder's Chase, K.I., 12.4.1958, J. B. Cleland (AD 95817049); south end of Flinder's Chase, K.I., 13.4.1958, J. B. Cleland (AD 95817047); South Australia, F. v. Mueller (MEL); South Australia, 1900, W. Gill (MEL). WESTERN AUSTRALIA: Qualup, Gairdner River, "diffuse 4-8 ins. high, flowers green, sandstone cliffs", 16.10.1928, C. A. Gardner (Perth); West Australia, A. Drummond (MELU).

Infraspecific leaf variation within *A. cordata* ranges from elliptical-oblong leaves (2 × 12 mm.) to ovate-oblong leaves (4 × 5). A photograph of the type specimen *A. ovalifolia* var.? *oblongifolia* Benth. was examined. The leaves were elliptical-oblong, their characters within the infraspecific variation.

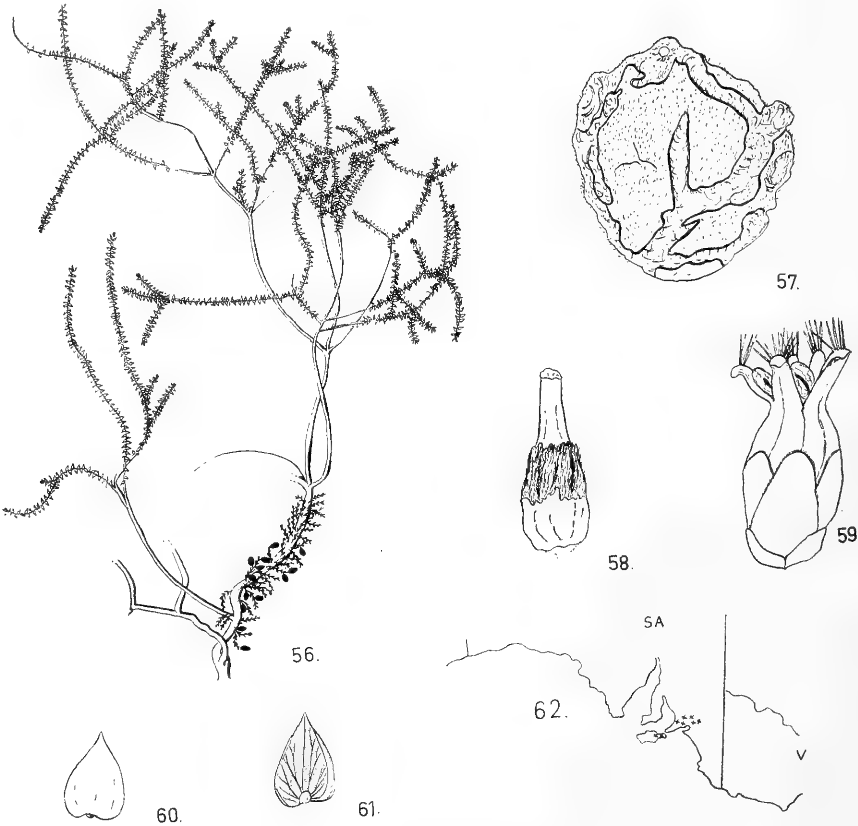
9. ACROTRICHE DEPRESSA R.Br., *Prod.*, 648 (1810). (Text-figs 56–62.)

Synonymy: *Styphelia depressa* (R.Br.) Spreng., *Syst.*, i: 655 (1824). *Acrotriche depressa* var. *loddigesii* DC., *Prod.*, vii: 757 (1838). *Styphelia depressa* (R.Br.) F. Muell., *Fragm.*, vi: 44 (1867).

A rigid spreading, intricately branched shrub 0·6–1·7 m. high, young branches pubescent. *Leaves* thick, glabrous, reflexed, ovate-lanceolate, to subcordate, 2·5–3 mm. long, 1·5–2 mm. broad; with a mucronate pungent tip, flat or convex above, margins rough, slightly recurved; lower surface bears microscopic hairs between the veins, giving a pale colour to this region. *Inflorescence*: Flowers 12–20 in long spikes massed towards the base of the stem. *Bracteoles* keel-shaped, 1 mm. long. *Sepals* lanceolate, glabrous except for a marginal fringe, obtuse, 2·5 mm. long, 1 mm. broad. *Corolla* pale green, tube 3–4 mm. long, lobes 1–2 mm. long; hairs at throat in tufts arising directly from the epidermal cells. *Stamens*: Anthers brick red, oblong, 0·5 mm. long. *Ovary* egg-shaped with adpressed hairs, 0·8 mm. diameter, 1·5 mm. long, 2–3-celled; proximal half covered by a much dissected nectary 0·8 mm. high. *Style* straight, 1 mm. long, flat stigma. *Fruit* fleshy, ovoid, dark purple when ripe, 5–7 mm. diameter, 8–10 mm. long, short scattered hairs; 1–2 trigonous seeds usually ripen.

Range: North-western Victoria, South Australia, Kangaroo Is., and Western Australia, usually on sandy soils.

Specimens Examined.—SOUTH AUSTRALIA: Near Millbrook Reservoir, "in *Eucalyptus obliqua-E. elaeophora* sclerophyll forest", 7.2.1950, R. L. Specht (ADU); Hartley, 24.8.1958, B. R. Paterson (INGRAM, NE, NSW, PERTH); Chauncey's Line Wild Life Reserve, *ca* 11 Km. south of Monarto South, 16.4.1956, Hj. Eichler 12402 (AD 95904117); Strathalbyn, "2 feet", 26.8.1958, B. R. Paterson (AD, MELU, NSW); Goolwa Shrub, 8.1896, O. E. Menzel (MEL); American River K.I., "bush spreading ½ to 2 feet, fruits almost black", 18.8.1958, B. R. Paterson (AD, ADW, BRI, HO, MEL, NE, NSW, SYD, PERTH); 13 Km. due south of Kingscote on the road Kingscote-Penneshaw, "shrub ca. 1·7 m high", 13.11.1958. Hj. Eichler 15485 (AD, NE); 13 Km. due south of Kingscote on the road Kingscote-Penneshaw, "shrub about 30 cms", 13.11.1958, Hj. Eichler 15486 (AD, NE).



Figs 56-62.—*Acrotriche depressa.* 56, Habit × 0·25; 57, fruit × 5·5; 58, pistil × 9·5; 59, flower × 5·5; 60, upper surface of the leaf × 2·5; 61, lower surface of the leaf × 2·5; 62, distribution.

A. depressa has a fairly wide range, including north-western Victoria and Western Australia as well as South Australia, where it has the widest distribution. Only slight variation has been detected amongst the specimens examined, but unfortunately no specimens from Western Australia have been seen, although they have been recorded by Bentham (1868), Ewart (1930) and Black (1952).

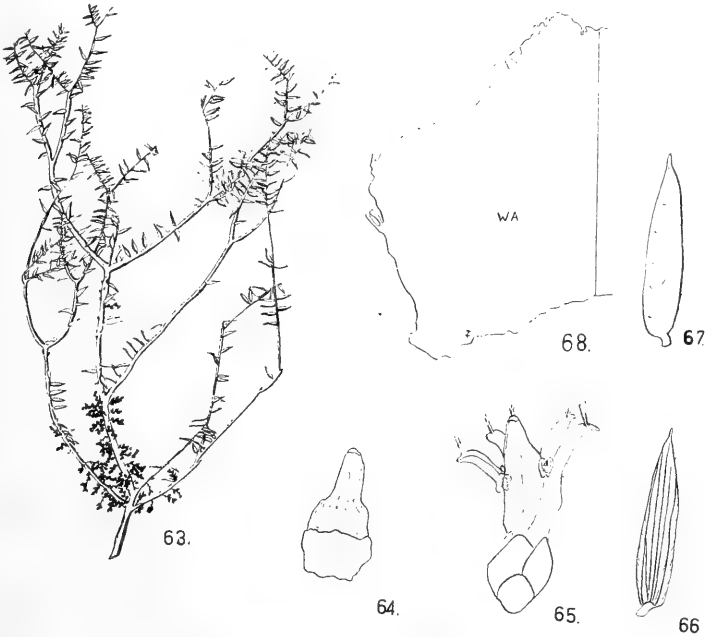
The erect habit of *A. depressa* var. *loddigesii* is within the range of infraspecific variation.

A. depressa forms a scraggy bush and from a distance it resembles *Kochia aphylla* ("cottonbush"). In South Australia it is usually known as "native currant" (on Kangaroo Is. also known as "cranberry") because of the numerous large fleshy purple fruits towards the base of the stems which are edible and are used to make jams and jellies. Large quantities of fruits are required to make a small amount of jam, and pickers in some areas have been destroying large numbers of plants by uprooting them.

10. ACROTRICHE RAMIFLORA R.Br., *Prod.*, 547 (1810). (Text-figs 63–68.)

Synonymy: *Styphelia ramiflora* (R.Br.) Spreng., *Syst.*, i: 659 (1824). *Acrotriche manglesii* Sond. in *Lehm. Pl. Preiss.*, i: 326 (1845).

Erect divaricately branched shrub 0·5–1 m. high; glabrous or slightly pubescent. *Leaves* linear-lanceolate, 6–8 mm. long, 1–2 mm. broad, spreading attenuate pungent-pointed; margins recurved, smooth or slightly serrated; upper surface scabrous, with numerous small microscopic hairs on lower surface between the veins. *Inflorescence*: Flowers 6–10 in spikes scattered along the old wood; spikes 8–10 mm. long. *Bracteoles* keel-shaped, 1·5 mm. broad. *Corolla* pinkish, tube 2·5 mm. long, lobes 1·5 mm. long; tip of lobes only slightly reflexed, hairs at throat arising from a spongy mat. *Stamens* bear microscopic hairs on filaments. *Ovary* globular, smooth, reddish, 1 mm. diameter, 1 mm. long, 4–5-celled; nectary smooth, 0·5 mm. long, covering proximal half of the ovary. *Style* straight, 0·8 mm. long, globose stigma. *Fruit* depressed-globular, red.



Figs 63-68.—*Acrotriche ramiflora*. 63, Habit × 0·25; 64, pistil × 9·5; 65, flower × 5·5; 66, lower surface of the leaf × 2·5; 67, upper surface of the leaf × 2·5; 68, distribution.

Range: Above 2000 feet, southern areas of Western Australia.

Specimens Examined.—Ellen's Peak, Stirling Range, "divaricately branched shrub, 2-3 feet high", 5.10.1928, C. A. Gardner (PERTH); the description of *A. manglesii* by Sonder (1845) is in complete agreement with two specimens of *A. ramiflora* examined; one specimen was destroyed by fire. Sonder's description is based on a specimen collected in the Swan River district by Captain James Mangles, but whether the species still exists in this locality is not known.

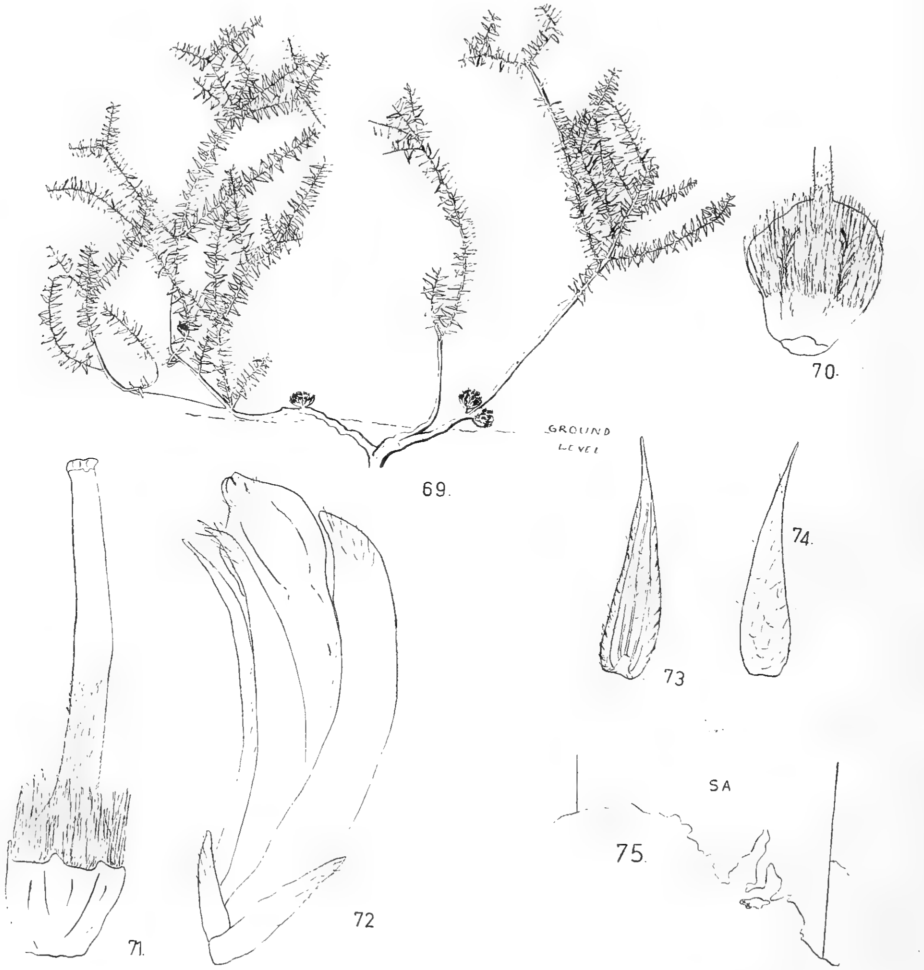
A. ramiflora superficially resembles *A. rigida*. The two species may be distinguished vegetatively as follows:

A. Leaves linear-lanceolate, 6-8 mm. long, 1-2 mm. broad; lower surface without grooves between the veins .... *A. ramiflora.*

AA. Leaves linear-lanceolate, 7·5-11 mm. long, 1-1·5 mm. broad; lower surface with deep grooves between the veins .... *A. rigida.*

11. ACROTRICHE HALMATURINA, n. sp. (Text-figs 69–75.)

Holotype: Ten miles from Rocky River off the Western Highway, Kangaroo Is., "forms small clumps 6–9 inches high, flowers in small clusters at ground level, pinkish tips on corolla", 19.8.1958, B. R. Paterson (AD). *Paratypes*: *Loc. cit.* (BRI, HO, K, L, MEL, NE, NSW, PERTH, UC, W).



Figs 69-75.—*Acrotriche halmaturina.* 69, Habit × 0·25; 70, fruit × 5·5; 71, pistil × 9·5; 72, mature bud × 5·5; 73, lower surface of the leaf × 2·5; 74, upper surface of the leaf × 2·5; 75, distribution.

Frutex humilis, in massas 0·15–0·3 m. altas collectus, cui stirpium basis sub terra sepelitur. *Folia* lanceolata, 5–12 mm. longa, 2–5 mm. lata, acumine attenuato, macronato, 1 mm. longo; marginibus recurvatis, capillis longis in et superioribus et inferioribus foliorum partibus. *Flores* curvati, 8–12 numero in stirpe ubi e terra oritur in racemis positi. *Bracteolae* angustae, 2 mm. longae, 1 mm. latae, capillos minutissimos in parte superiore ferentes. *Sepalis* subviridis, anguste lanceolatus, acutus, 8 mm. longus, 1·5 mm. latus, tenus apicem capillos minutissimos ferens. *Corollae*-tubus 5 mm. longus, capillos parvos prope acumen in parte interiore ferens; capillis longis in gula recte a cellis epidermalibus orientibus. *Stamina* antheris orbicularibus, 1 mm. longis, infilamentis brevibus positis. *Ovarium* lobatum, 1·5 mm. per medium, 2 mm. altum, in quinque partes divisum, dimidio proximo glabro et nectario lobato 1 mm. alto tecto; dimidio distanti capillos longos ferente. *Stylus* rectus, 5 mm. longus, capillos minutissimos tenus basim ferens. *Drupa* globularis, 4 mm. per medium, 4–5 mm. alta, capillis sparsis.

A low shrub forming clumps 0·15–0·3 m. high, with the stem bases buried beneath the ground surface. *Leaves* lanceolate, 5–12 mm. long, 2–5 mm. broad, with an attenuate mucronate tip 1 mm. long and margins recurved; long hairs on both upper and lower leaf surfaces. *Inflorescence*: Flowers curved, 8–12 in each cluster on the stem at ground level. *Bracteoles* narrow, 2 mm. long, 1 mm. broad, microscopic hairs at summit. *Sepals* pale green, narrow-lanceolate, acute, 8 mm. long, 1·5 mm. broad with microscopic hairs towards the apex. *Corolla*-tube 5 mm. long, with small hairs near tip on exterior surface, and reflexed reddish hairs near the tip of lobes; long hairs at the throat arise directly from epidermal cells. *Stamens*: Anthers orbicular, 1 mm. long, on short filaments. *Ovary* lobed, 1·5 mm. diameter, 2 mm. long, 5-celled, the proximal half glabrous and covered by a lobed nectary 1 mm. long; distal half bears long hairs. *Style* straight, 5 mm. long, with microscopic hairs towards the base. *Fruit* globular, 4 mm. diameter, 4·5 mm. long, with sparse hairs.

Range: Localized to Flinders Chase, Kangaroo Is., where it is found only on poor soils.

Specimens Examined.—KANGAROO I.: 3 Km. east of Western Highway and 9·5 Km. north of South Coast Rd., 8.11.1958, Hj. Eichler 15297 (AD, NE, topotype); west side of Western R., about 6·5 Km. north of Playford Highway and 29 Km. east of Cape Borda, 10.11.1958, P. G. Wilson 837 (AD, NE).

Cleland and Black (1941) were the first to notice the distinctive characters of this species. They noted that "*Acrotriche fasciculiflora* (Regel) Benth., recorded by Tate and Tepper, appears as a small form 9 inches high, with the fruit clusters less numerous in mainland species; on laterite hilltops near Bull's Creek and Rocky River, Flinder's Chase; it has not yet been found in flower and may be a new variety".

The inflorescence resembles somewhat *A. prostrata*, with its globular cluster. The habit and the leaves bear a likeness to *A. fasciculiflora.*

A. Shrub 0·15-0·3 m. high, leaves 0·275-0·325 mm. thick .... *A. halmaturina.*
AA. Shrub up to 1 m. high. Leaves 0·137-0·225 mm. thick .... *A. fasciculiflora.*

12. ACROTRICHE FASCICULIFLORA (Regel) Benth., *Fl. Austral.*, iv: 229 (1869).

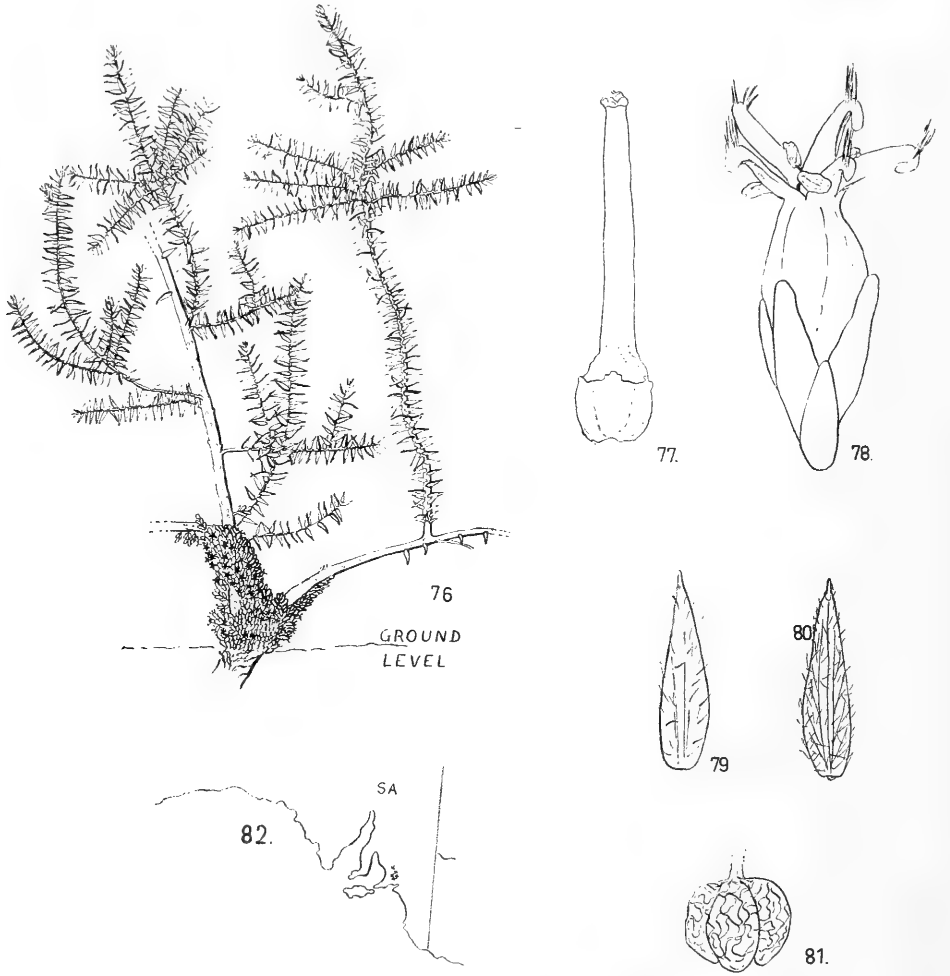
(Text-figs 76–82.)

Synonymy: *Froebelia fasciculiflora* Regel, *Gartenfl.*, i, t.18 (1852). *Acrotriche ramiflora* Sond. in *Linnaea*, xxvi: 251 (1854). *Styphelia ramiflora* (R.Br.) F. Muell., *Fragm. Phytog.*, vi: 44 (1867). *Styphelia fasciculiflora* (Regel) F. Muell., *Fragm.*, 8: 55 (1873).

Hirsute rigid shrub up to 1 m. high. *Leaves* lanceolate, thin, spreading at right angles to the stem, 7–11 mm. long, 2–4 mm. broad, with an attenuate mucronate tip 0·8 mm. long, margins recurved; long hairs on upper surface; on lower surface a few hairs scattered amongst short microscopic hairs, found between the veins. *Inflorescence*: Flowers in thick clusters crowded at the base of the stem forming a mass 4–5 cm. long; spikes contain 8–16 flowers. *Bracteoles* lanceolate, reddish, 2–3 mm. long, 1·5 mm. broad. *Sepals* reddish, lanceolate, obtuse, a few hairs near the apex. *Corolla*-tube 4–5 mm. long, inflated, lobes 2–3 mm. long, tips of lobes much reflexed and thickened; a few short hairs borne at the back of the lobes; hairs at throat arising from an oblong shaped pad or cushion. *Stamens*: Anthers oblong, pale orange, 1·5 mm. long. *Ovary* lobed, pinkish, 1–1·2 mm. diameter, 1–1·2 mm. long, 3–5-celled; glabrous, a lobed nectary 0·5–0·8 mm. long covers the proximal half. *Style* straight, 3·5–6 mm. long, the globose stigma sometimes slightly lobed. *Fruit* depressed-globular, pink, splitting on pressure to form 3–5 nutlets, 2–3 mm. diameter, 2–2·5 mm. long; style inserted.

Range: Localized to the dry sclerophyll forest of the Mt. Lofty Ranges, South Australia.

Specimens Examined.—South Australia: Mt. Lofty, 10.1955, R. M. Caraill (AD 95814022); Mt. Lofty, 3.6.1939, E. H. Ising (AD 95813095); Mt. Lofty Range, 8.1950, F. v. Mueller (MEL); Mt. Lofty, "shrub 1-3 feet, flowers at ground level, corolla inflated, pale pink near the tip, calyx reddish", 24.8.1958, B. Paterson (MEL, NSW); between Stirling West and Crafers, 17.8.1957, Hj. Eichler 13910 (AD 95813071); National Park, 1954, J. B. Cleland (AD 95815016); National Park, 1953, J. B. Cleland (AD 95815014); Mylor, 26.8.1958, B. R. Paterson (BRI).



Figs 76-82.—*Acrotriche fasciculiflora*. 76, Habit × 0·25; 77, pistil × 9·5; 78, flower × 5·5; 79, upper surface of the leaf × 2·5; 80, lower surface of the leaf × 2·5; 81, fruit × 5·5; 82, distribution.

The corolla-tubes are inflated and are half-filled with a thin honey.

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NOTES ON METAMORPHIC AND PLUTONIC ROCKS AND THEIR BIOTITES FROM THE WANTABADGERY–ADELONG–TUMBARUMBA DISTRICT, N.S.W.

By T. G. Vallance.

(Four Text-figures.)

[Read 30th March, 1960.]

Synopsis.

Variations in the chemical composition of biotites from pelitic rocks belonging to a metamorphic sequence of the Buchan type are related to the bulk composition and the nature of the ferromagnesian phases occurring with the biotites. With increase in metamorphic grade there is a decrease in the ratio Fe_2O_3/Fe_2O_3+FeO of both host rocks and biotites; the low-grade biotite is especially rich in ferric iron. Development of cordierite involves a change in the Fe/Mg ratio of the associated biotites. The biotites from plutonic rocks associated with the metamorphic sequence are generally similar in composition to those of the higher-grade metasediments.

INTRODUCTION.

H. H. Read (1952) has drawn attention to two contrasted regional metamorphic zonal sequences observable in the Dalradian pelitic rocks of eastern Scotland. The first of these, the so-called Barrovian sequence, to be seen in the Deeside area of Aberdeenshire, consists of chlorite, biotite, almandine, staurolite, kyanite and sillimanite zones (Barrow (1912), with modifications by Tilley (1925)) in order of increasing metamorphic intensity. Further north in Aberdeenshire and in Banffshire, rocks of generally similar chemical composition to those of Deeside are marked by the development of andalusite and cordierite at intermediate to high metamorphic grades and by the rarity or absence of almandine, staurolite and kyanite. This second type of association has been called the Buchan type by Read. The two types are believed to represent differences in the physical conditions of metamorphism. Examples of both Buchan and Barrovian patterns have been recorded from various parts of the world; no doubt there are also instances with characters gradational between the two contrasted patterns. In Japan, Miyashiro (1958) has used the term Central Abukuma type in referring to an association similar to that in the Buchan type of metamorphism.

A belt of rocks, showing signs of a Buchan type of metamorphism, and associated with various granitic bodies, extends for a distance in excess of 200 miles from north-eastern Victoria into southern New South Wales. Howitt (1888) and Tattam (1929) have described rocks from the Victorian end of the belt. In New South Wales metamorphic zones have been mapped and described in the Albury district by Joplin (1947) and in the Wantabadgery-Adelong-Tumbarumba district, east and south-east of Wagga Wagga, by Vallance (1953*a*). East of this main belt, similar rocks occur at Cooma, N.S.W.; these were studied in detail by Joplin (1942).

In the Wantabadgery-Adelong-Tumbarumba area, aluminous pelites and sandier rocks (originally subgreywackes and related siltstones) are associated with granitic masses belonging to two main age groups. Variations in metamorphic intensity have been plotted by means of isograds delimiting the following zones: (1) low-grade zone, (2) biotite zone, (3) knotted schist zone, and (4) high-grade zone. Increase in metamorphic grade occurs in the field with approach to the Wantabadgery Granite or the Green Hills Granite which together constitute the older granite group. Rocks of the low-grade zone typically contain a colourless to very pale green mica and chlorite. With increase in grade the phyllites and fine mica-schists acquire brown biotite at the expense of chlorite and the pale mica and thus pass into the biotite zone. At a more advanced grade, colourless andalusite and some cordierite porphyroblasts are developed in the pelites which become knotted schists. In the highest-grade zone the metasediments may have little or no schistosity. These rocks have been termed spotted granulites, following Joplin (1942, p. 175). The spotted granulites contain such minerals as sillimanite, pink pleochroic andalusite, cordierite, oligoclase and sometimes potash feldspar. Reddish-brown biotite is found in most of the metasediments from within, or of a higher grade than, the biotite zone. At the metamorphic "peak" biotite may be replaced by sillimanite. Muscovite is present in all grades, but it is clearly not of a single generation; in some high-grade rocks fine muscovite replaces sillimanite. The high-grade zone has a maximum width in outcrop of from four to five miles, but in some places is very restricted in extent. The width of the knotted schist zone is also variable. Garnets (both almandine and spessartine), staurolite and kyanite are absent from the metasediments of the present area.

In terms of the scheme of facies outlined by Fyfe, Turner and Verhoogen (1958), the mineral associations in the present metamorphic succession are much more like those of the "facies of contact metamorphism" than those of the "facies of regional metamorphism". The Barrovian metamorphic sequence falls within the "facies of regional metamorphism" while the Buchan type of regional metamorphism is considered with the "facies of contact metamorphism" by Fyfe, Turner and Verhoogen. Unfortunately the terminology may appear somewhat misleading. Both types of metamorphism discussed here are regional in extent, but, whereas the Barrovian association includes pelitic mineral assemblages "characteristic" of regional metamorphism, the mineral assemblages of pelites in the Buchan type of metamorphism are similar to those of pelites in contact thermal aureoles. It should be emphasized, however, that the fabrics of rocks in a Buchan-type sequence are quite different from the typical hornfels fabrics found in many contact aureoles. There need be little real ambiguity in the matter if it is recognized that the two groups of facies simply represent different sets of physical conditions between which a complete gradation exists. Whether or not the Buchan type of metamorphism is truly a reflection of contact metamorphism related to intrusive bodies is a matter open to question. The writer prefers to consider the older granites and the metamorphism of the sedimentary rocks of the present area as related genetically, with the granitic rocks representing a product rather than a cause of the metamorphism (Vallance, 1953*b*). The association of potash feldspar with sillimanite or andalusite in apparent equilibrium in the high-grade rocks of this area suggests an approach to Pyroxene Hornfels Facies conditions at the higher-grade end of the metamorphic series. At the low-grade end, pelitic rocks contain mineral assemblages typical of the Greenschist Facies. There is no evidence of a Zeolite Facies (Fyfe, Turner and Verhoogen, 1958) in the region, even in rocks (metamorphosed intermediate-basic igneous rocks) the composition of which would be favourable to the development of zeolites at appropriate grades.

Whilst our knowledge of the chemical compositions of biotites in plutonic rocks is fairly extensive, chemical information concerning biotites of pelitic schists is most limited. The main reason for this deficiency is, no doubt, connected with the mechanical difficulties involved in preparing pure concentrates of pelitic biotites. In 1893, Barrow published a partial analysis of a biotite from a metasediment collected in Deeside. Snelling (1957) gives analyses of six biotites also from Deeside. Barth (1936) analysed two biotites from metasediments of Dutchess County, New York. These data refer to biotites from Barrovian sequences. Miyashiro (1958) and Shidô (1958) have analysed pelitic biotites from Buchan-type metamorphic sequences. No data are available on the pelitic biotites from Banffshire.

DATA AND DISCUSSION.

Three of the analysed biotites discussed here are from metamorphosed pelites, one is from a sample of a granite and one from a biotite-rich inclusion (probably of sedimentary origin) in the granite body. The biotites were concentrated by gravity methods involving first a rough separation using bromoform followed by centrifuging in methylene iodide. Each concentrate, after several centrifugings, was checked finally with the aid of a binocular microscope. The biotite samples and the host rocks were

TABLE 1.

	1		2		3		4		5	
	Rock.	Biotite.	Rock.	Biotite.	Rock.	Biotite.	Rock.	Biotite.	Rock.	Biotite.
SiO_2	56·74	36·64	56·28	36·72	54·01	34·67	54·86	34·58	72·53	35·81
Al_2O_3	23·11	20·54	23·02	18·86	24·41	19·54	18·32	19·05	14·57	19·48
TiO_2	0·56	1·16	0·77	2·63	0·85	3·63	1·18	2·96	0·42	3·10
Fe_2O_3	3·73	9·82	1·82	4·01	1·39	3·76	2·01	3·48	0·74	3·93
FeO	2·98	10·18	5·84	16·56	5·95	17·96	8·01	17·25	2·02	16·65
MnO	0·04	0·12	0·06	0·13	0·07	0·23	0·14	0·65	0·04	0·22
MgO	2·46	8·10	3·28	8·42	2·91	8·17	4·16	9·09	1·04	7·34
CaO	0·21	0·10	0·14	0·24	0·36	0·26	1·95	0·42	0·70	0·42
Na_2O	0·21	0·25	1·21	0·61	1·09	0·38	2·46	0·79	2·25	0·54
K_2O	6·39	8·43	4·97	7·51	5·45	7·63	5·22	8·41	4·96	8·69
H_2O^+	3·30	4·11	2·82	3·91	2·64	3·67	1·30	3·07	0·72	3·50
H_2O^-	0·53	0·45	0·24	0·52	0·28	0·58	0·22	0·66	0·11	0·37
P_2O_5	n.d.	n.d.	0·10	n.d.	0·15	n.d.	n.d.	n.d.	0·09	n.d.
Total	100·26	99·90	100·55	100·12	99·56	100·48	99·83	100·41	100·19	100·05
mg	0·41	0·43	0·44	0·43	0·42	0·41	0·43	0·44	0·41	0·39
Fe_2O_3/Fe_2O_3+FeO	0·56	0·49	0·23	0·20	0·19	0·17	0·20	0·17	0·27	0·19

Key.

1. Biotite-muscovite-quartz phyllite (with accessory iron-oxide minerals).
   Loc.: Por. 45, Par. Borambula, Co. Wynyard.

2. Knotted schist (biotite-muscovite-andalusite-cordierite-quartz).
   Loc.: Por. 65, Par. Yabtree, Co. Wynyard.

3. Spotted granulite (biotite-muscovite-andalusite-cordierite-quartz-oligoclase-K feldspar-sillimanite (minor)).
   Loc.: Por. 32, Par. Wallace, Co. Wynyard.

4. Inclusion (biotite-oligoclase-muscovite-quartz-sillimanite-K feldspar) in granodiorite.
   Loc.: Por. 218, Par. Tenandra, Co. Clarendon.

5. Biotite granite (quartz-K feldspar-oligoclase-biotite-muscovite-sillimanite (minor)).
   Loc.: Por. 235, Par. Oura, Co. Clarendon.
   Anal.: T.G.V.

Biotite Cations: 24 (O, OH, F)

		1	2	3	4	5
Z	Si	5·411	5·494	5·243	5·303	5·427
	Al	2·589	2·506	2·757	2·697	2·573
Y	Al	0·988	0·818	0·726	0·745	0·906
	Ti	0·129	0·296	0·413	0·341	0·352
	Fe^{+++}	1·090	0·451	0·427	0·400	0·448
	Fe^{++}	1·257	2·071	2·271	2·211	2·110
	Mn	0·014	0·016	0·029	0·084	0·028
	Mg	1·782	1·877	1·841	2·077	1·658
X	Ca	0·015	0·038	0·042	0·068	0·067
	Na	0·071	0·176	0·111	0·234	0·159
	K	1·587	1·433	1·470	1·644	1·679
	OH	4·049	3·902	3·702	3·142	3·537

Optical Data:

	1	2	3	4
X ..	Pale greenish-yellow.	Pale straw-yellow.	Pale straw.	Pale straw.
Y ..	Brown, slightly greenish.	Medium reddish-brown.	Dark reddish-brown.	Dark reddish-brown.
Z ..	Brown, slightly greenish.	Medium reddish-brown.	Dark reddish-brown.	Dark reddish-brown.

	5
X ..	Pale straw-brown.
Y ..	Reddish-brown.
Z ..	Reddish-brown.

	1	2	3	4	5
α ..	—	1·595	1·598	1·600	1·603
β ..	—	1·638	1·643	1·644	1·649
γ ..	1·665	1·638	1·644	1·645	1·651

analysed according to the standard methods of Groves (1951) with the exception that alkalis in rock (1) and biotite (1) were estimated by means of flame photometry and that combined water in all cases was determined by the Penfield method. Analytical results and appropriate optical information are collected in Table 1.

Biotites from the Metamorphic Zonal Sequence.

Biotite (1) is from a fine-grained buff-coloured phyllitic rock not far inside the biotite isograd. In this area brown or greenish-brown biotite usually appears first in the sandier rocks and there is often a distinct lag before it develops in the pelites. As indicated above, biotite apparently forms at the expense of chlorite and muscovite. The reaction may involve the conversion of an antigoritic chlorite to an amesitic chlorite, though little is known of the chlorites in this succession. Chlorite often does not persist far into the biotite zone. With increase in grade the biotite becomes reddish-brown in colour and the next sample (2) from a dark-brown knotted schist is of this colour. The knotted schist contains a few relict grains of andalusite, but most of the porphyroblasts have been converted to fine white mica. Biotite (3) is from a spotted granulite well within the high-grade zone. In this case fresh andalusite is common; unaltered cordierite is also present, but typically this mineral has been replaced by micaceous aggregates. Muscovite is present in each of the analysed rocks.

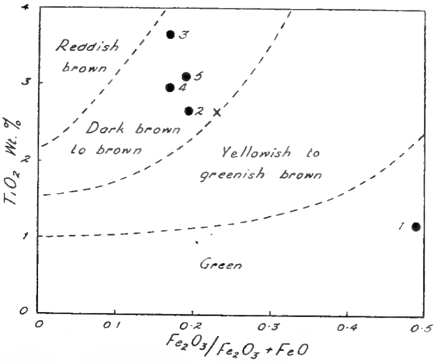

Figure 1. Diagram based on Hayama's (1959) chart showing the relation between colour and composition in the biotites. The numbered spots refer to the biotites of this paper; the X represents the biotite from a quartz-muscovite-biotite schist from north-eastern Victoria (Tattam, 1929).

The lowest grade biotite (1) has a notably higher Fe^{+++} content than the other metamorphic biotites; its brown, slightly greenish colour contrasts with the reddish-brown of the other samples. The refractive index γ is variable, but the lowest grade mica has the highest γ.

According to Hayama (1959) the change in colour of biotites from green through greenish-brown and brown to reddish-brown is related to a decrease in the ratio Fe_2O_3/Fe_2O_3+FeO and/or an increase in the TiO_2 content. Hayama argues that there is a tendency for these chemical variations to take place in a given terrain with increase in metamorphic grade. Tilley (1926), also noting similar colour changes in biotites, suggested that the FeO content of biotites from certain metamorphosed areas may increase with increase in metamorphic grade. There is general agreement with Hayama's conclusions regarding the relation between colour and compositional variations, but our biotites consistently fall outside the appropriate colour fields on Hayama's chart (fig. 1). The biotite analysed by Tattam (1929) from a quartz-muscovite-biotite schist in north-eastern Victoria was probably red-brown in colour; if so, it too falls outside the appropriate field in Figure 1.

In assessing chemical variations in the biotites of various metamorphic grades we must consider the relation between the compositions of the hosts and those of the biotites, the extent of chemical variability in the hosts, and the influence of mineral reactions within the hosts. In a given rock we may expect that the biotite will accommodate, *inter alia*, Al, Mg, Fe^{+++}, Fe^{++}, Ti, Mn and K. Most pelitic schists have an excess of Al over Fe + Mg which leads to the development of other aluminous phases in addition to the biotite at appropriate grades. Such is certainly the case here. It can be seen from Figure 2 that the biotites have distinctly lower proportions of Al_2O_3 than their host rocks. Biotites must share the Al_2O_3 available with muscovite and, in the higher grades, with andalusite and cordierite as well. What effect the development of andalusite and cordierite has on the Al content of biotite is not clear, although biotite (1) from a rock without these minerals is the most aluminous of the group. Each of the pelitic biotites, however, contains important amounts of Al in both Z- and Y-groups of the formula $X_2Y_6[Z_8O_{20}](O.OH.F)_4$ as can be seen in Table 2.

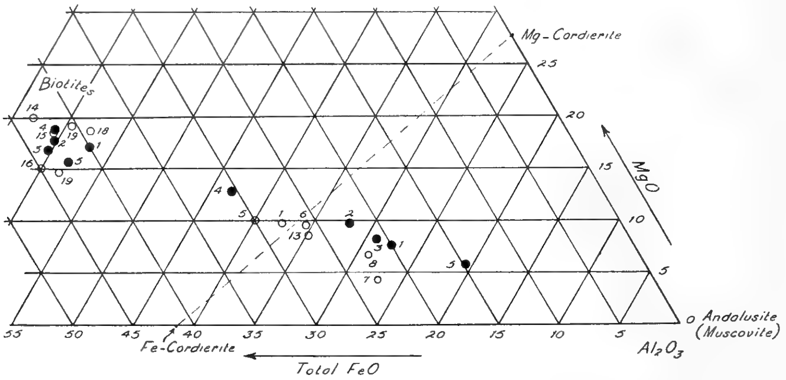

Figure 2. Portion of the diagram $MgO - Al_2O_3 -$ total FeO showing the relation between composition of biotites and the composition of the host rocks. The spots represent the analysed biotites and rocks of this paper; the open circles refer to data published by Snelling (1957). Snelling's host-biotite pairs are 1-14, 5-16, 6-15, 7-18, 8-17 and 13-19.

TABLE 2.

Pelitic Biotites.

	This Paper.				Miyashiro (1958).	Snelling (1957).
	1	2	3	Mean.	Mean.	Mean.
Si in Z group	5·41	5·49	5·24	5·38	5·37	5·24
Al in Z group	2·59	2·51	2·76	2·62	2·63	2·75
Al in Y group	0·99	0·82	0·73	0·84	0·73	0·76
Total Y group	5·26	5·53	5·71	5·50	5·56	5·56

Snelling (1957) has suggested that with increase in grade there is an increasing degree of replacement of Al for Si in the Z-group of biotites from Deeside. Certainly, in the present case, the high-grade biotite (3) has a higher content of Al in the Z-group than do the lower grade biotites. It must be admitted, however, that the evidence for increasing substitution of Al for Si with increase in grade is not especially convincing. The variation in the Si/Al ratio of the analysed metasediments (pelites, psammopelites and psammites) from the Wantabadgery-Adelong-Tumbarumba area is a feature of original composition dependent mainly on the sand/clay ratio of the original rocks. Although there are only slight differences in the Si/Al ratios of the rocks (1), (2) and (3) from which biotites were separated, Snelling's biotites come from rocks representing a wider range of Si/Al. The close association of the points representing analysed biotites in Figure 3 is noteworthy.

Figure 4 indicates a rough constancy in the MgO/total FeO ratios of the host rock–biotite pairs. In the absence of other ferromagnesian minerals, *mg** (biotite) will approximate *mg* (rock). Some fifty chemical analyses of metasediments of various grades are available from north-eastern Victoria and south-eastern New South Wales. Although there is a considerable range in *mg* values, no systematic variation with grade is evident (fig. 4—based on examples from N.S.W.; the Victorian rocks are as yet unzoned). Higazy (1954) has noted an over-all constancy of the ratio Fe/Mg in the rocks of Deeside ranging from chlorite to sillimanite zones; Snelling's (1957) results, also on rocks from Deeside, indicate much the same state of affairs. In such cases, it is reasonable to suppose that, if biotite is the sole ferromagnesian mineral present, variations in *mg* (biotite) will reflect variations in bulk composition and we can hardly

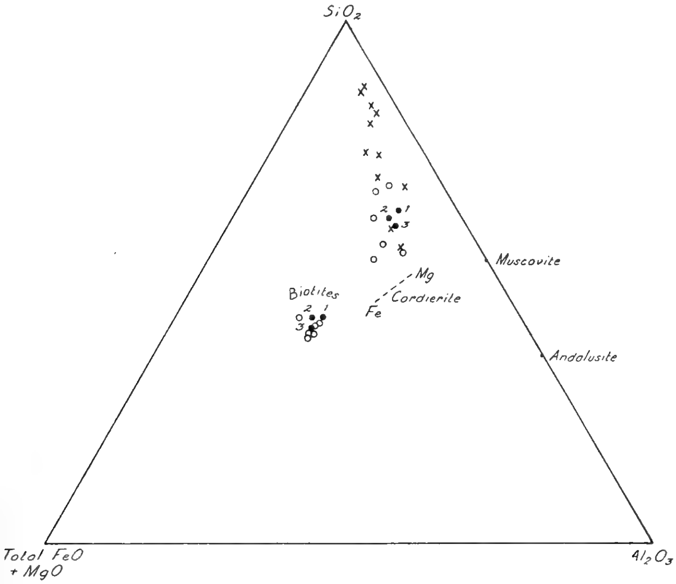

Figure 3. $SiO_2 - Al_2O_3$ – total FeO + MgO diagram showing the relation between biotites and their host rocks. The spots refer to the analyses in this paper, the crosses represent other analysed metasediments from the Wantabadgery-Adelong-Tumbarumba district (Vallance, 1953*a*). Biotites and host rocks from Deeside (Snelling, 1957) are indicated by open circles. Important phases which may co-exist with biotite in the present area are plotted on the diagram.

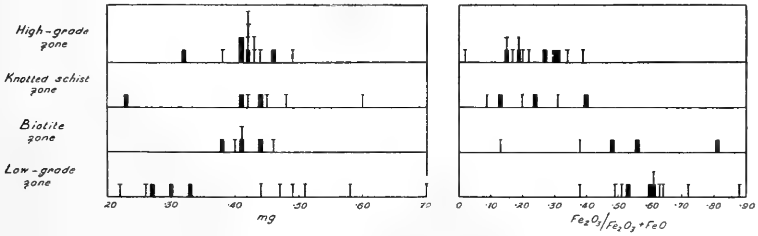

Figure 4. Diagram showing the relations between metamorphic grade and the *mg* and $Fe_2O_3/Fe_2O_3 + FeO$ values of metasediments from the Cooma, Albury and Wantabadgery-Adelong-Tumbarumba districts of New South Wales. The thick lines represent analysed rocks from the latter area.

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* Niggli value—derived from MgO/FeO + MnO + MgO.

expect to find systematic changes in *mg* (biotite) with variation in metamorphic grade. However, in the Buchan type of metamorphism, cordierite is a possible phase in pelitic rocks, while in the Barrovian sequence almandine and staurolite may appear. Biotite co-existing with cordierite may be expected to have a lower *mg* value than the host (analysed examples are given by Mathias (1952) and Hietanen (1956); the opposite relation should hold where biotite co-exists stably with almandine or staurolite (see, for example, Pawlica (1919)). There may thus be contrasting patterns in *mg* variations in the two zonal sequences. The differences between host and biotite in the two sequences may, however, be relatively small. Figure 2 shows the relations between the biotite—host pairs listed in Table 1, together with the pairs described by Snelling. If lines are drawn from the apex Al_2O_3, through the points representing the host rocks, and extended to the opposite side of the triangle, it will be seen that each of the biotites from rocks containing cordierite falls on the "Fe" side of the appropriate line whilst those biotites from almandine or staurolite-bearing schists fall on the "Mg" side of the line. Presumably these differences are connected with the redistribution of material during the development of new mineral phases. Biotite (1), from a muscovite-biotite phyllite, is relatively more magnesian than its host; it should be noted that this rock contains accessory iron oxide minerals. The appearance of cordierite in the knotted schist zone is apparently associated with the change to a less magnesian biotite. In this case MgO and FeO must be regarded rather as separate components; the four components K_2O, Al_2O_3, (MgFe)O, (FeMg)O lead to the assemblage muscovite, biotite, andalusite, cordierite in the knotted schist zone.

The TiO_2 contents of the analysed biotites appear to increase with increase in grade. This may, however, be more apparent than real. No sign of systematic variation in TiO_2 content with metamorphic grade is evident in the analyses of metasediments from the Cooma, Albury or Wantabadgery-Adelong-Tumbarumba districts. As most of the TiO_2 contained in these rocks occurs in the biotite it seems reasonable to expect that those rocks with the highest TiO_2 will carry biotites richest in TiO_2. In the present case, the hosts have TiO_2 (wt. %) 0·56 (1), 0·77 (2), 0·85 (3), and so the apparent increase in TiO_2 in the biotites may well be connected with the sampling. The development of phases such as cordierite, almandine or staurolite would have little effect on the distribution of TiO_2 since these minerals have slight tolerance for Ti-substitution. Snelling's data on the Deeside biotites indicate no systematic variation in TiO_2 content with grade. The pelitic biotites of the Gosaisyo-Takanuki district (Central Abukuma Plateau, Japan) show a rough tendency to have higher TiO_2 contents in the high-grade zone (Miyashiro, 1958), but in the absence of analyses of the individual host rocks it is difficult to establish the significance of this variation.

Miyashiro has also drawn attention to the fact that in his area the biotites of the high-grade zone are poorer in MnO than the biotites of a lower grade zone. The difference in Mn content is attributed to changes in equilibrium relations between biotites and co-existing Mn-bearing garnets. In the present cases garnets are absent, but it seems likely that the Mn of the rock will be shared between biotite and cordierite. Analyses of co-existing cordierites and biotites given by Mathias (1952) and Hietanen (1956) indicate, in each case, that the MnO content of the cordierite exceeds that of the biotite. It must be admitted, however, that the analytical results in Table 1 give no clear picture as to the distribution of Mn. The rock having the highest content of cordierite (no. 3) has a biotite with a substantially higher MnO content than those of the other pelites. All that can be said here is that the pelite with the highest MnO has the most manganiferous biotite.

On the other hand, the oxidation state of iron does show signs of systematic variation. It may be seen from Figure 4 that the higher grade rocks have generally lower Fe_2O_3/Fe_2O_3+FeO values than their lower grade equivalents. A similar tendency is apparent in the analysed biotites (1), (2) and (3). The highly ferric low-grade biotite (1) is especially noteworthy. Biotites with high Fe^{+++} contents have also been recorded from low-grade rocks in Scotland (Dalradian Green Beds—Phillips, 1930) and Japan (Miyashiro, 1958; Shidô, 1958). The pelitic and psammopelitic rocks from Deeside of which analyses are quoted by Higazy (1954) and Snelling (1957) give little indication of a declining Fe_2O_3/Fe_2O_3+FeO ratio with increasing grade. In the case of the biotites described by Snelling there appears to be only slightly more evidence of this relation. At any rate, the values of Fe_2O_3/Fe_2O_3+FeO for Snelling's biotites are distinctly lower than those of the pelitic biotites listed in Table 1. From Dutchess County, New York, Barth (1936) noted a reddish-brown biotite with little Fe^{+++} from a pelite occurring near the biotite isograd in a Barrovian succession. On the evidence available it seems that the biotites of low-grade pelites in the Buchan type of environment tend to have higher values for Fe_2O_3/Fe_2O_3+FeO than do those in the biotite zone of a Barrovian sequence. In the higher grade zones the situation is less clear, though the tendency mentioned may well be general.

Miyashiro (1958) and Hayama (1959) have discussed the change in oxidation-state of iron in pelitic/psammitic biotites. The oxidation-state will vary according to the physical environment of metamorphism—temperature, solid-pressure and O_2-pressure being important factors. Miyashiro and Hayama suggest that the O_2-pressure is determined mainly by the dissociation of water. There would thus be a tendency for higher values of Fe_2O_3/Fe_2O_3+FeO associated with metamorphism under higher water-pressures. Both Miyashiro and Hayama compare Snelling's biotites with samples from the Abukuma Plateau of Japan and conclude that the Barrovian metamorphism took place under lower water-pressures than those prevailing during the Abukuma metamorphism. The Fe_2O_3/Fe_2O_3+FeO ratios of the biotites from the Wantabadgery-Adelong-Tumbarumba district are much closer to those from the Abukuma Plateau than to those from Deeside. Tattam's biotite from a metasediment in Victoria has an oxidation-ratio of iron (0·23) within the range of values for the pelitic biotites in Table 1. These relations are noteworthy in view of the fact that the metamorphism in the Australian and Japanese examples is of the Buchan type in contrast to the Barrovian metamorphism of Deeside. It is especially unfortunate that there is no information available on the biotites of pelitic schists in Banffshire. The values of (OH) in the calculated formulae for the biotites (1), (2) and (3) are, in order of increasing metamorphic grade, 4·049, 3·902 and 3·702. No information is available on the relation between the ratio F/OH and grade of metamorphism.

Biotites from Plutonic Rocks.

The biotites (5) and (4), separated respectively from a representative sample of the Wantabadgery Granite and a biotite-rich inclusion from a granodioritic phase of that body, are generally similar in composition and optical characters to samples (2) and (3) from metasediments. The inclusion has a medium-grained, almost granitic, fabric, but contains sillimanite and is probably of sedimentary origin. In contrast, however, to the local metasediments with comparable SiO_2 contents the inclusion holds greater quantities of Na_2O and CaO, possibly derived from the granitic host. Although Na_2O and CaO do not contribute substantially to the composition of common biotites, it should be noted that biotite (4) from the inclusion carries greater amounts of these constituents than the pelitic biotites. The Fe/Mg ratio of the inclusion is similar to those of the analysed pelites, but the total FeO + MgO is considerably greater in the inclusion (see fig. 2). The granite (5) also carries iron and magnesia in similar relative proportions, but the total ferromagnesian content of the granite is, of course, much lower. Figure 2 indicates the richness of the granite in Al_2O_3 relative to total FeO + MgO. The biotite from the granite, reflecting this compositional feature, is richer in Al_2O_3 than that from the inclusion. As is to be expected in a rock rich in K-feldspar, the ratio K_2O/Al_2O_3 is higher for the granite than for the pelitic metasediments. Of the five analysed micas, that from the granite has the highest K_2O content. Both plutonic biotites have higher values for the X-group (K, Na, Ca) of the structural formula than the biotites from pelites. In this regard there appears to be a connection between composition of the biotite and composition of the host rock. As the *mg* values for these plutonic rocks are similar to those of the metasediments quoted here it is not surprising that *mg* of the biotites should also be roughly similar. It is not clear, however, why the granitic biotite should appear to be slightly less magnesian than the host rock. The relatively high MnO content of biotite (4) from the inclusion is presumably a reflection of the high MnO content of the host.

Nockolds (1947) has collected data on the relation between paragenesis and chemical composition of biotites in granitic rocks. Referring to the information collected by Nockolds it may be seen that there are differences in the distribution of Al in the Z- and Y-groups of the structural formulae of biotites according to the nature of the minerals associated with the dark micas. In the present case muscovite occurs with biotite in both granite and inclusion; sillimanite is present in both cases, though in the granité it is a minor accessory. The biotites from these rocks have their Al distributed in proportions similar to those of Nockolds' biotites associated with muscovite (see Table 3). For comparison, the distribution of Al in two plutonic biotites from north-eastern Victoria is given in Table 3. The rock from which Tattam separated his biotite no. 16 appears to have contained muscovite; biotite no. 15 was from an inclusion lacking muscovite in a granite body. It can be seen from Table 2 that the biotites from metamorphosed pelites, in which muscovite consistently appears, have their Al distributed in a manner comparable with that of the biotites of plutonic rocks containing muscovite.

TABLE 3.

Plutonic Biotites.

	This Paper.		Tattam (1929).		Nockolds (1947).	
	4	5	(16)	(15)	(*a*)*	(*b*)
Si in Z group	5·30	5·43	5·34	5·33	5·26	5·43
Al in Z group	2·70	2·57	2·66	2·64	2·74	2·57
Al in Y group	0·74	0·91	0·62	0·17	0·78	0·40
Total Y group	5·86	5·50	5·36	5·44	5·42	5·61

* (*a*) refers to mean values for biotites associated with muscovite in rocks ranging from granites to quartz-diorite.
(*b*) refers to mean values for biotites "occurring alone" in rocks ranging from granites to tonalite.

The oxidation-ratios of iron in the plutonic biotites are of the same order as those in the biotites of the higher grade metasediments. From this it might be suggested that water-pressures were roughly equivalent in both the high-grade metamorphic and plutonic environments. If such were the case there is at least no conflict with the field and petrographic evidence (Vallance, 1953*a*, *b*) suggesting a close relation in time and in the physical conditions under which the metamorphism was accomplished and the granite locally introduced and crystallized. The forty biotites from granites, adamellites, granodiorites, tonalites, quartz diorites and diorites quoted by Nockholds (1947) have an average Fe_2O_3/Fe_2O_3+FeO ratio of 0·17. In terms of paragenesis there appears to be little significant variation in the oxidation-ratio of the iron. Thus of the seven biotites occurring with muscovite, the average ratio is 0·18 and the range 0·08–0·36; sixteen biotites occurring alone have an average of 0·16 and a range of 0·07–0·34; while seventeen biotites associated with hornblende have values ranging from 0·04–0·29 with an average of 0·19. In comparing these values with those of the present samples it must be remembered that Nockolds' biotites represent a wide sampling of plutonic environments. The biotites (4) and (5) have values for Fe_2O_3/Fe_2O_3+FeO very close to the average based on Nockolds' collection.

Granites and Metamorphism in Buchan and Barrovian Environments.

If, in the present case, water-pressures were of the same order in both higher grade metasediments and in the granitic environments it is interesting to speculate on this association in relation to the Buchan-type metamorphism. The suggestion was made earlier, following the arguments of Miyashiro and Hayama, that the metamorphism was accomplished under rather higher water-pressures than those obtaining during the Barrovian metamorphism in Deeside. Not much information is available on the granites and granitic biotites associated with the Deeside metamorphism. Barrow (1893) published a partial analysis of one biotite from an Older Granite. This biotite, though less magnesian ($mg = 0{\cdot}25$) than the biotites from metasediments quoted by Barrow (1893) and Snelling (1957), is, on the whole, fairly similar in composition to the pelitic biotites. The value of $Fe_2O_3/Fe_2O_3 + FeO$ for Barrow's granitic biotite (0·11) is well within the range (0·03–0·20; average 0·10) of values for the biotites from metasediments of the almandine and higher grade zones in which the Older Granites are emplaced in the Deeside region. The evidence, such as it is, suggests lower oxidation ratios for iron in the biotites of both metasediments and plutonic rocks of the Barrovian association when compared with the biotites of higher grade pelites and plutonic rocks of the present case. This difference is also to be seen in the oxidation-ratios of iron in the plutonic rocks of the two areas. Williamson (1935) gives analyses of three samples of an Older Granite (Duchray Hill Gneiss) from Glen Shee, adjacent to Deeside. The range of values for $Fe_2O_3/Fe_2O_3 + FeO$ in Williamson's examples is 0·09–0·20 (average 0·14). From the Wantabadgery, Cooma and Albury districts of New South Wales, we have seven analysed samples of granitic rocks associated with the Buchan-type metamorphism; the range of $Fe_2O_3/Fe_2O_3 + FeO$ for these cases is 0·14–0·46, with an average value of 0·22. No firm conclusions can be based on evidence such as this, but certainly the nature of the granitic rocks (which may be, in part, migmatitic) associated with these two types of regional metamorphism is a matter deserving of close attention. In both cases it seems evident from field and chemical studies that the granitic rocks are derived largely from materials in the metamorphosed terrain. Most, if not all, of the iron and magnesium of the plutonic rocks may have been supplied from the metasediments. The average mg values for thirty-seven metasediments from Cooma, Albury and the Wantabadgery-Adelong areas is 0·42; the average mg for the seven associated granitic rocks is 0·38. Within the latter area, the similarity is more striking; for fourteen metasediments the average mg is 0·37, while four analysed granitic rocks also give an average mg of 0·37. Comparisons such as these involve, of course, the assumption that the analysed rocks constitute really representative samples. For twenty-one analysed metasediments from Deeside and Glen Shee (Barrow, 1893; Higazy, 1954; Snelling, 1957; Williamson, 1935) the average mg is 0·36; the average for Williamson's Older Granite is 0·37.

Fyfe, Turner and Verhoogen (1958—fig. 108) suggest that the Buchan and Barrovian environments differ in that the Buchan metamorphism is accomplished under conditions of lower load pressure (lower depths) than the Barrovian metamorphism. The temperature range, on the other hand, may be of the same order in both cases. As yet we know little about the influence of stress on the mineralogy of the rocks produced in the two environments. Harker (1939) suggested that the Buchan-type metamorphism is effected under conditions of lower stress than those associated with a Barrovian metamorphism. It seems likely from the present study, as well as from the observations of Japanese workers, that water-pressures are higher in metamorphism of the Buchan type. Both regional metamorphic sequences lead to the development of migmatitic and granitic rocks which apparently bear the impress of the physical environments appropriate to the higher grades of metamorphism in the two cases.

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ARICIID POLYCHAETES IN AUSTRALIA.

By D. T. ANDERSON, Department of Zoology, University of Sydney.

[Read 30th March, 1960.]

Synopsis.

The discovery of a dense population of the ariciid polychaete *Haploscoloplos fragilis* (Verril) at Botany Bay is reported. Nomenclature in *Scoloplos* and *Haploscoloplos* species is discussed and the latter upheld as a genus.

Few records exist of the occurrence of ariciid polychaetes in and around the Australian littoral. Apart from the description by Kinberg (1865) of a specimen of *Labotas novae hollandiae* collected at Port Jackson by the "Eugenie Expedition", re-examined by Augener (1922) and transferred by him to the genus *Scoloplos* as *S. novae hollandiae*, the only other identifications rest on a small number of specimens collected in Western Australia and described by Augener (1914) under the names *Scoloplos armiger* O. F. Muller (a cosmopolitan species: see Eisig (1914)), *Scoloplos cylindrifer* Ehlers (previously recorded from New Zealand by Ehlers (1904)) and *Scoloplos* (*Naidonereis*) *dubius*, n. sp., the latter represented only by a single obviously young specimen of doubtful identity. Whitelegge (1889) also mentions in his fauna list of Port Jackson a species of *Scoloplos* and of *Aricia*, but makes no attempt at description or further identification.

With an immensely long continental coastline offering innumerable sandy and muddy environments suitable to ariciid life, this paucity of members of the family in Australia is surprising, and it is gratifying to report the discovery of a dense ariciid population in the sandy flats exposed by the low tide at Botany Bay on the New South Wales coast. After examining the adults and early stages of the life history, I have identified the species as conspecific with *Haploscoloplos fragilis* (Verril) (Hartman, 1942, 1944), a species not previously recorded elsewhere than on the eastern American seaboard. The adults differ from those described by Hartman only in the absence of an interramal cirrus on the anterior abdominal parapodia, a character very variable within the family. A full description of development in the species will be published elsewhere (Anderson, 1959*b*).

Some confusion of nomenclature exists in the *Scoloplos* group of Ariciidae. *Scoloplos armiger* O. F. Müller, whose development is described by Anderson (1959*a*), was defined by Eisig (1914) as synonymous with *Scoloplos kerguelensis* (McIntosh). Okuda (1937, 1946), however, who gives an account of the development of a species *Haploscoloplos kerguelensis*, follows Fauvel (1932) in promoting *S. kerguelensis* (McIntosh) to independent specific rank and follows Monro (1933, 1935) in transferring it to the genus *Haploscoloplos*. The validity of the distinction between *armiger* and *kerguelensis* as species is upheld by a comparison of their developments, which differ in several important ways (Anderson, 1959*a*, *b*; cf. Smith, 1958, who shows that reproductive pattern can be used as a specific character among nereid polychaetes), but there is some controversy over the systematic validity of the genera *Scoloplos* and *Haploscoloplos*. Hartman (1944) favours the placing of several species previously assigned to *Scoloplos* into the genus *Haploscoloplos*, on the basis of the absence of hooks from the thoracic neuropodia. To the *H. kerguelensis* (McIntosh) of Okuda, Hartman adds, among species with known development, *Haploscoloplos bustoris* (Eisig) previously *Scoloplos bustorus* (Eisig) (development described by Horn and Bookkout (1950)) and also the subject of the present notice, *Haploscoloplos fragilis* (Verril) (previously *Scoloplos fragilis* (Verril)). Pettibone (1954), however, considers that the *Haploscoloplos alaskensis* of Hartman (1948) shows insufficient variation from the generic characters of *Scoloplos* to be placed other than in the genus *Scoloplos* and assigns it to the species *Scoloplos alaskensis*. In support of this, she quotes the view of Fauvel (1914) that the so-called thoracic neuropodial hooks of *Scoloplos* species are in fact the bases of worn down capillary chaetae of older specimens and suggests that descriptions of species assigned to the genus *Haploscoloplos* have been taken from young specimens in which such wearing down has not occurred. A detailed examination of numerous specimens of the *Haploscoloplos fragilis* recorded above reveals that all of them show complete absence of hooks from the thoracic neuropodia, thus confirming the original generic definition of Monro (1933), upholding Hartman's view of the validity of this genus and reinforcing her transfer (1944) of *Scoloplos fragilis* (Verril) to the species *Haploscoloplos fragilis*.

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Addendum.—Since preparing this notice, it has come to my attention that Hartman (1957) has recently surveyed the species and distribution of the Ariciidae (Orbiniidae), recording several species new to Australia and commenting on the nomenclature of previously recorded species. The *Scoloplos armiger* of Augener (1914) she refers to *Haploscoloplos kerguelensis* and his *Scoloplos cylindrifer* to *Haploscoloplos cylindrifer*. The new species described by Hartman are *Haploscoloplos bifurcatus* from South Australia and Port Jackson and *Scoloplos (Leodamas) fimbriatus* and *Nainereis grubei australis*, both from South Australia.

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AUSTRALIAN MOSQUITOES DESCRIBED BY MACQUART. I.

Species in the Paris Museum, Aëdes (Finlaya) alboannulatus (Macquart), Aëdes (Finlaya) rubrithorax (Macquart), Aëdes (Ochlerotatus) albirostris (Macquart). New synonymy and a new species from New Zealand.

By J-M. Klein, Office de la Recherche Scientifique de la France d'Outre Mer, Paris, and Elizabeth N. Marks, National Mosquito Control Committee, Department of Entomology, University of Queensland.

(Two Text-figures.)

[Read 27th April, 1960.]

Synopsis.

The type material of the three species, *Culex albo-annulatus, Culex rubrithorax* and *Culex albirostris,* described by Macquart (1850), has been examined, redescribed and compared with specimens from the Australian region. Lectotypes of *C. rubrithorax* and *C. albirostris* are designated. The Lectotype of *C. rubrithorax* is a species of *Aëdes* (*Finlaya*) and *A. queenslandis* (Theobald) is synonymous with it. The name *A. procax* (Skuse) is available for the species of subgenus *Ochlerotatus* hitherto identified as *A. rubrithorax* (Macquart). The type locality of *C. albirostris* is New South Wales, not Akaroa, New Zealand, as stated by Macquart. The Lectotype of *C. albirostris* is a species of *Aëdes* (*Ochlerotatus*) and *A. vigilax* (Skuse) is synonymous with it. It is proposed to apply for validation of the specific name *vigilax* Skuse, 1889, for this species. The specimen from Invercargill, New Zealand, identified by Edwards (1924) as *A. albirostris* (Macquart) is described as *Aëdes* (*Ochlerotatus*) *subalbirostris,* n. sp.

There is no indication in the literature that the Australian mosquitoes in the Paris Museum described by Macquart (1850) have ever been compared by subsequent workers with specimens from the Australian region. The current concept of the identity of *C. albirostris* dates from Edwards (1924) and of *C. rubrithorax* from Theobald (1901); identification of *C. alboannulatus* has never been in doubt. The type series of these species have been examined by one of us (J-M.K.) and compared with specimens of Australian species and notes on their distinctive characters supplied by the other (E.N.M.), who has also compared descriptions of the type series with further Australian material.

C. alboannulatus was described from a single specimen which is therefore the Holotype. Macquart did not designate a type specimen of either *C. albirostris* or *C. rubrithorax* in his original descriptions, but one specimen in each series now bears the label "TYPE". In order to comply with the rules of Zoological nomenclature, we hereby designate the specimen of *Culex albirostris* Macquart marked "TYPE" and the specimen of *Culex rubrithorax* Macquart marked "TYPE" as Lectotypes of their respective species. Full data are given below.

On the pins of all the Types in the Paris Museum studied by Macquart, there is the same handwriting on the folded paper as that found on the Types of the species discussed here; it is clearly the writing of Macquart himself.

The principal synonymy of each species is given, but errors and emendations of spelling have not been listed.

In the following descriptions leg measurements were made with an ocular micrometer with Zeiss Opton. Oc. 20, obj. 25; about 26 divisions = 1 mm.

Aëdes (Finlaya) alboannulatus (Macquart).

Culex albo-annulatus Macquart, 1850, *Dipt. Exot.*, suppl. 4: 10. *Culicelsa alboannulata.* Theobald, 1907, *Monogr. Culic.*, 4: 382. *Ochlerotatus alboannulatus*, Edwards, 1912, *Ann. Mag. nat. Hist.*, (8), 9: 524. *Aëdes* (*Ochlerotatus*) *alboannulatus*, Cooling, 1924, *Comm. Aust. Dep. Hlth. Serv. Publ.*, 2: 20. *Aëdes* (*Finlaya*) *alboannulatus*, Edwards, 1924, *Bull. ent. Res.*, 14: 384.

Original Description:

"13. *Culex albo-annulatus*. Nob.

Fuscus. Abdomine nigro incisuris albis. Femoribus tarsisque albo-annulatis.

Long. 2l. ♀. Voisin du *C. annulatus*. Trompe noire; un peu de blanchâtre au milieu en-dessous. Antennes brunes; les deux premiers articles testacés. Thorax brun; métathorax d'un testacé brunâtre. Abdomen noir, à léger duvet gris et incisions blanches. Cuisses d'un jaunâtre pâle; tiers postérieur noir, à anneau blanc, avant l'extrêmité; jambes jaunâtres, à extrémité noirs; tarses noirs; chaque article à base blanche, peu distincte aux quatrième et cinquième. Ailes claires, à petites écailles brunes.

De la Nouvelle-Hollande, côte orientale. Muséum. C'est peut-être une variété du *C. albirostris*."

Holotype Female.—The single specimen in the Paris Museum bears printed data "Type. J. Verreaux." and manuscript data "Nouvelle Hollande. 2.47.". It now consists only of the thorax with one wing and a fragment of the other wing. The scutum is without scales, the wing bears only dark scales, and r-m is about its own length distant from the base of M_{3+4}.

Identification of this species from Macquart's description has never been in doubt; the most recent description of it is by Dobrotworsky (1959).

AËDES (FINLAYA) RUBRITHORAX (Macquart).

Culex rubrithorax Macquart, 1850, *Dipt. Exot.*, suppl. 4: 9. *Culex occidentalis*, Theobald (not Skuse, 1889), 1901, *Monogr. Culic.*, 1: 419. *Ochlerotatus occidentalis*, Edwards, 1912, *Ann. Mag. nat. Hist.*, (8), 9: 524. *Aëdes (Finlaya) occidentalis*, Mackerras, 1926, *Aust. Nat.*, 6: 36. *Culicelsa similis* Strickland, 1911, *Entomologist*, 44: 132. *Culicelsa queenslandis* Strickland, 1911, *Entomologist*, 44: 179. *Aëdes (Finlaya) queenslandis*, Edwards, 1924, *Bull. ent. Res.*, 14: 384. *Culicada demansis* Strickland, 1911, *Entomologist*, 44: 202. *Culicada cumpstoni* Taylor, 1914, *Trans. ent. Soc. Lond.*, 1913: 692. *Culicada hybrida* Taylor, 1916, PROC. LINN. SOC. N.S.W., 41: 568.

Original Description:

"12. *Culex rubrithorax*, Nob.

Thorace testaceo. Abdomine nigro, incisuris albidis. Pedibus flavidis; tarsis fuscis albo-annulatis.

Long. 2 1/2l. ♀. Trompe fauve, à base et extrémité noires, quelquefois entièrement noire. Palpes noirs, à base fauve. Front brun, à duvet gris. Antennes noires. Thorax d'un rouge testacé (dénudé). Abdomen d'un noir plus ou moins luisant, à duvet d'un blanc grisâtre sur les incisions. Pieds d'un jaune assez pâle; cuisses postérieures quelquefois noires dans le tiers postérieur; jambes postérieures d'un brun noir; tarses noirs, quelquefois jaunâtres; les trois premiers articles à anneau blanc à la base, étroit et quelquefois peu distinct aux antérieurs et intermédiaires, large aux postérieurs. Ailes assez claires; nervures normales, couvertes de petits poils noirs.

De la Tasmanie. Muséum. Cinq individus ♂ dont l'un avait les anneaux des tarses presque nuls."

Lectotype Female.—The insect is directly transfixed by the mounting pin at the level of the thorax. Below it are labels in the following order. 1. A card with red printed inscription "TYPE". 2. A pink card with printed inscription "Museum de Paris. TASMANIE. Verreaux 3–47.". 3. A folded paper, pinned through, with the manuscript inscription "Culex rubrithorax n. sp. Macquart Tasmanie". The terminalia have now been mounted between two coverslips attached to a card, which is pinned near the specimen and carries the following information: "*C. rubrithorax* Macq. TYPE (Finlaya) ♀."

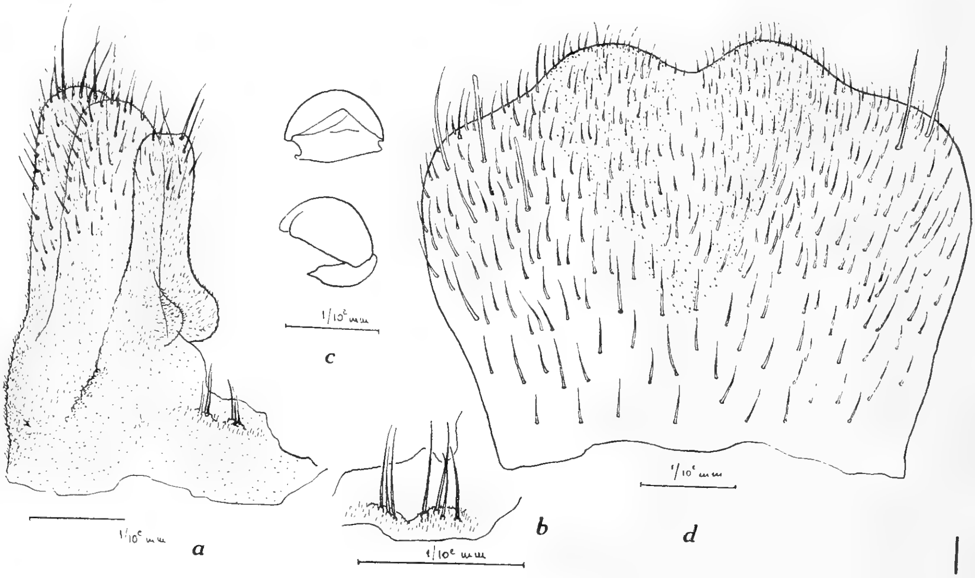
Head and thorax are covered by an old web of mould; no scales are visible. The antennae and wings are missing. The palps are dark brown as described by Macquart, but at the apex there is distinctly observable at high magnification on both palps (which are in good condition) a small patch of white scales, quite surrounded and almost hidden by a crown of brown scales which cover the remainder of the palps. It is difficult to distinguish the scales which clothe the proboscis; they seem to be adherent to the integument which is of a dark brown colour throughout the length of the proboscis. Macquart wrote "Trompe fauve, à base et extrêmité noires" (fauve = reddish-brown) and he added "quelquefois entièrement noire". It is impossible to recognize an actual difference of colour between a middle part and the extremities which may perhaps be a darker brown ("noires"). There is no indication of a median zone covered with white scales.

Legs.—Right fore leg: Femur 52; tibia 59; tarsal segment I, white 4, brown 32; II, white 4, brown 11; III, white 2, brown 7; IV and V brown, a little clearer at the base, lengths respectively 4 and 6; claws with a distinct tooth about the middle. Left fore leg: Femur 55; tibia 58; tarsal segment I, white 4, brown 31; II, white 3, brown 11; III, brown 9, a little clearer at the base; IV, brown 4; V, brown 6. Right mid leg: Femur 65; tibia 68; tarsal segment I, white 5, brown 39; II, white 5, brown 15; III, white 3, brown 8, broken at this level. Left mid leg: Femur 65; tibia 70, broken here. Left hind leg: Femur not measurable; tibia 76; tarsal segment I, white 8, brown 45; II, white 8, brown 2, broken here. Right hind leg: Femur 67; tibia 76; tarsus missing. The scaling of the hind legs is as follows: Left femur on its outer aspect with about the proximal half light coloured, yellowish, with some pale scales, then mixed brown and pale scales, the distal third dark brown, the knee lighter coloured; on its upper edge, dark brown scales; its inner aspect scarcely visible. Left tibia with a uniform dark brown appearance, but very few scales visible. Right femur on its outer aspect with the proximal half yellowish-white, then a mixture of brown and pale scales, some yellowish-white scales visible around the knee; on its upper edge, dark brown scales on the distal five-sixths; on its inner aspect with the proximal half of clear yellowish-white appearance, then mixed white and brown scales, the brown appearance intensified distally, light coloured scales around the knee. Right tibia with a brown appearance, few scales visible.

Abdomen.—On tergite II there is a basal median triangular zone of dull light-coloured scales, which does not reach the lateral margin of the tergite. On tergites III, IV and V, there are some vestiges of basal pale scaling mesially which never reach the lateral margin. On tergite VI a small, very irregular median basal area of pale scales is distinctly visible. One can state that on no tergite does the basal band reach the lateral margin, that it exists only in the median basal zone, and that it is distinctly broader on tergites II, III, V and VI. On the remainder of the surface of tergites VI and VII it is now impossible to distinguish the pale scales from the others; they are more or less massed together giving a dirty brown appearance to the whole. On the distal margin of tergites V, VI and VII the integument appears bare and slightly lighter coloured. On the left side the sternites have become rolled up over the lateral extremity of the tergites; at this level, at the elevation of the basal bands one can see distinctly one or two broad scales, entirely, even vividly, white which belong to the tergites; these appear on tergites III-VII. On the right side the tergites themselves are rolled up under the lower surface of the specimen; at this level at the base of tergites III and IV there seems to be a lighter coloured zone, but no scales are distinguishable; on tergite V at the level of the end of the basal band there is a group of 4 or 5 scales; on tergite VI there is a similar patch of 6 white scales forming a small point directed posteriorly; on tergite VII there are 4 or 5 white scales at the base forming a posteriorly directed point.

It is very difficult to observe the sternites. Sternite III shows sparse white scales in the median zone; the peripheral regions are dark brown. Sternite IV has a median basal triangular white area; other white scales scattered over all the median portion; peripheral and distal zone dark brown except on the middle of the right lateral sternal region which shows a patch of white scales. On sternite V there is the same central basal area of white scales extending three-quarters the length of the sternite, and some white scales scattered over the right lateral sternal portion from the base to about mid length of the sternite, with brown scales elsewhere. On sternite VI there is a large central basal area of white scales, a patch of white scales in the middle of the right sternal region, and brown scales elsewhere. Terminalia (Fig. 1): Sternite VIII is large and the cerci short as in subgenus *Finlaya.*

Identification.—Hardy (1929) produced evidence that led him to conclude that the majority, if not all, of the Diptera described by Macquart in his fourth supplement as being from Tasmania were actually from Sydney, and this possibility must be considered in attempting to identify the type of *C. rubrithorax.* We may reasonably assume that *C. rubrithorax* was not so rare that it has not since been collected.



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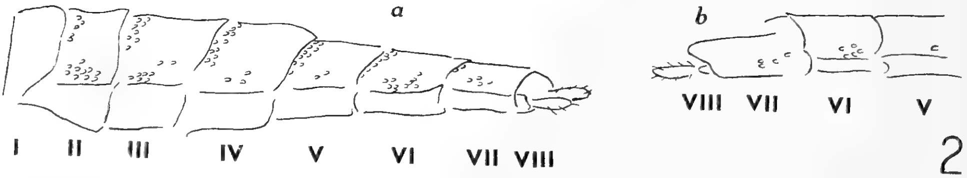

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Fig. 1.—*Aëdes (Finlaya) rubrithorax* Macquart. Terminalia of Lectotype Female. *a*: Cerci, postgenital plate and IXth tergite. *b*: IXth tergite. *c*: Spermathecae. *d*: VIIIth sternite.

Fig. 2.—*Aëdes (Ochlerotatus) albirostris* (Macquart). Abdomen of Lectotype Female. *a*: Left side. *b*: Right side.

The characters of the Lectotype of *C. rubrithorax* may be summarized as follows: (1) Occurs in Tasmania and/or New South Wales. (2) Tip of abdomen of *Finlaya*-type. (3) Palps with white patch at tip. (4) Proboscis without a distinct median area of white scales. (5) Scutal integument reddish (we believe that it must have been a very distinct reddish for Macquart to have referred to this character in the specific name). (6) Banded tarsi. (7) Toothed claws. (8) Basal bands of the tergites only in the median zone of the tergites. (9) Lateral patches of the tergites basal.

In Australia and Tasmania, the only genus of mosquitoes with toothed female claws is *Aëdes*, and the only species of *Aëdes* with reddish scutum and banded tarsi belong to the subgenera *Ochlerotatus* and *Finlaya*. On terminalia characters *C. rubrithorax* must be placed in *Finlaya*. In this subgenus there are two species, *Aëdes monocellatus* Marks and *Aëdes queenslandis* (Strickland), which agree with the Lectotype of *C. rubrithorax* in occurring in Tasmania and/or New South Wales, and in having white-tipped palps, reddish scutum and banded tarsi. *A. monocellatus* is a rare species not known to occur in Tasmania, and has a distinct antero-ventral white basal patch or band on the hind tibia, which excludes it from possible synonymy with *C. rubrithorax*. *A. queenslandis* is a common species in both New South Wales and Tasmania, frequently taken biting man, and corresponds well to the Lectotype of *C. rubrithorax* in most characters including terminalia. Differences are: (1) The ratio of white to dark scaling on hind tarsal segment I, which in *A. queenslandis* is usually between 1:3 and 1:3·5. However, the band is poorly preserved on the Lectotype (in which the ratio is 1:5·6), and a rubbed specimen of *A. queenslandis* has the ratio 1:5, while a rather poor and puny specimen has the ratio 1:5·5. (2) The scaling of the sternites. This is very variable in *A. queenslandis* and specimens from Mittagong, N.S.W., correspond fairly well with the Lectotype.

Aëdes rupestris Dobrotworsky, which has recently been distinguished from *A. queenslandis*, is recorded from Victoria and Queensland and presumably occurs also in New South Wales. It differs from *C. rubrithorax* in having scutal integument dark brown, the areas of dark scaling intensely black, the mottling of the femora striking and above all in the characteristic scale pattern of its sternites.

We have no hesitation in regarding *Aëdes queenslandis* (Strickland) (and its various synonyms) as conspecific with the Lectotype of *Culex rubrithorax* Macquart, and we believe that as this species occurs in Tasmania, Macquart's citation of Tasmania as the type locality should be regarded as correct. Dobrotworsky (1959) has described and figured adults and larvae of *A. queenslandis*.

Paratypes.—Four specimens each transfixed by the mounting pin and each labelled with a single pink card with the printed data "Museum de Paris. TASMANIE. Verreaux 3–47.".

PARATYPE No. 1. Female.—Head, thorax, one wing and one leg remain, abdomen missing. Head with narrow-curved golden scales in the middle and broad white scales on the sides; many upright forked dark scales. Palps dark brown, white scales at the apex very distinct; some scales elsewhere, perhaps the joints. Proboscis uniformly dark brown.

Thorax: Scutum with narrow golden scales, integument brownish; no lower mesepimeral bristles (upper are still distinct). Foreleg: Femur 52, sprinkled with white scales, darker on the distal half; tibia 57; tarsal segment I, white 4, brown 31; II, white 5, brown 10; III, brownish 9; IV, brownish 6; V, brownish 5; III-V, a little clearer at the base. Claws toothed. Wing: Dark scaled; shift of crossveins in proportion 7:11:7 (not the same scale as for the legs).

It seems probable that this specimen is conspecific with the type of *C. rubrithorax* since the characters observable agree with it or with specimens of *A. queenslandis*, but it is too incomplete for certain identification.

PARATYPE No. 2.—Thorax and abdomen without scales; head, wings and legs missing. The specimen is not identifiable.

PARATYPE No. 3.—Head and thorax are covered with an old web of mould; wings missing; abdomen without scales. The specimen is not identifiable.

PARATYPE No. 4. Female.—Head without antennae and palps. Thorax covered with a web of mould. Wings shrivelled. Legs unbanded; on one leg two claws and a pulvilla visible; hind legs with tibia and tarsal segment I approximately equal in length. Abdomen slightly tapering; basal white bands uniformly broad on tergites III-VII; terminalia mounted. The presence of a pulvilla and the terminalia characters indicate that this is a specimen of *Culex*, but it is not specifically identifiable.

The terminalia have been mounted between coverslips attached to a card labelled "*C. rubrithorax* Macq. Paratype No. 4 (Culex ♀)" which is pinned near the specimen.

Nomenclature.—Following the interpretation of Theobald (1901) the name *Culex rubrithorax* Macquart has consistently been applied to a species of *Ochlerotatus*, which Edwards (1912) showed was identical with *Culex procax* Skuse, the latter name then falling into synonymy. In addition to subgeneric terminalia differences, the type of *C. procax* and all other females examined of the species hitherto known as "*rubrithorax*" have the palps entirely dark-scaled, and cannot be conspecific with the Lectotype of *C. rubrithorax* Macquart. The name *Aëdes* (*Ochlerotatus*) *procax* (Skuse) is available for this species.

A. queenslandis was for many years treated as a synonym of *Aëdes occidentalis* (Skuse), and there are not a large number of published references to it under the name *queenslandis*, nor is there an extensive literature on *A. procax* under the misidentification of *A. rubrithorax*. Comparatively little confusion should result from the change in names and an application for suspension of the law of priority does not appear warranted in this case.

AËDES (OCHLEROTATUS) ALBIROSTRIS (Macquart).

Culex albirostris Macquart, 1850, *Dipt. Exot.*, suppl. 4: 10. *Culex vigilax* Skuse, 1889, PROC. LINN. SOC. N.S.W., (2), 3: 1731. *Culicelsa vigilax*, Theobald, 1907, *Monogr. Culic.*, 4: 382. *Ochlerotatus vigilax*, Edwards, 1912, *Ann. Mag. nat. Hist.*, (8), 9: 524. *Aëdes* (*Ochlerotatus*) *vigilax*, Edwards, 1922, *Bull. ent. Res.*, 13: 99. *Culex marinus* Theobald, 1901, *Monogr. Culic.*, 1: 396. *Culex annulifera* Ludlow, 1903, *J. N.Y. Ent. Soc.*, 11: 141. *Ochlerotatus annuliferus*, Edwards, 1917, *Bull. ent. Res.*, 7: 215. *Culex ludlowi* Blanchard, 1905, *Les Moustiques*: 630. *Aëdes* (*Ochlerotatus*) *vigilax ludlowi*, Knight and Hull, 1951, *Pacif. Sci.*, 5: 226. *Culicelsa pseudovigilax* Theobald, 1907, *Monogr. Culic.*, 4: 382. *Culicelsa uniformis* Strickland, 1911, *Entomologist*, 44: 131. *Aëdes* (*Ochlerotatus*) *vigilax vansomerenae* Mattingly and Brown, 1955, *Bull. ent. Res.*, 46: 78.

Original Description:

"14. *Culex albirostris*, Nob.

Niger. Thorace cinereo pubescente. Abdomine incisuris albis. Rostro albo. Pedibus flavidis; tarsis albo-annulatis.

Long. 2l. ♀. Trompe blanche, à base et extrémité noirs. Palpes noirs; un peu de blanc à l'extrémité. Face blanche. Front noir, à léger duvet brunâtre. Antennes noirâtres; premiers articles pâles. Thorax à duvet d'un gris un peu roussâtre. Abdomen d'un noir foncé; bord postérieur des segments blancs. Pieds d'un jaunâtre pâle; un peu de noirâtre à l'extrémité des cuisses; jambes brunâtres; postérieures un peu blanchâtres au milieu; tarses noirâtres; un anneau blanc à la base de chaque article. Ailes à nervures normales.

D'Akaroa, Nouvelle-Zéland. Muséum."

Lectotype Female.—The insect is mounted on a minuten pin which is set on the first card. A second card bears a red printed inscription "TYPE". A third card carries the printed inscription "Museum de Paris" and a manuscript inscription "Nlle Galle du Sud. J. Verreaux 4.9.47.". A folded paper carries the manuscript inscription "Culex albirostris ♀ Macquart n. sp. Nouv. Zélande.".

Head with narrow curved golden scales in the middle; with many upright forked scales; on the sides one or two patches of broad scales, white and yellowish. Palps: apex with very conspicuous patch of white scales. Proboscis with basal and distal parts dark; proportions about 10:30:20.

Thorax: Only one lateral half remains. Scutal integument brown. Scutal scales narrow and golden, some dark brown scales visible. No trace of lower mesepimeral bristle insertion.

Wings: A fragment of each wing remains sufficient to see many pale grey broad scales on the veins. There is a group of white scales on the lower surface of the wing, on the posterior side of the costal vein, inside the humeral cross vein and extending almost to the level of it; on the left wing there are 8 white scales in this site, on the right 9 or 10. On the left wing the cross veins are visible; r-m is its own length distal to the base of M_{3+4}.

Legs: Only the left mid leg and right hind femur remain. Mid leg: Femur length 57, no scales visible on proximal two-thirds, on the distal one-third outer surface with dark brown and scattered pale scales, upper edge dark brown, some pale scales visible; tibia with brown scales and scattered pale scales, length 60; tarsal segments I-III with basal white bands; I, white 3, brown 32; II, white 3, brown 11; III, white 3, brown 7; tarsal segments IV and V brown, rather yellowish at the base, lengths respectively 5 and 6; no claws. Hind femur length 55, outer surface strongly mottled with pale scales over its whole surface, the distal half slightly darker; upper edge with mixed brown and pale scales; inner surface of yellowish appearance, with pale scales on the proximal three-quarters except along the upper border where these scales are scarcer, and the brown numerous; distal end of the inner surface with mixed brown and pale scales.

Abdomen (Fig. 2): In good condition. Sternite VIII seems to be small; cerci are long. The basal bands on the tergites are distinctly white and uniformly broad; on tergite II about one-quarter length of tergite, on III and IV one-fifth length; on V the white band is slightly broader in the middle and there are some white scales along the posterior border; on VI the basal band is about one-sixth or less and along the whole width of the posterior border are many scattered pale grey scales; on VII no basal band is visible, but along the posterior quarter is a broad band of scattered pale grey scales; the anterior border of this band is very irregular. The tergites have lateral patches of white scales about the middle of the lateral margin; there is a large clear space between the white scales of the basal band and those of the lateral patch; the lateral patches do not extend distinctly towards the middle of the tergite, but two of them extend upwards and backwards. Thus one finds: on the left on tergite II, a group of 10–12 white scales; on tergite III, 8 scales in ascending order; on tergite IV, 3 scales at the middle of the lateral border; on tergite V, 2 scales similarly placed; on tergite VI, 10 scales, the posterior ones extending upwards; on tergite VII, 4 scales. On the right, no scales are visible on tergites II, III and IV; on tergite V, one white scale at the middle of the lateral margin; and on tergite VI, 5 scales similarly placed.

Identification.—On the folded paper the inscription with locality "Nouv. Zélande" is in Macquart's handwriting. It seems then that the written inscription on the third card, which carries the name of the collector and the date of collection, gives us also the original inscription with regard to the place of collection. This writing is apparently in the hand of Verreaux and can be recognized on each of the three paratypes. Consequently one must retain as the place of collection, New South Wales, and reject the inscription of Macquart, New Zealand.

The characters of the type of *C. albirostris* may be summarized as follows: (1) Occurs in New South Wales. (2) *Ochlerotatus*-type tip to abdomen. (3) Palps white-tipped. (4) Proboscis with base dark, middle portion pale and apex dark in proportions 10:30:20. (5) Dark scutal integument. (6) No lower mesepimeral bristle. (7) Scattered pale scales on wings. (8) Mottled femora. (9) Banded tarsi. (10) Straight basal white bands on tergites. (11) Apical pale scales on tergites VI and VII. (12) Lateral patches at mid length of tergites, well separated from basal bands.

There is only one species which corresponds in all these characters—that is *Aëdes vigilax* (Skuse). A few specimens of *Aëdes theobaldi* (Taylor) would fit all but (12), but this species has basal lateral patches on the tergites. (Among the species of Australian *Ochlerotatus* without lower mesepimeral bristles, only *A. vigilax* has the lateral patches at about mid length of the tergites.) Moreover it is most unlikely that Macquart would have overlooked the speckled appearance of the wings of *A. theobaldi* with numerous distinctly white scales. The pale wing scales of the type of *C. albirostris* are pale grey and in the same proportion as in specimens of *A. vigilax*, and its tarsal bands on the mid leg correspond in width to those of *A. vigilax*.

We have no hesitation in regarding *Aëdes vigilax* (Skuse) (and its various synonyms) as conspecific with the Lectotype of *Culex albirostris* Macquart.

Paratypes.—Three specimens each directly transfixed by the mounting pin and each bearing a single card with the printed inscription "Museum de Paris" and the manuscript inscription "Nlle Galle du Sud. J. Verreaux 4.9.47.". All three appear conspecific with the Lectotype.

PARATYPE No. 1. Female.—Head with narrow golden scales in the middle, broad white scales on the sides. Apex of palps with a very distinct patch of white scales. Proboscis with basal and distal parts dark, proportions about 12:27:17.

Thorax: Scutal integument dark brown. Scutal scales golden and in places mixed with dark brown ones; no lower mesepimeral bristle insertions. No wings. Only one incomplete hind leg with femur with distal quarter brown; tarsal segment I with white basal band—white 4, brown 34; II with white 6, brown 8, broken here.

Abdomen: Basal white bands rather irregular; posterior border of tergite VI with a row of white scales; numerous white scales in the neighbourhood of the posterior border of tergite VII. On the right side, there is a lateral patch only on tergite VII; it is made up of some ten white scales, forming a group at the middle of the lateral margin and extending slightly upwards and backwards. On the left side, on tergite IV is a group of 4 to 6 white scales about the middle of the lateral margin and extending posteriorly; on tergite V is a group of 10 white scales forming a triangle the apex of which extends towards the mid line of the tergite; on tergite VI there are 5 scales at the middle of the lateral margin.

PARATYPE No. 2. Female.—Head: Tips of both palps with white scales. Proboscis with basal and distal parts dark, proportions 8:34:27 (not a very precise measurement as proboscis is curved).

Thorax: Scutal integument reddish, covered with golden scales; no lower mesepimeral bristle insertions. Wings rubbed, but some white scales are visible; on the right wing is a group of five white scales at the level of the humeral cross-vein. Legs: Left fore leg with femur 45, distal part darker; tibia 52; tarsal segment I, white 3, brown 25; II, white 3, brown 7; III, white 3, brown 4; IV, yellowish, length 5; V, yellowish, length 4; claws with distinct tooth. Left mid leg with femur 55, on the last six divisions dark brown scales; tibia broken. Right mid leg with femur 55; tibia 65; tarsal segment I, white 3, brown 35; II, white 4, brown 12; III-V, yellowish; III, 10; IV, 5; V, 6. Hind legs missing.

Abdomen rubbed, but some white scales are still visible at the posterior border of tergite VII.

PARATYPE No. 3. Female.—Head with golden scales in the middle; proboscis broken; apex of palps with white scales.

Thorax: Scutal integument brown; scales golden; no lower mesepimeral bristle insertions. Wings rubbed, but some white scales present; on the lower surface of the right wing there are three pale scales on C at the level of the humeral cross-vein. Legs: Forelegs missing. Mid leg with femur length 55, distal third brown; tibia length 61; first tarsal segment, white 2, brown 35, broken there. Hind leg with femur 55, distal quarter brown; tibia 65; tarsal segment I, white 3, brown 46; II, white 5, brown 21; III, white 6, brown 9; IV and V yellowish, length of both 5.

Abdomen: White scales visible on the posterior margin of tergites VI and VII; some scattered on VII; a lateral patch visible on the left side of tergite IV, formed of six white scales grouped at mid length.

Nomenclature.—Hitherto following Macquart's published locality record of Akaroa, *C. albirostris* has been regarded as a New Zealand species, though Theobald (1903, p. 162) identified (most probably correctly) specimens from Port Darwin, Australia, as *C. albirostris.*

There are a vast number of references in the literature to *Aëdes vigilax* (Skuse) which is the common pest species of the tropical and subtropical coasts of Australia and occurs also in New Guinea, Solomon Islands and the Indo-Malayan region, with subspecies in Philippine Is. and Seychelles, and which is an important vector of filariasis in New Caledonia. Much confusion would result from a change in the name of this species which is well known to public health workers. It is therefore planned to apply to the International Commission on Zoological Nomenclature to use its plenary powers to validate the specific name *vigilax* Skuse, 1889 (as published in the combination *Culex vigilax*), and reject the specific name *albirostris* Macquart, 1850 (as published in the combination *Culex albirostris*). Until a decision on this application is given it is desirable that authors continue to refer to this species as *A. vigilax* (Skuse).

Edwards (1924) treated *C. albirostris* as a species of *Aëdes* (*Ochlerotatus*) and described a specimen from Invercargill, New Zealand, as probably that species; no other specimens have been recorded from New Zealand and inquiry indicates there are apparently none in collections in that country. The specimen described by Edwards was received on loan from the British Museum (Natural History) through the kindness of Mr. P. F. Mattingly and was compared with the type of *C. albirostris*. It does not agree with this or with any other known species from the Australian region and represents a new species.

AËDES (OCHLEROTATUS) SUBALBIROSTRIS, n. sp.

Aëdes (*Ochlerotatus*) *albirostris*, Edwards (not Macquart, 1850), 1924, *Bull. ent. Res.*, 14: 376.

Holotype female in the British Museum (Natural History) bears a printed label "New Zealand, W. Wesché 1920–68" and manuscript label "Invercargill 23.xi.86.".

Edwards' (1924) description is as follows:

"Head with ochreous scales in the middle and round the eyes, surrounding a pair of patches of darker scales. Proboscis largely clothed with whitish scales, especially in the middle, but leaving the base and the apical fourth dark. Palpi narrowly white at the tip and at each joint. Thoracic integument reddish-brown, darker above. Proepimera with narrow ochreous scales above, flat black and white ones below. Mesonotal scales all narrow, reddish brown in the middle, lighter at the sides; no distinct markings. No lower mesepimeral bristles. Abdomen blackish, with narrow white bands which are mainly basal but spread onto the apical margin of the last four segments. Cerci long. All the femora largely pale-scaled, except towards the tips; the anterior pairs with scattered dark scales in front and more especially above. Tibiae and tarsi dark; first two segments of the front tarsi, three of the middle and four of the hind tarsi narrowly ringed with white at the base; remaining segments all dark. Claws all toothed. Wing-scales all dark."

The following are additional characters: Wing: On the lower surface of the wing, on the costal margin at some millimetres from the base, mixed with the brown scales there are 10 to 15 distinctly lighter pale grey scales; there are also 3 to 5 lighter scales on the costal vein at the level of the humeral cross-vein and at the same level on the radius is a projecting tuft of dark brown scales. Leg measurements: Left fore tarsus: I, white 2, brown 47; II, white 3, brown 16; III, white 2, brown 10; IV, brown 6; V, brown 8. Right fore tarsus: I, white 2, brown 47; II, white 3, brown 17; III, white 1, brown 11; IV, brown 7; V, brown 8. Left mid femur, 82; tibia, 84; tarsus: I, white 4, brown 54; II, white 4, brown 21; III, white 3, brown 13; IV, brown 8; V, brown 7. Left hind tarsus: I gummed to stage; II, white 8, brown 31; III, white 7, brown 23; IV, white 3, brown 15; V, brown 10. Right hind tarsus: I, white 5, brown 70; II, white 7, brown 32; III, white 7, brown 23; IV, white 2, brown 15; V, brown 10.

Abdomen: The basal bands on the tergites are uniformly broad, and the scales have yellowish reflections contrasting with the vivid whiteness of the lateral patches on tergites V and VI; there is no basal band on VII. There are pale grey scales along the posterior margin of tergites II to VII and others are sprinkled relatively abundantly on the dark areas of the tergites. Lateral patches: On the right side an oval patch of white scales covers the whole side of tergite I; there is no lateral patch on tergites II-IV, on tergite V a lateral patch of white scales fuses at the base with the basal band and extends posteriorly to the midlength of the tergite; on tergite VI the lateral basal patch is visible dorsally as a triangular area of white scales extending the basal band outwards and backwards; on tergite VII there is a small patch broad at the base and pointed posteriorly, which is also visible from above. The left side is difficult to observe as the insect is pinned and gummed by a leg onto a large card, so that it rests on the left side of the abdomen; patches on tergites VI and VII are similar to the right side.

In this specimen outstanding differences from the Lectotype of *C. albirostris* are the basal lateral patches on the tergites, the reddish-brown scutum; the wing scales which appear uniformly dark as described by Edwards and have not the speckling found in the type (of the lighter scales described above one can say at the most that they are lighter than the brown, perhaps discoloured by time), the size (length of mid tarsal segment I approximately 2·23 mm. compared with 1·35 mm. in the type and also the whole size of the insect—compared to the type it is a very large one).

Acknowledgements.

We gratefully acknowledge generous help received in this study from Professor E. Séguy of the Museum of Paris, Mr. P. F. Mattingly of the British Museum (Natural History), Dr. P. Grenier of the Institut Pasteur of Paris and Mr. N. V. Dobrotworsky of the Zoology Department, University of Melbourne.

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AUSTRALIAN MOSQUITOES DESCRIBED BY MACQUART. II.

SPECIES IN BIGOT'S COLLECTION, AËDES (OCHLEROTATUS) NIGRITHORAX (MACQUART). NEW SYNONYMY.

By ELIZABETH N. MARKS, National Mosquito Control Committee, Department of Entomology, University of Queensland.

(One Text-figure.)

[Read 27th April, 1960.]

Synopsis.

The holotype male of *Culex nigrithorax* Macquart, 1847, is redescribed, and the terminalia figured. *Aëdes* (*Ochlerotatus*) *macleayanus* Mackerras, 1927, is shown to be synonymous with it and distinctive characters of the species are given.

AËDES (OCHLEROTATUS) NIGRITHORAX (MACQUART).

Culex nigrithorax Macquart, 1847, *Dipt. Exot.*, Suppl. 2: 9. *Aëdes* (*Ochlerotatus*) *nigrithorax*, Edwards, 1924, *Bull. ent. Res.*, 14: 377. *Aëdes* (*Ochlerotatus*) *macleayanus* Mackerras, 1927, PROC. LINN. SOC. N.S.W., 52: 291.

Original Description:

"10. *Culex nigrithorax*, Nob.

Thorace nigro. Abdomine fusco incisuris albidis. Pedibus rufescentibus.

Long. 3 1/21. ♂. Trompe noire. Palpes et antennes brunâtres. Thorax et flancs d'un noir assez mat. Abdomen: bord antérieur des segments d'un blanc jaunâtre; dernier segment et armure copulatrice noirs; ventre à poils blanchâtres. Pieds d'un fauve assez clair; extrémité des cuisses brunâtre; tarses postérieurs brunâtres. Ailes un peu jaunâtres, à nervures roussâtres; cellules normales.

De la Tasmanie. Collection de M. Bigot."

Holotype Male in Bigot's Collection, now in the possession of Mr. J. E. Collin, "Raylands", Newmarket, England. The insect is mounted on a small pin through the thorax into a piece of celluloid carried on a large pin which bears the label "Culex nigrithorax n. sp. Macq. nom. Van Diemen.". The terminalia are mounted on another piece of celluloid attached to the same large pin.

Nothing recognizable of the head remains except one antenna in a mass of matted mycelium on the anterior portion of the thorax; the femur, tibia and first tarsal segment of the left fore leg are also partly involved in this mass. Very little of the thoracic integument can be seen because of the coating of extraneous material; the scutal integument, however, is shining blackish-brown and the postnotum appears similar. The pleura are dark brown and the following characters can be observed: Some narrow curved white scales on *ppn*. About 9 or 10 golden postspiracular bristles. Rather elongate flat white scales on subspiracular area; anterior border, posterior border and upper part of *stp*; prealar area; upper half of *msp*, extending onto lower half posteriorly; fore and mid coxae. No trace of insertion of lower *msp* bristles on either side.

The wings are matted together above the abdomen; there appear to be a few white scales on C and R_1 near the base; the scales remaining towards the wing tip are dark and plume scales on the forks are long and narrow; cell R2 1·1 times length of its stem; cell M1 0·56 times length of its stem, broader than and with its base proximal to that of cell R2; r-m its own length distal to base of M_{3+4}

Legs.—The left fore leg is practically denuded, but bears some dark scales; there may be also some scattered pale scales, but it is impossible to be certain of this owing to extraneous material. No other legs remain on the specimen, but one, probably a hind leg, is gummed to the celluloid mount; from proportions, all tarsal segments appear to be present, though no claws can be seen; scales on the tarsus appear all dark, with a few pale at the joints of segments I-II and II-III.

Abdomen.—Tergites are obscured by the wings; tergite I has white scales on the lateral margin. Sternites have a brownish-black integument and are mainly white scaled with black lateral apical patches.

Terminalia (Fig. 1, *a*).—Coxite cylindrical, about three times as long as broad at mid length, with fairly well-developed apical and basal lobes. Tergally the coxite bears numerous short setae towards the base. On the sternal aspect there are some short fine setae mesially but no rows of long setae. The basal lobe is elongate and bears a large patch of about 30 fairly short, fine, mesially-directed setae. The apical lobe is small but distinct, bearing 2–3 broadened, flattened setae. The style is about four-fifths length of coxite, more slender and curved on the apical third which bears 1–3 short setae. Its terminal appendage is about one-sixth length of style and tapers to a rounded tip. The

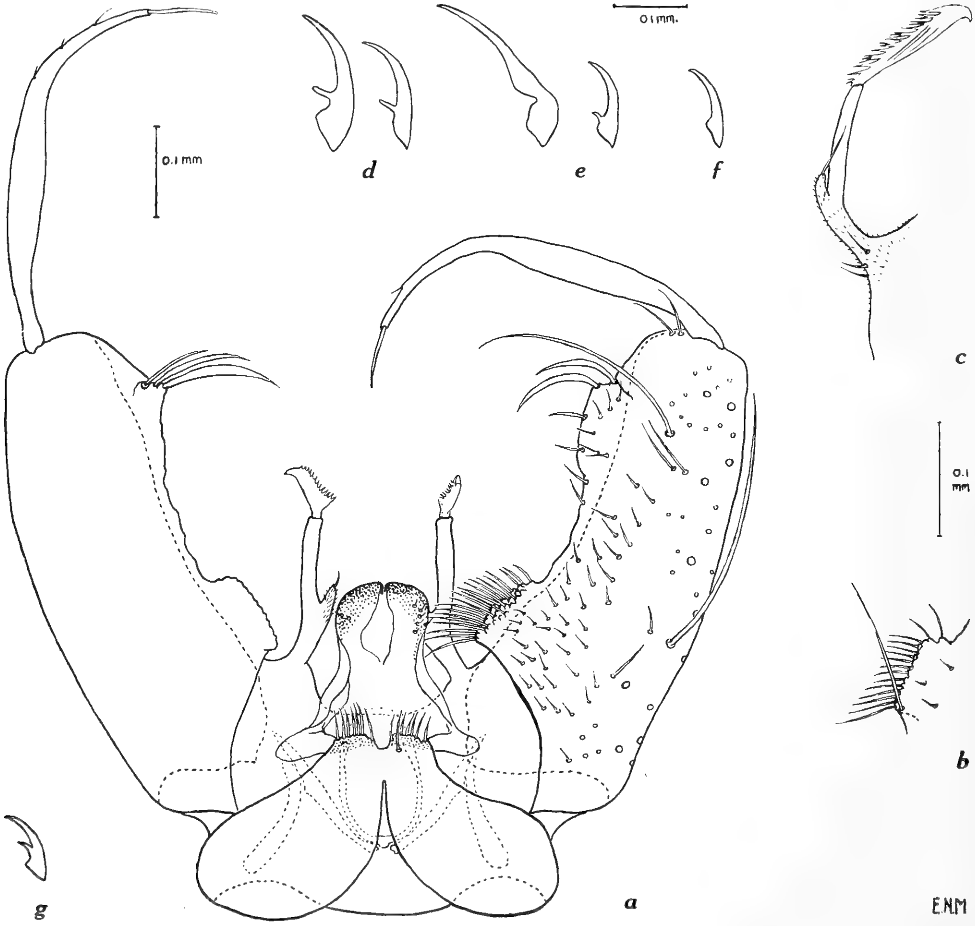

Fig. 1.—*Aëdes* (*Ochlerotatus*) *nigrithorax* (Macquart). *a*, terminalia of holotype male, tergal view (appendage of left harpago is a reconstruction of how it seemed likely to appear in lateral view); *b-g*, specimens from Epping, near Launceston; *b*, *c*, male terminalia; *b*, basal lobe of coxite, tergal view; *c*, right harpago, inner lateral view; *d-f*, male tarsal claws; *d*, fore; *e*, mid; *f*, hind; *g*, female hind tarsal claw.

harpago is long and fairly stout with a subbasal thumb on the inner side; the thumb is pilose, the rest of the harpago mainly non-pilose; one thumb bears a short terminal seta, the other does not. The appendage is terminal, shorter than the harpago, lightly sclerotized, with a fairly short pointed tip, and with its distal margin bearing short fimbriations. In the mount neither appendage is in lateral view, the left appendage in the figure is a reconstruction of how it seemed likely to appear in lateral view. Paraproct with a single stout tooth. Phallosome simple, oval. Lobes of tergite IX with 7–8 stout setae; sternite IX with 1 long and 2 shorter setae.

Identification.—Edwards (1924) described the terminalia of the above specimen and noted the resemblance to those of *A. vittiger* (Skuse) and *A. burpengaryensis* (Theobald). Though he overlooked in his description the fimbriations on the appendage of the harpago, these are present also in the latter two species. Edwards (1932) queried whether *A. macleayanus* Mackerras might be a synonym of *A. nigrithorax.* Marks (1957), on the basis of male terminalia characters, included *A. burpengaryensis*, *A. vittiger*, *A. nigrithorax*, *A. macleayanus* and *A. sagax* (Skuse) in the Burpengaryensis Section of Australian *Ochlerotatus.*

The principal characters of *A. nigrithorax* may be summarized as follows: (1) Belongs to the Burpengaryensis Section. (2) Occurs in Tasmania. (3) Scutal integument black. It differs from *A. burpengaryensis* and *A. vittiger* on the apical lobe of the coxite and from the male of *A. sagax* described and figured by Mackerras (1927) (now known to represent an undescribed species) on the harpago. It is indistinguishable from *A. sagax, sensu stricto*, and from topotypical males of *A. macleayanus*, except that in both these on the basal lobe of the coxite there is one long seta on the lower tergal edge of the setal patch. A similar seta may have been overlooked when the type of *A. nigrithorax* was examined in 1949, or may have been lost at the time the terminalia were mounted, and this difference is not considered significant. The relationships of *A. sagax* and *A. macleayanus* in Victoria are at present being studied by Mr. N. V. Dobrotworsky.

Lee (1948) listed the mosquitoes recorded from Tasmania. Males of all but one of the species of *Ochlerotatus* listed are now known. The exception is *A. tasmaniensis* (Taylor), which has a chestnut-brown scutal integument and cannot be conspecific with *A. nigrithorax*; Edwards (1932) regarded it as a synonym of *A. andersoni* Edwards. Of species in the Burpengaryensis Section, the type male of *A. nigrithorax* and the type female of *A. macleayanus* (from Launceston) are the only specimens of which there are published records from Tasmania. A fair number of collections have been made on the island in recent years and *A. macleayanus* is the only species of this Section represented in them.

On the basis of the foregoing considerations, I have no hesitation in regarding *A. nigrithorax* and *A. macleayanus* as conspecific.

Descriptive Notes.—Five females and nine males from Epping, near Launceston, Tasmania (25.xi.1952, F. N. Ratcliffe) have been examined; these may be regarded as topotypical *A. macleayanus.* The following combination of characters will distinguish *A. nigrithorax* from other Australian species of *Ochlerotatus*: Wings dark scaled (except at base of C and R1), fore and mid femora mottled; hind femur pale almost to apex anteriorly, with apico-dorsal dark scaling; tarsi unbanded; scutum with black integument and with well-defined broad margin of pale scales, broader on the anterior half and covering the fossa, contrasting with darker scales mesially; a small patch of white scales immediately below anterior spiracle.

Females: The holotype of *A. macleayanus* Mackerras in the South Australian Museum was examined in 1958. The following notes supplement the original description. Torus clothed with small oval pale scales. Palps with a few scattered pale scales on lower surface. On the scutum the lateral zone of bronzy-brown scales is behind the scutal angle; similar scales seen from above anterior to this are on the upper part of *ppn.* There are dense white scales on propleuron, subspiracular area, a patch immediately below the spiracle, postspiracular area (with some narrow curved creamy scales also), paratergite, below prealar knob (also sparse scales on knob), upper half of *stp*, along posterior border of *stp*, upper three-quarters *msp*. There is a slight mottling of pale scales at base of hind tarsal segment II. No note was made of wing scaling. The specimen lacks antennae, right mid and hind legs, left fore leg, mid tarsal segments IV and V, and left wing.

Four topotypical females have wing length 4·5–5·5 mm.; a few bronzy scales among the white on the fossa; lower *msp* bristles present (as they are in the holotype); claws (Fig. 1, *g*) on all legs equal with a strong tooth, or one or both hind claws simple; a few white scales at the base of C and R1; lateral basal patches extending two-thirds or more the length of tergites II-VII. A fifth has the areas of darker scaling on the thorax pale bronze; more numerous scattered pale scales at base of C and R1 (extending to level of humeral cross-vein); tergites II-V with broad basal bands covering about the basal half of the segments, produced on the distal half into a more or less complete mesial broad stripe; tergites VI and VII pale with lateral apical dark patches; sternites entirely pale scaled.

Males: Nine topotypical males have wing length 4·7–5·4 mm. Palps are dark scaled, or with some scattered pale scales on shaft, and exceed the proboscis (excluding labella) by almost the length of the apical segment. Scales on vertex entirely pale. Scutal pattern with same variations as in females; no lower *msp* bristles. Tarsal claws (Fig. 1, *d-f*). Fore claws subequal, the anterior longer, each with a strong blunt tooth at one-third its length. Mid claws markedly unequal, the anterior long with a swelling ventrally before mid length, but no tooth, the posterior short with a slender pointed tooth near base. Hind claws equal, simple, or one or both toothed. Sometimes no white scales at base of C and R1; cell R2 0·9–1·4 times length of its stem; cell M1 0·5–0·8 times length of its stem. Tergite II with median white stripe; basal white bands more or less produced in mid line on III-V; and to apex on VI; VII pale with lateral apical dark patches; or tergites II-VII pale with lateral subapical dark patches.

Terminalia (Fig. 1, *b*, *c*): At the base of the coxite on its inner sternal margin are 2–3 strong setae; style with 2–5 setae on distal third; thumb of harpago with a single seta; appendage of harpago four-fifths length of harpago; lobes of tergite IX with 4–9 setae; sternite IX with 2 stout and 3–4 finer setae.

Acknowledgements.

Gratitude is expressed to Mr. J. E. Collin who kindly made the holotype of *A. nigrithorax* available for study at the British Museum (Natural History) in 1949; to Mr. F. N. Ratcliffe, C.S.I.R.O. Wildlife Survey Section, whose collection of topotypical *A. macleayanus* enabled this synonymy to be worked out; and to Mr. G. H. Gross, Entomologist, South Australian Museum, for facilitating the examination of the holotype of *A. macleayanus*.

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PRELIMINARY STUDIES IN POPULATION ESTIMATION OF TWO SPECIES OF STICK INSECTS (PHASMATIDAE PHASMATODEA) OCCURRING IN PLAGUE NUMBERS IN HIGHLAND FOREST AREAS OF SOUTH-EASTERN AUSTRALIA.

By K. G. Campbell, Forestry Commission of N.S.W.

(Four Text-figures.)

[Read 27th April, 1960.]

Synopsis.

Plagues of the phasmatids *Didymuria violescens* (Leach) and *Podacanthus wilkinsoni* Macleay have occurred in certain highland areas of south-eastern Australia; these are shown on a map and the current series of outbreaks is briefly discussed. The behaviour of these insects in so far as it affects their feeding, oviposition, dispersal, life history and their host preferences is discussed.

The method of predicting the occurrence of plague numbers of nymphs and adults, based on field sampling of the egg stage, is outlined and the results obtained critically examined.

Sampling methods and the procedure adopted are stated, the shortcomings of these and suggestions for their improvement being also stated.

Methods of estimating numbers of nymphs and adults by the frass fall method are described and the application of this method in assessing the effects of aerial application of insecticide mentioned. Estimation of numbers of females by measurement of egg production is described and discussed and the results of these methods examined. The application of these methods to provide accurate figures of numbers of phasmatids for studies in population ecology is reviewed and suggestions are made for improvements and refinements of the various techniques employed.

Introduction.

Populations of the stick insects *Podacanthus wilkinsoni* Macleay and *Didymuria violescens* (Leach) (Phasmatodea Phasmatidae) have been recorded as reaching plague proportions at intervals since 1880 in the highland forests of south-eastern Australia (Macleay, 1881; Olliff, 1891). Outbreaks have occurred intermittently since then and Froggatt (1905) records an outbreak in the Nowendoc distinct in 1905. These outbreaks were probably as severe as those of the current series, but, since the forested areas are now smaller, extensive defoliation must now be regarded far more seriously.

Since 1947, outbreaks have been recorded in the Nundle area (Nundle, Hanging Rock, Tomalla, Nowendoc and Tuggolo State Forests), the Jenolan area (Jenolan and Konangaroo State Forests) and the southern highlands of New South Wales and Victoria, Bago State Forest, the Snowy Mountains Area in N.S.W., and the highlands of the Mt. Bogong, Mt. Stanley and Mt. Pinnibar areas and near the Eildon Weir in Victoria (see map).

The outbreak in the Nundle area reached a peak in the 1949–50 summer season, and in 1951–52 very serious and extensive defoliation occurred followed by a sudden reduction in phasmatid numbers over extensive areas. The decrease in numbers was only temporary and the population again reached plague numbers a few years later, notably in the Tuggolo State Forest which was devastated in the 1955–56 season and most of the remaining forested area (except for areas burnt late in 1957) in the 1957–58 season. In the Jenolan area there was no such spectacular crash and defoliation resulted in the deaths of large numbers of trees over many thousands of acres. A widespread fire in the summer of 1957 in this area also destroyed large numbers of phasmatids.

In the Nundle and Jenolan areas two species of phasmatid, *D. violescens* and *P. wilkinsoni*, occur in plague numbers, though the latter is probably responsible for the greater part of the defoliation. In the southern highlands area, *D. violescens* alone is involved. Adults of *P. wilkinsoni* are most abundant during the even numbered years and those of *D. violescens* during the odd numbered years.

In the Bago area serious defoliation was first noticed during the 1952–53 season and has recurred every second year up to the present time. More intensive investigation has revealed the occurrence of other concurrent outbreaks further south.

In all areas most of the outbreaks have occurred at elevations of more than 2,000 feet above sea level, but it has been noted that the most intensive defoliation has occurred at altitudes above 3,000 feet. It has also been noted that the southern limit of the distribution of *P. wilkinsoni* coincides with the northern limit of the winter rainfall zone.

The following table illustrates the general climatic conditions occurring in the areas where outbreaks have been recorded:

Area.	Mean Temperature of Coldest Month. (M T C M)	Mean Temperature of Hottest Month. (M T H M)	Mean Annual Rainfall. (M A R)	Occurrence of Lowest Rainfall.
Mt. Warning	55°–67°	Over 75°	60″–100″	Winter or spring.
Nundle	46°–55° 34°–46°	Over 75° Over 72°	Below 40″ Over 60″	,, ,, ,, ,,
Jenolan	34°–46°	Below 72°	40″–60″	,, ,,
Bago S.F.	34°–46°	Below 68°	40″–60″	Summer and autumn.
Snowy Mountains	34°–46°	Below 68°	Below 40″–over 60″	,, ,,

(*After* de Beuzeville: A Climatological Basis for Forestry.*)

BIOLOGY AND BEHAVIOUR.

Until recently it was not known that two species of phasmatid were present in certain affected areas, and Froggatt (1923) records *D. violescens* as an immature stage of *P. wilkinsoni.* In the Nundle and Bago areas it has been observed that there were some nymphal and adult phasmatids present each year with high numbers in each alternate year. Richards (1953) recorded this for *P. wilkinsoni* and the same is true of *D. violescens.* A two-yearly life cycle predominates in both these species (except in the case of a population of *D. violescens* occurring in the Mt. Warning area) and the term "semi-voltine"† is proposed to describe this.

By far the longest part of the life cycle of these phasmatids is spent in the egg stage. Eggs laid by the adult females during the late summer and autumn of one season generally lie in the forest litter for up to eighteen months and hatch during the spring of the second year after oviposition.

The eggs may be parasitized, soon after being laid, by several species of small wasps, *Myrmecomimesis* spp., of the family Cleptidae (Riek, 1955; Riek, personal communication, 1956), but these do not exercise a great degree of control on this stage. The wasp larvae develop at the expense of the phasmatid embryo and, instead of the eclosion of a phasmatid nymph, a mature wasp emerges from the egg.

After eclosion the phasmatid nymphs climb any vertical object. Occasionally this is the stem of a *Eucalyptus* sp., and after reaching the terminal branchlets the insect commences to feed on the leaves.

Most species of *Eucalyptus* are acceptable as food, though the narrow-leaved peppermints, *E. radiata* Sieb. and *E. robertsoni* Blakely, the broad-leaved peppermint *E. dives*

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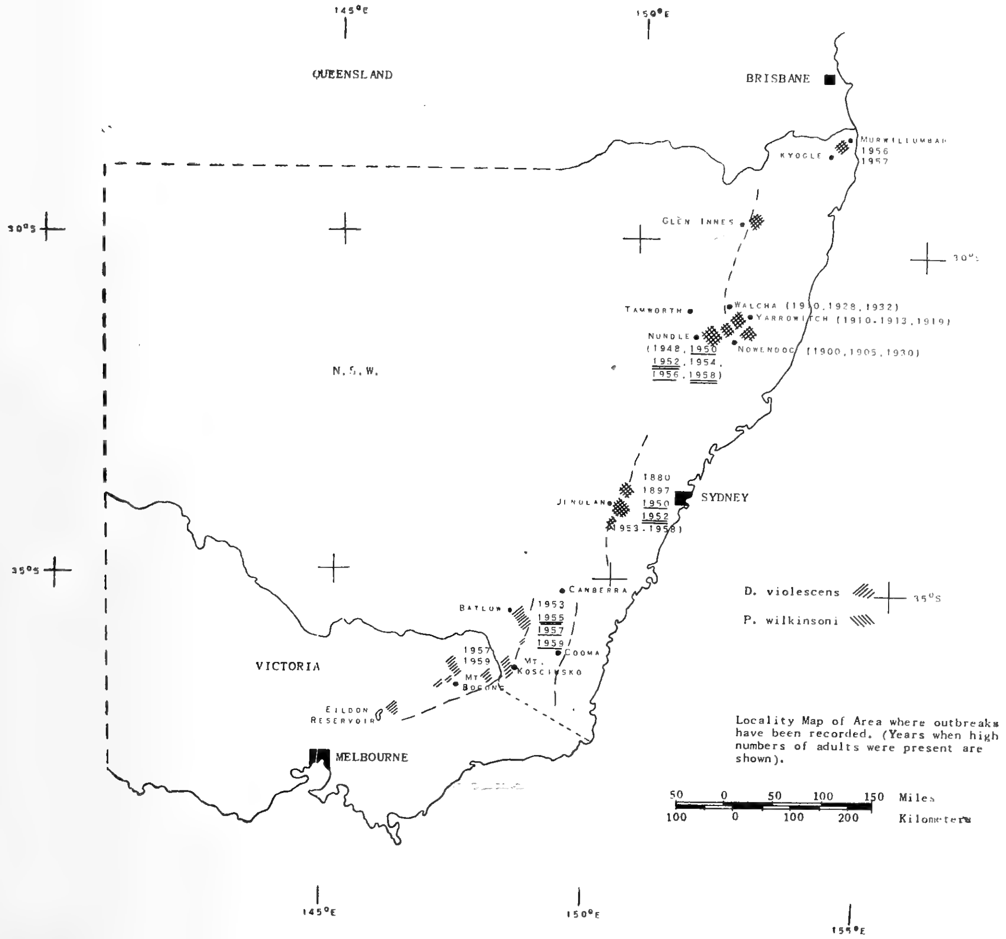
* A summary of evidence given before the Commonwealth Reconstruction Committee, September, 1943.

† i.e., having half a generation per year.

Schauer and the gums *E. viminalis* Labill., *E. huberiana* Naudin, *E. dalrympleana* Maiden, *E. mannifera* (A. Cunn. Herb.) Mudie, *E. stellulata* Sieb., *E. pauciflora* Sieb. and *E. bicostata* Maiden, Blakely and Simmonds appear to be favoured species and are the first to be defoliated. Other species which are known to have been severely defoliated are *E. laevopinea* R. T. Baker, *E. obliqua* L'Hérit., *E. delegatensis* R. T. Baker and *E. fastigata* Deane and Maiden, though these appear to be less favoured than the former groups.



Locality Map of Area where outbreaks have been recorded. (Years when high numbers of adults were present are shown).

In the field no other genera have been found to be eaten, though *Angophora* sp. has been accepted as food in captivity.

The reason for this preference is not known, but it appears in all areas of defoliation that in both sequence and intensity the order 1. peppermint, 2. gum-barked and 3. rough-barked is observed.

Quite often the nymph may climb a grass stem or some other plant unacceptable as food. Should this occur it drops off or climbs down to the ground and continues its searching. Most of this activity takes place in daylight and is usually confined to periods when the relative humidity is high.

This process of searching at first appears to be at random and solely a result of the negative geotaxis exhibited by these insects, but there also appears to be a visual appreciation of the situation by the insect and an individual phasmatid may seek out the nearest tallest object. If this is a suitable source of food further searching is inhibited, but, if not, the searching proceeds until food is found or death occurs.

The behaviour of the nymph is influenced by the composition of the forest association into which it has ecloded. If the understorey consists of *Eucalyptus* sp. trees or saplings, numbers of nymphs will be found on the foliage of these as well as that of the understorey trees. As the insects grow and as the food supply is depleted the nymphs will move to these from the smaller trees. The phasmatids themselves will tend to modify the composition of the stand since repeated defoliation will kill seedlings and even large trees of certain poorly refoliating species such as some of the "Ash" group (*E. delegatensis* and *E. fastigata*). If numbers are high and defoliation is intense for several seasons in succession even the more resistant tree species will be killed. In any case, the extreme negative geotaxis exhibited by these phasmatids results in the newest shoots of the current year's growth being the first to be defoliated. This results in energy, normally devoted to the general growth of the tree, being diverted to refoliation, resulting in loss of wood increment during the current and often the succeeding year during which most refoliation takes place. Many *Eucalyptus* sp. in the highland regions, although not deciduous, have a marked dormant period during the winter and a flush of growth during the warmer period of the year.

Quite often when phasmatids are feeding or resting on small trees they react to any movement, the near approach of an observer being sufficient to cause them to drop from the foliage, when they may move toward any upright object which may even be the observer. Both nymphal and adult phasmatids are markedly negatively geotactic and are usually found feeding on the leaves of the terminal shoots, retreating from these only when the food supply is exhausted or if there is excessive crowding.

It has been observed in the field, but particularly in the case of caged phasmatids nearing maturity, that much of the food provided for them is wasted because of the insects' habit of biting through the leaf near the petiole, resulting in the excision of a large part of the leaf-blade. An insect may fall with the excised portion of the leaf, which it then abandons and climbs to another branchlet where it resumes feeding. This occurs in the field also and results in a more rapid defoliation than would be the case if the insect consumed all of the leaf. Both this and crowding contribute to the cyclic movement of the phasmatids which, when numbers are high, are continually falling or gliding to the ground only to reclimb the nearest vertical object.

Dispersal.

References sometimes made to the dispersal of these phasmatids suggest that the population appears to increase in localized areas and then disperses or migrates as do the plague locusts. It is the opinion of the writer that this is not so and that these outbreaks are the result of static populations increasing in density in discrete areas throughout a wide range in which the phasmatids commonly occur.

When population density is low, procryptic coloration of the phasmatids renders detection of the insects difficult. Severe defoliation, as well as the presence of insects dislodged from the trees because of crowding, usually occurs before they are noticed by inexperienced observers. Population increases often appear very localized because of limited observation, but, as investigations are intensified, larger areas may be found to be affected, giving the impression of a focus of infestation spreading out. Some dispersal of phasmatids within affected areas does occur through transport of young nymphs on air currents or by the limited flight of adult insects.

As well as the predisposing factor of host preference, the food supply actually available often influences the distribution of the population within areas of high density. If food is not a limiting factor at maturity, the female phasmatids may drop their eggs anywhere beneath the crown of a tree on the forest floor. If it becomes exhausted in certain localities, they either die or move to the margin of the defoliated areas or to certain trees which, by chance or for other reasons, have not yet been defoliated. This may result in a patchy distribution of the eggs over the forest floor, with the highest numbers often being found at the edges of the seriously defoliated areas.

Males of *P. wilkinsoni* and *D. violescens* often travel sporadically in flight for considerable total distances during their lifetime, but they must launch themselves from elevated positions and cannot rise from the ground as do the males of *P. viridoroseus* (Gray). Females do not fly at all, but merely glide for short distances; in this respect *D. violescens* is more limited than *P. wilkinsoni* because of the former's relatively smaller wings. Consequently, differential dispersal of males and females is not uncommon and high numbers of males with low numbers of females, or vice versa, are observed in certain localities through an area of outbreak. As a result females may be unfertilized or competition by males for copulation with the females may be intense. Unless parthenogenesis is common, and this has not yet been demonstrated for either of these species, this may account for part of the proportion of eggs which fail to develop for unknown reasons and for their pattern of distribution over the forest floor.

METHODS OF POPULATION ESTIMATION.

Egg Stage.

Since both these species of plague phasmatids are semi-voltine the possibility of assessing population trends by sampling the egg stage was soon recognized. At first, egg collections were made at random in the forest litter several times a year in areas which had been defoliated and examinations of eggs were made to ascertain the stage of development of the embryo and the effects of any parasitism or disease. A high percentage of embryonic development alone was used, at this time, to predict a probable outbreak, without any attempt being made to relate this to actual numbers of insects expected to be present.

Although the predictions made on this basis were in fact correct, the method was most imprecise. Some interesting biological data were obtained from this work, however.

Figures 1 and 2 illustrate the results obtained by this procedure at Bago State Forest No. 560 near Batlow, N.S.W. Eggs were collected from 25 sites at intervals of about three months throughout the period and approximately 15,000 eggs were dissected.

Each egg was inspected by removing its operculum and examining the contents by means of a low-power binocular microscope. If reasonable care was exercised the vitelline membrane was undamaged and in many cases the phasmatid embryo or wasp parasite larvae continued to full development. Eggs were classified under the following headings: (1) Fully developed embryo. (2) Partly developed embryo. (3) No embryonic development visible. (4) Parasitized. (5) Contents diseased or deteriorating. (6) Empty shell.

The results were expressed (*a*) empty shells as a percentage of the total sample, and (*b*) eggs with contents as a percentage of the total less the number of empty shells.

The lines depicting development of the embryo indicate the rapid development during the early summer of the year following oviposition. After this time very little further development of the embryo could be detected except that the amnionic cavity became less moist as the time of eclosion approached.

It may be inferred from the increase in the number of empty shells in the early summer period of 1955 that a definite eclosion of one segment of the phasmatid population took place, although the greater proportion of the eggs did not hatch. The two probable explanations for this are that either one population segment is univoltine and the other semi-voltine or that both are semi-voltine, one segment being low density and the other high.* It has been observed in the field in the case of both *D. violescens* and *P. wilkinsoni* that there are a few nymphal and adult phasmatids present each year with high numbers in alternate years.

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* More recent work has revealed that at Bago the latter explanation is correct and that both segments of the *D. violescens* population are semi-voltine.

Eggs parasitized by the Cleptid wasps were not readily detectable until the wasp larvae were obvious within. In the parts of the forest where Alpine Ash, *E. delegatensis*, predominated, the percentage of parasitism was low, but where Mountain Gum, *E. dalrympleana*, predominated it was considerably higher, though not sufficient to exercise any appreciable measure of control, and did not affect the egg population to a very marked degree. There was a definite fall in the percentage of parasitism after the summer period suggesting that segment of the parasite population was in phase with one segment of the phasmatid population and that some adult wasps emerged in time to oviposit in the eggs laid that season by the phasmatids. Most of the parasites, however, did not emerge until the following summer. Most mortality in the egg stage was attributed to "disease and deterioration", although the factors involved were not identified.

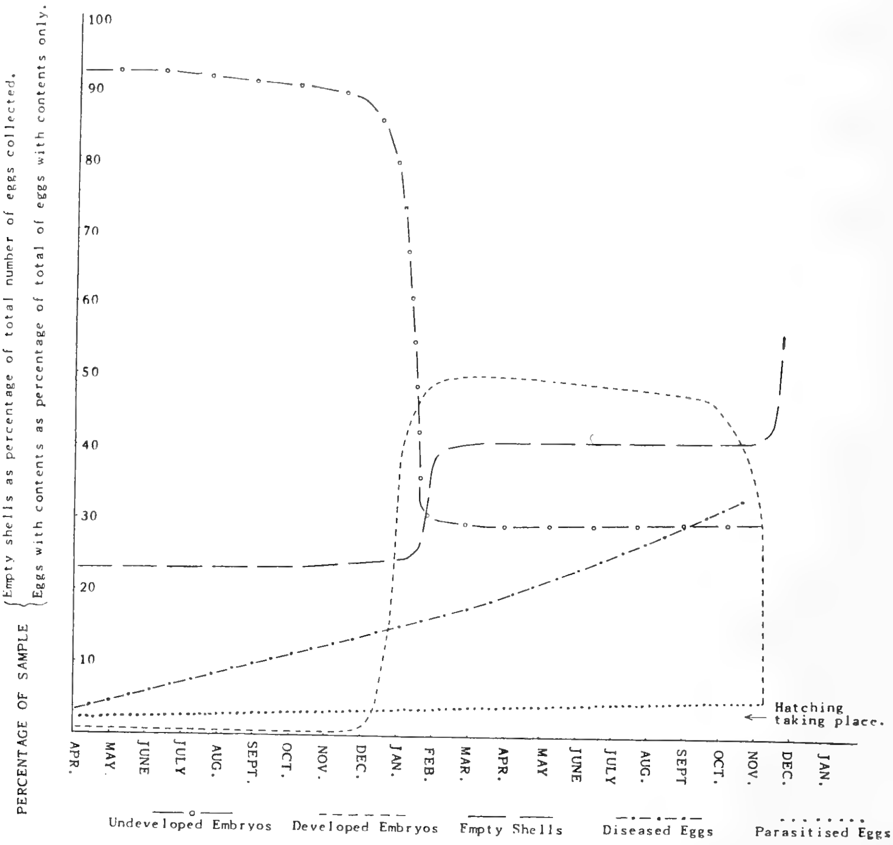

Fig. 1.—Alpine Ash, *E. delegatensis*, predominates.

It was soon realized that this method provided only information of the state of the egg population without indicating the probable insect numbers which could be expected at eclosion.

The primary concern of the writer was to predict the probable occurrence of plague numbers of phasmatids throughout the areas affected. The areas concerned were widely separated and occasionally the services of employees of the various interested authorities were of necessity required for sampling. The separation of the eggs from the litter was slow and laborious, even with the aid of a mechanical sieve shaker, the final search for eggs of necessity being done by hand.

SAMPLING.

The sites for sampling were chosen observing the following provisos: (1) The eggs are dropped by the female phasmatids onto the ground from the foliage of trees so that sites should not be located in the open. (2) It is probable that eggs would be found mainly near the margin of areas which had previously been totally defoliated and most sites should be located to sample this. (3) In an area where defoliation was not complete, it is probable that the eggs will be found anywhere throughout the area and the sites could be located at random. (4) Sites should not be located in areas where there will be interference subsequent to the natural distribution of the eggs, e.g., roads, tracks, gutters or localities subject to the wash of water. (5) In areas where defoliation is widespread and variable an attempt should be made to sample localities of varying defoliation intensity. (6) Sites should be reasonably accessible at all times of the year. Within these limits plots were located without bias.

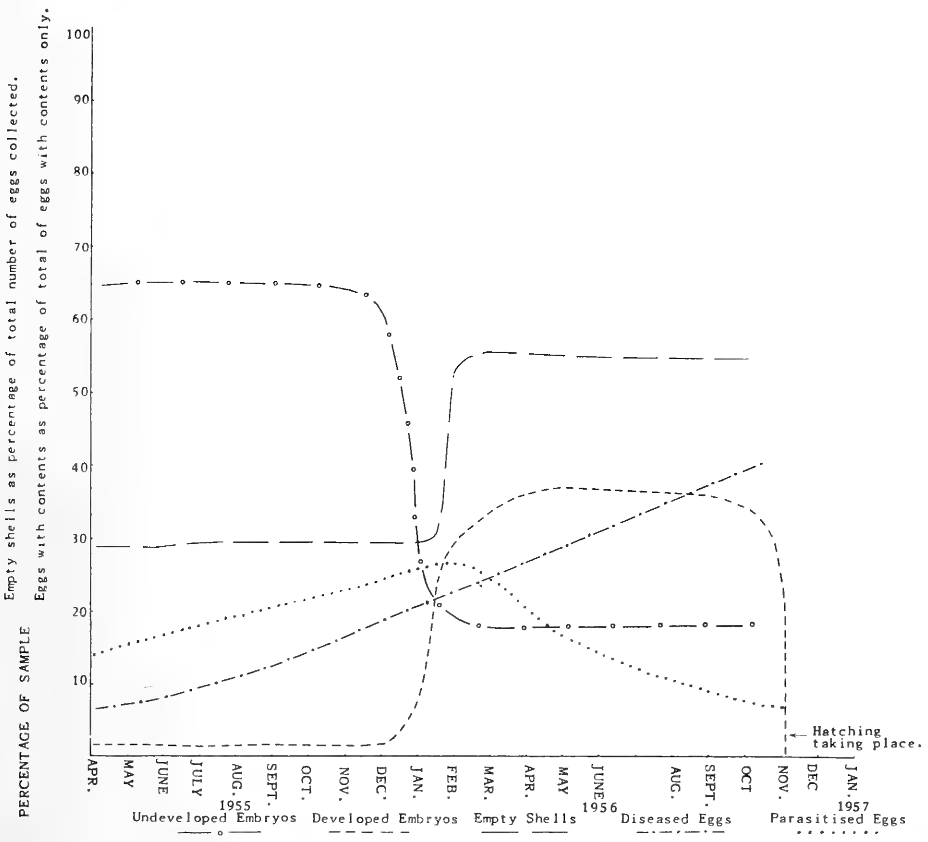

Fig. 2.—Mountain Gum, *E. dalrympleana*, predominates.

The actual sampling of the eggs in the field was standardized as follows: a plot of one square yard was measured, all grass, etc., chipped off with a hoe and all the litter down to the mineral earth collected together. This litter was sieved, mesh apertures being chosen so that a certain fraction would contain the eggs. This fraction was taken to the laboratory to be further sieved if necessary and all eggs, including the empty egg shells, were removed by hand.

Egg estimation studies were initiated by the writer in the Kiewa Area, the Island Bend Area, the Bago State Forest and the Nundle group of State Forests. Most of the litter collections in the field were made by the staff of the Electricity Commission of

Victoria and the Snowy Mountains Hydro-Electric Authority in areas where they were concerned, all sorting and examination of the eggs being made in the laboratory of the Entomological Research Section of the Forestry Commission of N.S.W.

Nundle Area.

During the 1955–56 season almost complete defoliation of a large area of Tuggolo State Forest was caused by nymphal and adult phasmatids (mainly *P. wilkinsoni*), and it appeared probable that an increase in numbers could be expected in the adjoining forests during the 1957–58 period. An egg survey was carried out to determine the probable population density and to provide a choice of locations for an experimental insecticidal treatment which was to be applied by aircraft when the phasmatids were in the nymphal stage.

The results of dissection of eggs obtained by litter sampling during the survey are contained in Appendix 3. Since the total area of forest involved was large (about 43,000 acres) and the greater part not readily accessible except by foot, the plot sites attempted to sample known differences of past defoliation in Tuggolo State Forest and in accessible areas on Tomalla and Nundle State Forests, the sites being placed at random in the latter two forests.

TABLE 1.

Numbers of Eggs per Acre (Excluding Empty Shells), Minimum and Maximum, Potential Phasmatid Population at Eclosion per Acre—Minimum, Maximum and Mean.

State Forest.	No. of Samples.	No. of Eggs/Acre.		P.P.P. at Eclosion/Acre.		
		Minimum.	Maximum.	Minimum.	Maximum.	Mean.
Tuggolo ..	9	42,000	1,230,000	3,000	357,000	72,000
Tomalla	4	63,000	189,000	6,000	69,000	33,000
Nundle	7	21,000	483,000	3,000	159,000	43,000

The litter samples collected in June, 1957, were each taken from a quadrat one square yard in area, and it is possible to relate the numbers per square yard to numbers per acre of forest floor if the average crown cover of the area is taken into account. Numbers of eggs and of expected phasmatids are expressed in this way in all the following tables.

The formula $\dfrac{\text{No. of square feet per acre}}{\text{No. of square feet per quadrat}} \times$ average crown cover per cent. was used; the average crown cover was estimated visually at about 60 per cent. so that a factor of 3,000 was obtained:

$$\left(\frac{43{,}560}{9} \times \frac{60}{100} \doteqdot 3{,}000\right)$$

The figures obtained by examination of the eggs collected from the litter samples are shown in Appendix No. 1 and numbers of the following order estimated to be present. The number of phasmatids expected at eclosion or "potential phasmatid population at eclosion" was calculated by using the figures for "eggs with developed embryos". These could, by this time, be reasonably expected to hatch in the coming spring.

Since very little information was available it was arbitrarily determined by the writer that if a population of about 50,000 late instar nymphal or adult phasmatids per acre could be expected then defoliation in the area would be serious and probably complete.*

A critical examination was made of the figures obtained, and it was predicted on the available evidence that plague numbers of phasmatids would be present throughout

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* This figure was derived from a population estimation study carried out at Bago State Forest in the previous year.

the area with intensive defoliation over much of it, particularly Tuggolo and Nundle State Forests.

Eclosion of phasmatid nymphs took place as expected and incipient defoliation was evident throughout the area. Severe fires during November, 1957, burnt over a large portion of Tuggolo State Forest, part of Tomalla and a small part of Nundle State Forest. These markedly reduced the phasmatid population on the burnt areas which included that set aside for the experimental spraying. Studies of the nymphal and adult numbers planned to assess this were as a result not carried out. However, the area was inspected during March, 1958, by Forester N. C. Gare, Tamworth Subdistrict. and the writer and the following observations recorded:

State Forest.	*Extent of Defoliation.*
Nundle	Very severe, mostly complete defoliation.
Tomalla	Defoliation light to medium on unburnt area—about 1,500 acres affected.
Tuggolo	Defoliation light to medium throughout the whole forest, greater in the south where defoliation was advanced before fire reduced phasmatid numbers.

TABLE 2.

Total Number of Eggs per Acre (Excluding Empty Shells), Expected Maximum, Minimum and Mean Numbers of Phasmatids at Eclosion per Acre.

Date of Collection.	No. of Eggs/Acre.		Potential Phasmatid Population at Eclosion/Acre.		
	Minimum.	Maximum.	Minimum.	Maximum.	Mean.
31/10/57	3,000	174,000	0	9,000	1,500 (1957/58)
			3,000	102,000	33,000 (1958/59)
3/ 3/58	0	171,000	0	72,000	16,000 (1958/59)
			0	18,000	4,000 (1959/60)

It was obvious that the only part of the area which had escaped serious defoliation on Tuggolo and Tomalla was that burnt in November, 1957. It was concluded that the sampling carried out was quite adequate for a general prediction of high numbers followed by extensive defoliation. However, it was quite apparent that the population density, at least at eclosion, was very variable throughout the area and that more intensive ecological studies would require a much greater intensity of sampling.

Kiewa Area.

Egg estimation studies were initiated by the writer at the request of the State Electricity Commission of Victoria following noticeable population increases of the phasmatids in the Bogong–Mt. Beauty area. Twelve sites were chosen, observing the prescribed conditions, and litter samples one square yard in area were collected from each site. Eggs collected from these samples were examined and the results are shown in Appendix No. 2.

Using the figures obtained, numbers of the order shown in Table 2 were estimated to be present in the area.

(These figures were derived from the dissections, again using the factor of 3,000 obtained as indicated.)

The Potential Phasmatid Population at eclosion for each year was calculated by using the number of eggs with developed embryos found in the samples collected in

October, 1957, in the case of the year 1957 and the number of eggs with undeveloped embryos in the case of the year 1958. By the time of the next sampling in March, 1958, these embryos had developed and the expected numbers at eclosion were again calculated in a similar manner.

The fall in the expected numbers (P.P.P. at eclosion) per acre is most probably due to disease or deterioration with a slight increase in discernible parasitism. (See Appendix 4 for details.)

It was predicted that there would be low numbers of *D. violescens* present during the 1957–58 season and slight defoliation would occur, but that medium to high numbers could be expected during the 1958–59 season with serious defoliation in certain localized areas, i.e., above Bogong township, in the vicinity of the 6–7 mile peg on the No. 1 Road and near the Pretty Valley Bridge.

The area was inspected during February, 1959, and this prediction was found to be reasonably accurate. The sampling carried out was adequate, but could be extended to other areas of infestation in the vicinity which were known.

Snowy Mountains Area.

D. violescens was present in large numbers and serious defoliation occurred around Island Bend in the 1955–56 season. Five sites were sampled in this area by staff of the Snowy Mountains Hydro-Electric Authority following directions given by the writer. The results obtained by examination of the eggs collected from these samples are given in Appendix 3.

Estimated numbers using the results obtained are shown in Table 3.

TABLE 3.

Maximum and Minimum Number of Eggs (Excluding Empty Shells) per Acre; Maximum, Minimum and Mean Number of Phasmatids per Acre Expected at Eclosion.

Date.	No. of Eggs/Acre.		Potential Phasmatid Population at Eclosion per Acre.		
	Minimum.	Maximum.	Minimum.	Maximum.	Mean.
June, 1957	6,000	477,000	3,000	51,000 (1957/58)	23,000
			63,000	202,000 (1958/59)	101,000

Using these figures as a basis it was predicted that moderate numbers of *D. violescens* would be present in this area, with high numbers in localized areas during the 1957–58 season. High numbers could also be expected during the 1958–59 season.

The area was inspected during April, 1958, and, as expected, phasmatids were present and serious localized defoliation had occurred. It was known to the writer, however, that high numbers might occur over a much more extensive area than the locality from which the samples were drawn and it was recommended to the Authority that litter samples be collected from such areas (particularly the Geehi area). Owing to shortage of staff this was not done and the prediction for the 1958–59 season had to be based on the samples drawn in June, 1957. No confidence was placed in this prediction by the writer because of lack of information as to subsequent embryonic development of the eggs.

Intensive defoliation did occur during the 1958–59 season in the Geehi area with a less severe infestation at Island Bend (unpublished report, Dr. M. E. Phillips, Soil Conservation Report No. SS1040, S.M.H.E.A., March, 1959), and an inspection by the writer during April, 1959, confirmed this report.

The sampling carried out in this area was quite inadequate to obtain the information required for an accurate estimate of expected numbers to be made. Sampling sites should have been located for this purpose within the areas of expected or suspected population increase.

Bago State Forest.

Nymphs and adults of *D. violescens* were expected to be present in high numbers in the Bago area during the 1958–59 season and an experimental aerial spraying was planned during this period. An area of about 500 acres comprising Compartments 34, 35 and part of 36 and carrying high site quality Alpine Ash, *E. delegatensis*, was chosen.

So that accurate estimate of numbers of the various stages could be made, seven sites were chosen at random within the area and litter samples one square yard in area were drawn from each site in March and again in September, 1958.

Figures obtained by examination of the eggs collected from the litter samples are detailed in Appendix 4. The estimations made using the figures obtained by examination of the eggs are shown in Table 4.

The expected number of phasmatids at eclosion for the current and succeeding season were calculated as explained above.

The apparent decrease in the potential phasmatid population at eclosion is partly attributable to the death of advanced embryos and to disease and deterioration. If the figures are examined as percentages (see Appendix 4), it appears that the sampling, which was not carried out quite as prescribed because of bad weather and difficulty of access to the area, was responsible for a fair proportion of this. Only five samples were taken instead of seven, and at least one of the high density sites was missed.

TABLE 4.

Maximum and Minimum Number of Eggs per Acre, Excluding Empty Shells; Maximum, Minimum and Mean Expected Numbers of Phasmatids at Eclosion per Acre (Total Number of Eggs Including Empty Shells in Brackets).

Date.	No. of Eggs/Acre.		Potential Phasmatid Population per Acre at Eclosion.		
	Minimum.	Maximum.	Minimum.	Maximum.	Mean.
19/3/58	1 80,000	1,107,000	24,000	513,000	185,000 (1958/59)
	(201,000)	(1,467,000)	12,000	123,000	51,000 (1959/60)
30/9/58	120,000	537,000	18,000	168,000	77,000 (1958/59)
	(156,000)	(1,107,000)	6,000	69,000	28,000 (1959/60)

The intensity of sampling in this locality was much greater than that undertaken in other areas, since it was hoped to make estimations of the numbers of insects in the nymphal and adult stages of the insect both as a study of natural mortality and of the effects of the intended insecticidal treatment.

It was considered that the expected numbers at eclosion were great enough for a prediction of high numbers during the 1958–59 season with the probability of serious defoliation in the area chosen for treatment.

The planned census work on the nymphal and adult stages was not carried out due to circumstances beyond the writer's control, but the area was inspected during April, 1959. At this time, adult phasmatids were numerous and defoliation of this portion of the forest was intensive.

Nymphal and Adult Stage.

The nymphal and adult stages of both *D. violescens* and *P. wilkinsoni* are less easily sampled than the egg stage, because of the insects' behaviour and habitat.

Populations of the young nymphs have been sampled directly from small trees in limited localities by the writer, taking branchlets of a given length and using a catching frame to retain insects which dropped from the sample. This was satisfactory where most of the trees were small and could be easily reached by hand, but it restricted the study to a small stratum of the habitat and could not be used for large trees. As mentioned before, the insects are quite often sensitive to the mere approach of an observer, and may drop from the foliage if a shadow merely passes over them. Apart from the physical difficulty of reaching the top-most foliage, this behaviour must be taken into account when choosing a method for estimating numbers of the insects.

The frass pellet of a phasmatid is roughly cylindrical in shape and up to approximately 0·2 × 1 cm. in the case of a mature female *P. wilkinsoni.* The pellets of males are always smaller and lighter than those of a female of corresponding age. The ratio of the average weight of a mature male : mature female pellet of *D. violescens* is very close to 1:3. The pellet is compact, relatively dry, and holds its shape for up to several months. The frass of small nymphs may be dispersed by the wind or may be retained by moist foliage, but this is not the case with that of adult insects.

An experimental aerial spraying to control *D. violescens* at Bago S.F. was planned in 1957 and the writer had to determine the relative effectiveness of the insecticides used. Time, assistance and finance were all limited and, after due consideration, the method of frass-fall measurement was adopted. It was hoped that by comparison of the amount of frass fall before and after treatment an accurate appraisal of the effectiveness of the treatment could be made.

Frass Fall Measurement Method.

An area of 900 acres comprising portions of Compartments 13, 14, 15, 19, 20, 37, 39 and 40 mainly of high site quality Alpine Ash, *E. delegatensis*, was chosen and divided into three sections. Sixty frass traps located approximately on a 10-chain grid were located within the area, 20 to each section; traps were placed so as to be beneath the crown of whichever tree happened to be near the surveyed point, no choice being made with regard to size or species (provided it was a *Eucalyptus* sp.). (Unpublished Reports, F. J. Gay, Division of Entomology, C.S.I.R.O., Canberra, and K. G. Campbell, Forestry Commission of N.S.W., 1957.)

Frass Traps.

The frames of the frass traps were 5 feet by 5 feet in dimension and constructed of 1″ × 1″ hardwood joined by nailing at the corners with triangular plywood gussets. Four legs also of 1″ × 1″ hardwood were provided with plywood retaining pieces nailed to the top forming a slot into which the frame fitted, and sharpened so that they could be driven into the ground. The frame could be placed horizontally on practically any surface, and once the legs were driven into the ground the frame could be removed and replaced without moving them.

Over the frame was stretched doubled "mosquito" netting, the edges of the netting being slipped over small brads which had been nailed into the frame. Any damaged netting could thus be quickly removed and renewed. A tape was fixed to the centre of the netting which was tied to a stake about a foot long driven into the ground. This prevented the netting from flapping in the wind. The stake was provided with a loop so that the tape could be easily untied to remove the frame for clearing.

The traps were constructed entirely in the field using a hammer, saw and axe (the gussets being prefabricated), the procedure for location being as follows: The frames, legs, netting and stakes were conveyed as close as possible to the sites by motor vehicle (usually within twenty chains) and thence carried to the required place. First the frame was placed as desired and the legs placed and driven in until the frame was horizontal. The frame was then removed and the central stake driven in. The netting was then stretched over the frame which was replaced on the slotted legs and the tape tied to the stake. The traps were numbered B1–B20, C1–C20 and D1–D20 respectively.

Frass Collection.

As soon as the 60 traps were in position, frass collection commenced. Recordings were made, the time of location of each trap and at each succeeding time a trap was cleared of frass. Clearing was accomplished as follows: The tape was untied from the stake, the frame removed and the contents tipped onto a plastic sheet. The frame was replaced and the sheet picked up by the corners so that all the contents moved to the centre. These were carefully scooped into screw-top metal canisters (export cigarette tins) and a tag giving the number of the trap included within. Traps were cleared daily and about 36 man-hours per day were required for this purpose.

After all traps had been cleared, each batch was tipped onto a tray and all extraneous matter, pieces of bark, leaves, buds, flowers and excreta of other insects was removed by hand. Each batch was then placed into a separate drying tin and dried to constant weight. This took about 18 man-hours per day. The total quantity of frass fall per 20 traps per collection hours is shown in Appendix 5. This was reduced to frass fall per hour for each trap by computing:

$$\frac{\text{Weight of frass fall per collection per trap}}{\text{Period of time since last collection}}$$

The mean frass fall per hour is given in Table 5.

TABLE 5.

Bago State Forest.

Frass Fall in Grammes per 25 Square per Hour (Mean ±95% fiducial limits).

Period.	Control Area C.	Dieldrin Sprayed Area D.	B.H.C. Sprayed Area B.
5– 8/3/57	0·180 ± 0·020	0·149 ± 0·026 5– 7/3/57	0·051 ± 0·008
9–12/3/57	0·158 ± 0·020	0·152 ± 0·034 8–12/3/57	0·053 ± 0·004
5–12/3/57 inclusive	0·170 ± 0·015	0·150 ± 0·022 5–12/3/57 inclusive	0·052 ± 0·006
3– 4/4/57	0·140 ± 0·018	0·141 ± 0·036 3– 4/4/57	0·064 ± 0·015

It was noted in the field that rain caused a definite reduction in the rate of frass fall, but that this increased in the following dry period and made up for the reduction. This may have been due in part to retention of the pellets by wet foliage, but a similar observation was made with caged insects which were not exposed to the rain nor on wet foliage.

The method proved very satisfactory as a means of comparison of effects of the insecticides and the writer decided to attempt to derive actual numbers of insects from the results obtained from measurement of frass fall.

Nothing was known of the rate of frass fall per insect, and as *D. violescens* was being held at Epping, N.S.W., to provide data for rate of egg production, possible parasitism, etc., it was decided to measure the rate of frass fall of these insects. The insects were held in cages (*a*) and (*b*), 9″ × 9″ × 15″, and (*c*), 18″ × 18″ × 24″. Those referred to (*a*) were reared at Epping from eggs collected in the field and (*b*) and (*c*) were taken at Bago State Forest as last instar nymphs or recently mature insects. The insects were supplied with abundant food in the form of leaves of a Peppermint, *Eucalyptus andreana*. The cages were held in a bush house which simulated, to some extent, conditions of temperature and humidity which would be experienced in the field at Bago.

The frass was collected at intervals, dried to constant weight, and the rate of frass fall per hour calculated (see Appendix 5). Male and females were not held separately as the main object was to obtain fertile eggs, but it was determined that the weight of male : female frass pellets and their rate of production were both very close to the ratio 1:3. Figures for frass production per hour male and female were derived and the results are given in Table 6.

The figures for frass production by the insects in (*c*) were used to calculate figures for the mature phasmatid population sampled at Bago, since it was considered that these would most truly reflect actual field conditions. An average crown cover of between 50 and 60 per cent. was again assumed (supported by observation) and a factor of 1,000 used for conversion:

$$\left(\frac{43{,}560}{25} \times \frac{(50 \text{ to } 60)}{100} \div 1{,}000\right)$$

This gave figures of the order shown in Table 7.

Observations made of defoliation in the field were: (1) Most serious *C*. (2) Next most serious *D*, though not much less than *C*. (3) Defoliation noticeable but not serious *B*.

TABLE 6.

Average Frass Production per Insect per Hour (Oven Dry Weight).

	Males.	Females.	
(*a*)	1	2	Male .. 0·0015 gm./hour. Female 0·0046 gm./hour.
(*b*)	2	4	Male .. 0·0019 gm./hour. Female 0·0060 gm./hour.
(*c*)	12	46	Male .. 0·0015 gm./hour. Female 0·0046 gm./hour.
(*d*)	1*	1*	Male : Max. 0·0051 gm./hour. Min. 0·0031 gm./hour. Female : Max. 0·0087 gm./hour. Min. 0·0061 gm./hour.

* Hadlington and Hoschke, 1959. Insects held in separate cages.

Measure of Egg Production.

Oviposition commenced at Bago about the first week in March, 1957, and eggs were collected from the frass traps and counted (see Appendix 6). The average number of eggs produced per day by the crowded females (Cage C; Fig. 3) at Epping was just over one per day, particularly towards the end of their egg-laying life (during April at Bago when the main egg counts were made), although this figure was exceeded when the females first commenced laying.

TABLE 7.

Average Number of Phasmatids per Acre.

Period.	Control Area C.	Dieldrin Sprayed Area D.		B.H.C. Sprayed Area B.
5– 8/3/57 ..	60,000	50,000	5– 7/3/57 ..	17,000
9–12/3/57 ..	53,000	51,000	8–12/3/57 ..	17,000
5–12/3/57 inclusive	57,000	50,000	5–12/3/57 inclusive	17,000
3– 4/4/57 ..	47,000	47,000	3– 4/4/57 ..	22,000

If a 50:50 sex ratio is postulated the number of eggs expected may be calculated from Table 7. These and figures calculated from egg production figures are given in Table 8.

The writer realizes that there are approximations in the figures presented above, but the degree of agreement obtained indicates the possibility of accurate population estimated by a combination of frass fall and egg production measurement.

DISCUSSION.

The methods of population estimation described are attempts to assess the phasmatid numbers during (*a*) the egg stage, and (*b*) the nymphal and adult stages.

The eggs are readily available for sampling as they are dropped directly onto the forest floor. For predictions of expected numbers of phasmatids or the "potential phasmatid population at eclosion" the method is considered adequate, providing the intensity of sampling is scaled to the required accuracy of the prediction or estimation.

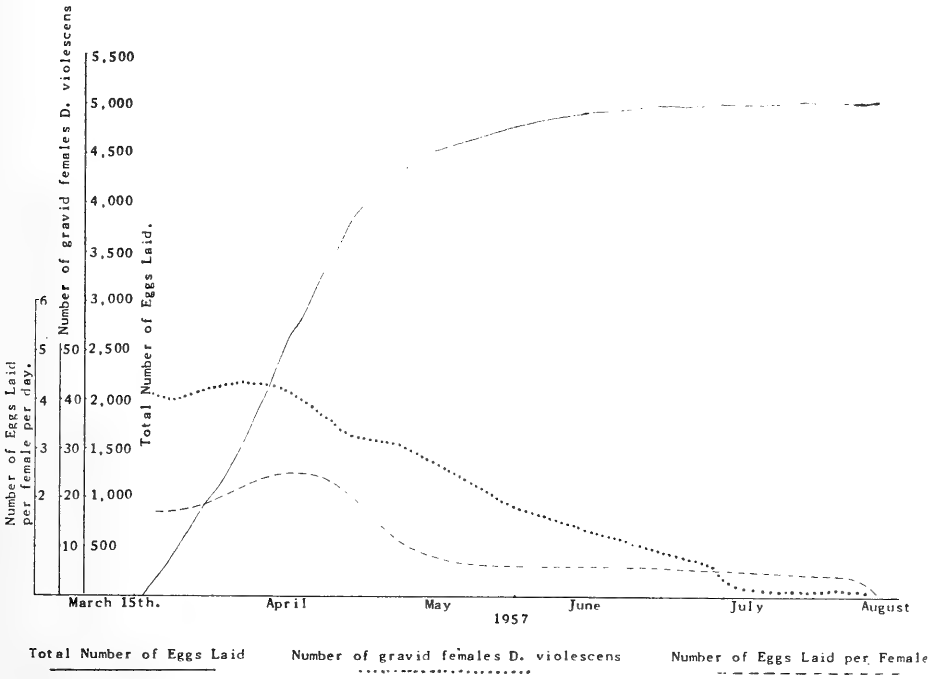

Fig. 3.—*D. violescens* held at Epping, N.S.W. Total number of eggs laid, and eggs per female per day.

Obviously, if an area prediction only is required, far fewer samples may be drawn than if a very accurate census is required, for example, a study of the population dynamics.

For the latter type of census the writer also considers that stratification of the sampling with regard to site-quality and floristic composition would be necessary.

TABLE 8.

Average Number of Eggs per Day per Trap 4/4/59.

Area.	Expected.*	Actual.†
C	24	21·7±4·8
D	24	26·8±9·8
B	6	7·5±3·3

* Mean±95% fiducial limits.

† Calculated from figure of frass production, number of females $= \frac{\text{Total number of phasmatids}}{2}$.

(There appears to be reasonable agreement between the figures derived by both methods.)

Although the predictions made on the basis of the figures obtained by the method outlined have proved correct, these were also based to some extent on the writer's local knowledge of the areas studied. At no time was sufficient assistance or time available either in the field or laboratory to collect or examine as many samples as the writer would have preferred.

Unless the collection sites are selected according to a pattern of past or probable courses of infestation, a quite unreal inference may be drawn from the figures obtained by examination of the eggs. Again, although the p.p.p. may be assessed with reasonable precision, it does not follow that actual defoliation of the area sampled will be as serious as might be expected from such as assessment. Little is known of the mortality factors acting on the nymphal and adult stages, nor has any attempt yet been made to measure their effects.

For a long-term study it is suggested that permanent traps of durable wire mesh ("fly wire" is adequate to retain the eggs of both *P. wilkinsoni* and *D. violescens*), placed in position prior to oviposition and laid directly on the mineral soil, should be established. Eggs falling onto these would be readily available for sampling and this would obviate the laborious separation from litter by sieving.

If numbers per acre are required, accurate measurements of crown cover per cent. should be determined for each site or at least for the area being studied.

The nymphal and adult stages are far less accessible, but the methods described seem quite satisfactory. If it is desired to carry out direct sampling of these stages some form of catching tray must be provided to intercept escaping insects which, as previously mentioned, are often very sensitive to any disturbance. This is likely to be practicable only when sampling from small trees.

The method of frass fall measurement appears satisfactory except in the case of very tall and isolated trees and first or second instar nymphs, where wind might cause the loss of portion of the frass; such a method appears suited to the estimation of numbers in intensive population studies. In the latter instars and more particularly with adult phasmatids, it is possible to distinguish between numbers of males and females if this is desired. The frass fall of *D. violescens* per day was reasonably constant (although this was affected by rain which apparently inhibited frass production). Whether the insects actually stopped feeding during the rain is not known, and this may be a result of very high humidity since caged insects not exposed to the direct effect of rain responded similarly.

The traps described were adequate in all respects, being cheap, easily constructed, light and readily handled. The double mosquito netting was quite satisfactory and retained the frass of last instar and mature insects, the netting was difficult to wet, and if wetted, dried easily. Even if the netting was damp the pellets could be removed, providing a little care was taken. Muslin may be used to cover the traps to retain the frass pellets of earlier instars. Damage was caused to these traps by wandering animals (wombats and cattle being the most troublesome).

For long-term population studies, metal frames with metal cloth covers would be more suitable, the mesh being chosen to retain the frass pellets as desired. Damage by animals may be minimized by fencing where necessary.

To convert the frass fall to numbers of insects, known numbers of phasmatids must be held in captivity under conditions as near as possible to those applying in the area being studied, the frass from these being collected and weighed as described. Some males and females should be held separately as well as together and varying sex ratios should be studied to determine the influence on frass and egg production. Adequate replications to sample the variable conditions of the area being studied are, of course, necessary.

When the insects are mature the rate of egg production appears to provide a good check against the frass fall method. The studies of egg production would be carried out concurrently with the frass studies outlined above, observing similar conditions.

These could be further related to studies of the egg stage in the field. Although these studies were initiated for the purposes mentioned, the writer was also attempting to develop suitable techniques which could be applied to a long-term study of these insects. These techniques had, of necessity, to be inexpensive and require as little labour as possible. The writer considers that the methods will prove satisfactory and intends to implement them when and wherever possible.

CONCLUSIONS.

1. The method of litter sampling and egg examination appears satisfactory for the purpose, i.e., the provision of reasonably accurate predictions of plague numbers of nymphal or adult phasmatids.

2. To obtain most accurate results, litter collections in the field should be made in late January when embryonic development is advanced, and in early September just prior to eclosion of the nymphs.

3. If long-term studies are intended, permanent plots should be established and traps with frames constructed of durable material should be provided to supplement litter samples made directly in the field.

4. The frass fall measurement method is satisfactory both for (*a*) assessment of an insecticidal treatment and with refinement, and (*b*) an accurate census of nymphal and adult phasmatids. Durable traps, with suitable coverings to retain the frass pellets, should be provided for long-term studies.

5. Egg production measurement provides a good check against frass fall measurement when the phasmatids are mature.

6. Detailed studies are necessary of the mortality factors acting on the nymphal and adult stages if the initial predictions are to be related to the probable defoliation of an affected area.

Acknowledgements.

I wish to thank Mrs. M. Casimir for assistance with many of the egg dissections. Considerable assistance with collections of eggs and litter in the field at Bago was given by Messrs. K. M. Moore and K. R. Shepherd and during the assessment of the aerial spraying by Messrs. F. J. Gay, C. Mayo and A. H. Wetherley of the Division of Entomology, C.S.I.R.O., Canberra, and by Messrs. K. M. Moore and J. Watt of the Forestry Commission of New South Wales.

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APPENDIX 1.

Figures of Egg Dissections of Survey made 3–6/6/1957.

Site No.	Advanced Embryos.	Developing Embryos.	Undeveloped Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Empty Shells.	Total.
Tuggolo State Forest.							
1	1		6		9	33 (6)	49 (6)
2	4		9		16 (1)	53 (1)	82 (2)
3	11		7	3	41 (3)	29 (5)	91 (8)
4	29		9	10	39 (1)	61 (10)	148 (11)
5	4		6	7	8	22	47
6	15		3	4	5	21 (2)	48 (2)
7	13	3	16	13	15 (1)	23 (4)	83 (5)
8	119	5	36 (1)	45	197 (1)	121 (27)	529 (29)
9	13		8	9	16	23 (5)	69 (5)
Total	209	8	100 (1)	91	346 (7)	386 (60)	1140 (68)
Tomalla State Forest.							
Nth. Junction of Collisons and S.G. Road	23		6 (1)	8	24 (1)	48 (24)	109 (26)
Margin of attack 1955/56	2	1	3	2	15 (3)	14 (7)	37 (10)
South of track	2		1	5	8 (5)	19 (24)	35 (29)
Edge of attack 1955/56	6		5	10	13 (2)	32 (5)	66 (7)
Total	33	1	15 (1)	25	60 (11)	113 (60)	247 (72)
Nundle State Forest.							
Below lookout Section	1 (1)		3		138 (18)	184 (78)	326 (97)
Big Flat near Murder Dog	5 (2)		2	20	12	36 (2)	75 (4)
One mile west of Murder Dog	15			18	8	16	57
Edge of past defoliation Murder Dog	1		2		4	14 (5)	21 (5)
Peppermint Flat	53	1	25 (1)	20	45 (2)	154 (34)	298 (37)
Snowball Break	16		4	2	15	18 (1)	55 (1)
One mile east of Snowball Break	6 (1)		8	1	5	7 (1)	25 (2)
Total	96 (4)	1	44 (1)	61	227 (20)	429 (121)	857 (146)

These figures are for eggs of *P. wilkinsoni*; those in brackets denote *D. violescens*.

APPENDIX 2.

(A.)

State Electricity Commission–Kiewa Area. Dissection of Eggs of *D. violescens* 30–31/10/57.
(Litter samples collected by H. Vyner.)

Site No.	Advanced Embryos.	Partly Developed Embryos.	Un-developed Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Total.	Empty Shells.	Grand Total.
1. Above Bogong Township	1	—	20	—	4	25	2	27
2. Above Bogong Township	—	—	12	—	3	15	1	16
3. Railhead Bench ..	—	—	17	—	2	19	10	29
4. ,, ,, ..	1(*e*)	1	9	2	5	18	5	23
5. 6–7 mile peg—No. 1 Road	—	—	4	—	2	6	1	7
6. 6–7 mile peg—No. 1 Road	3(*e*)	1	33	15	6	58	25	83
7. 6–7 mile peg—No. 1 Road	—	—	11	7	1	19	1	20
8. Bogong Lodge—No. 1 Road	1(*e*)	—	8	—	1	10	9	19
9. Pretty Valley Bridge	—	—	4	—	1	5	4	9
10. 11–12 mile peg—No. 1 Road	—	—	4	—	2	6	3	9
11. 11–12 mile peg—No. 1 Road	—	—	4	—	—	4	3	7
12. Test Point No. 11 ..	—	—	1	—	—	1	—	1
Total	6 (3·3%)	2	127 (68·4%)	24 (12·8%)	27 (14·5%)	186	64	250

(B.)

(Forest litter samples collected 3/3/58 by H. Vyner.)

Site No.	Advanced Embryos.	Un-developed Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Total.	Empty Shells.	Grand Total.
1. Above Bogong Township	16	5	2	9	32	6	38
2. ,, ,, ,,	4	—	—	6	10	3	13
3. Railhead Bench	—	—	—	—	—	—	—
4. ,, ,, ...	1	1	1	1	4	2	6
6. 6–7 mile peg—No. 1 Road	1	—	—	—	1	5	6
6. ,, ,, ,, ,,	15	4	24	14	57	41	98
7. ,, ,, ,, ,,	1	1	2	1	5	1	6
8. Bogong Lodge—No. 1 Road	2	1	—	7	10	10	20
9. Pretty Valley Bridge ..	24	6	1	9	40	23	63
10. 11–12 mile peg—No. 1 Road	1	—	—	9	10	8	18
11 ,, ,, ,, ,,	1	1	—	1	3	5	8
12. Test Point No. 11 ..	—	—	—	—	0	1	1
Total	66 (30%)	19 (11%)	30 (17%)	57 (33%)	172	105	277

APPENDIX 3.

Dissection of Eggs Collected at Island Bend, S.M.H.E.A., June 1957.
Phasmid: *Didymuria violescens* Leach.

Site No.	Advanced Embryos.		Undeveloped Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Total Eggs with Contents.	Empty Shells.	Grand Total.
	Alive.	Dead.						
1	—	—	—	2	—	2	1	3
2	1	1	21	19	49	91	119	210
3	17	1	67	5	69	159	240	399
4	11	1	56	—	56	124	179	303
5	9	1	23	7	63	103	205	308
Total ..	38 (9%)	4 (1%)	167 (35%)	33 (7%)	237 (48%)	479	744	1223

APPENDIX 4.

(A.)
Didymuria violescens Leach.
Bago S.F.—Cpts. 34 and 35.

Site No.	Advanced Embryos.	Partly Developed Embryos.	Undeveloped Eggs.	Parasitized Eggs.	Diseased or Deteriorating Eggs.	Total.	Empty Shells.	Grand Total.
34/1	28	1	4	—	27	60	7	67
34/2	8	—	4	2	65	79	93	172
34/3	34	—	6	3	44	87	34	121
34/4	84	—	27	2	37	150	101	251
35/1	15	1	6	2	36	60	207	267
35/2	171	—	41	4	153	369	120	489
35/3	91	—	30	4	81	206	85	291
Total ..	431 (43%)	2 (0·2%)	118 (12%)	17 (1·7%)	443 (44%)	1011	647	1658

(B.)
Didymuria violescens Leach—Bago S.F.
Egg Dissections—Collected 29–30/9/58.

Site No.	Advanced Alive.	Embryos Dead.	Partly Developed Embryos.	Undeveloped Eggs.	Parasitized Eggs.	Diseased or Deteriorating Eggs.	Total.	Empty Shells.	Grand Total.
Cpt. 36 near S.W. corner of Cpt. 35	56	7	2	23	2	89	179	189	368
Cpt. 35 near NC.. ..	6	1	—	3	—	30	40	12	52
Cpt. 35 near J24 ..	19	3	—	12	—	38	72	89	161
Cpt. 34 toward B33 ..	35	2	—	6	5	46	94	52	146
Cpt. 34 near B35 ..	12	—	—	2	—	28	42	113	155
Total ..	128 (30%)	13 (3%)	2 (0·4%)	46 (11%)	7 (1·6%)	231 (54%)	427	455	882

APPENDIX 5.

Total Frass Fall in Grammes per 20 Traps per 24 Hours.
Bago State Forest.

Block.	5/3	6/3	7/3	8/3	9/3	10/3*	11/3	12/3	13/3	14/3	23/4	34/4
C	100·92	82·97	69·14	88·57	117·33	15·06	88·53	70·46		46·60	59·26	69·49
D	139·34	72·39	61·56	74·13	111·07	15·11	77·96	67·94	75·12	10·99	57·00	69·91†
B	57·84	26·16	24·51	27·88	32·61	5·48	29·41	25·01	33·47	5·06	28·50	30·40†

* 5 plots measured only because of rain.
† 19 plots only, one damaged.

Frass Production by *D. violescens* held at Epping, N.S.W., fed *Eucalyptus andreana*.

	Number of Insects.		Dates 1957.	Total Fæcal Production in Grammes per Hour (O.D.W.).
	Male.	Female.		
(*a*)	1	2	23/3–24/3	0·0120
			24/3–25/3	0·0109
			25/3–26/3	0·0099
			26/3–27/3	0·0104
(*b*)	2	4	23/3–24/3	0·0266
			24/3–25/3	0·0276
			25/3–26/3	0·0283
			26/3–27/3	0·0290
(*c*)	12	46	18/3–19/3	0·202
			19/3–20/3	0·190
			20/3–21/3	0·212
			21/3–22/3	0·348
			22/3–23/3	0·264
			23/3–24/3	0·206
			24/3–25/3	0·211
			25/3–26/3	0·201
			26/3–27/3	0·216

APPENDIX 6.

Egg Production per Trap—Bago State Forest.
D. violescens.

Area.											
Plot.	Period.			Plot.	Period.			Plot.	Period.		
	12/3–2/4	3/4	4/4		12/3–2/4	3/4	4/4		12/3–3/4	3/4	4/4
C1	*	41	24	D1	*	50	55	B1	*	4	1
2	503	28	38	2	569	59	61	2	144	13	15
3		10	14	3		15	14	3	139	10	18
4		24	30	4		19	19	4		7	8
5		13	22	5		6	12	5	136	16	14
6		33	10	6		28	32	6		7	14
7		35	39	7	Plot destroyed†			7			
8		14	20	8		2		8	185	8	6
9		9	9	9	595	26	37	9		2	2
10		25	23	10	240	13	16	10		2	1
11		4	30	11	213	9	13	11	52	7	6
12	128	8	11	12		19	34	12	95	13	8
13		24	29	13			3	13		8	7
14	261	21	23	14	340	12	18	14		14	24
15		30	39	15	407	12	19	15	201	22	15
16	401	24	29	16		25	23	16	211	5	16
17		7	9	17	660	62	78	78		—	—
18		13	13	18	416	23	25	18		2	1
19	104	9	16	19		3	6	19		—	2
20	9	9	6	20		24	45	20		—	1
Total		381	434			407	510			140	159
Mean P=0·05*t*		19·5 ±5·0	21·7 ±4·8			21·4 ±8·6	26·8 ±9·8			7·1 ±2·7	7·5 ±3·3

* Some of the plots were damaged so the figures for egg production could not be relied upon and were not used.
† Plot No. D7 was smashed during the period 12/3–2/4 and was not used thereafter.

SPONTANEOUS CHROMOSOME BREAKAGE IN ASTROLOMA PINIFOLIUM.

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(Plate i; thirty-nine Text-figures.)

[Read 27th April, 1960.]

Synopsis.

Astroloma pinifolium is an old and relict species with a secondary polyploid constitution. It produces pollen in variable tetrads (VPTs), which contrast with the monad pollen of diploid species of the genus. The conformity of tetrad type frequency distributions to trinomial square forms suggests a dependence upon meiotic conditions.

Meiosis in pollen mother cells is irregular. The most frequent abnormality is the occurrence of fragmentation as a consequence of chromatid breakage. Bridge configurations, which occur with a variable frequency, are due partly to chromatid reunion and partly to subchromatid errors.

A relationship must exist between chromatid breakage and the consequent loss of acentric fragments and the production of VPT pollen. A study of fragment frequency and pollen fertility in ten plants suggests that this relationship is complex.

INTRODUCTION.

Astroloma pinifolium Benth. (Epacridaceae) is a hard-wooded perennial shrub native to eastern Australia. It occurs in small local populations in the coastal region, extending from southern Queensland to eastern Tasmania. Two very isolated occurrences are in the Warialda district of north-western New South Wales and in the Grampians of western Victoria.

All plants of the species which have been examined produce variable pollen tetrads (Smith-White, 1959*a*, *b*). In plants from the coastal regions the freqencies of the five possible categories of tetrad types often conform to the terms of trinomial squares. Frequency distributions of this form suggest that the causes of VPT development may be found in the characteristics of meiosis. The two second divisions, or half mother cells, in each mother cell must have similar and independent prospects of yielding one of three possible results: both microspores derived from a half mother cell may degenerate, one only may die, or both may survive. The whole tetrad frequency distributions will then conform to the trinomial $(x+y+z)^2$.

MATERIALS AND METHODS.

Investigations reported in this paper deal with the species in the east coastal region of New South Wales. The principal populations which have been studied are at Oatley and at La Perouse, both in the Sydney district and about ten miles apart. Additional populations have been examined from Pearl Beach, Tea Gardens and Evans Head, respectively, about 50, 150 and 400 miles north of Sydney. In the Grampians the species is known to be different both in its tetrad-type frequency distributions and in its meiotic characteristics, and presents a separate problem.

Acetic alcohol (1:3) and Bradley's high chloroform modification of Carnoy (Bradley, 1948) have been used as fixatives, followed by aceto-carmine and aceto-orcein stains. The chromosomes of the species stain poorly, and observations have been made with phase contrast. Feulgen staining has proved difficult owing to the characteristics of the cytoplasm, but confirmation of the presence of fragments has been obtained by its use.

OBSERVATIONS.

1. *The Karyotype.*

Mitosis has been examined in various tissues, including leaf initials, ovary wall, ovule integument, and embryos. It is entirely regular in these tissues, although polyploid cells have been found in young petals. At prophase, following cold treatment at 1–2°C. for 48 hours before fixation, the chromosomes show a banded or beaded structure which is suggestive of the localization of heterochromatin (Text-figure 1), but it has not been possible to define precisely the banding pattern nor to match the pattern in homologous chromosomes. The banding may have significance in relation to the occurrence of chromosome fragmentation in the pollen mother cells.

The somatic chromosome complement $2n = 14$ (Text-figure 2; Plate i, figure 1) contrasts with a basic genome of $x = 4$ in other species of the genus (Smith-White, 1955). Centromeres are median or submedian, and four chromosome length classes can be distinguished: long (two pairs), medium long (two pairs), medium short (one pair), and short (two pairs). The ratio of the length of the longest and shortest chromosomes approaches 3:1. One pair of the longest chromosomes possesses secondary constrictions. The karyotype of other species, with $2n = 8$, is quite different, all the chromosomes being of equal length and having median centromeres. It is probable that the origin of *A. pinifolium* has involved first allopolyploidy and then structural change and the loss of a pair of centromeres.

2. *Meiosis in Pollen Mother Cells.*

(*a*) *Chiasma characteristics.*

The early stages of first prophase are unfavourable for study, and no satisfactory observations have been made of pachytene or of diplotene. At diakinesis seven bivalents are present (Plate i, figure 2), but an analysis of chiasma characteristics at this stage has proved impossible.

With rare exceptions, seven bivalents are present at first metaphase. Usually the chromosomes of each bivalent are held together by chiasmata in both arms. In the larger bivalents there may be both proximal and distal chiasmata, with a strong suggestion of chiasma localization (Text-figures 3, 4). With proximal chiasmata on both sides of the centromeres there is a marked stretching effect, and strong centromere action is apparent even in the absence of proximal chiasmata. The smaller bivalents often have one or two chiasmata in one arm only (Text-figure 4), and where proximal chiasmata are absent open ring bivalent configurations result. With only one chiasma in a bivalent, the associated chromosomes may show precocious separation (Text-figure 5), and it is difficult to distinguish this from rare occurrences of univalents (Text-figure 6). That true univalents do occur, however, is indicated by occasional misdivision (Text-figure 7). At full metaphase, univalents may lie at the extremities of the spindle (Plate i, figure 3) in a manner reminiscent of univalent behaviour in the triploid *Leucopogon juniperinus* (Smith-White, 1948).

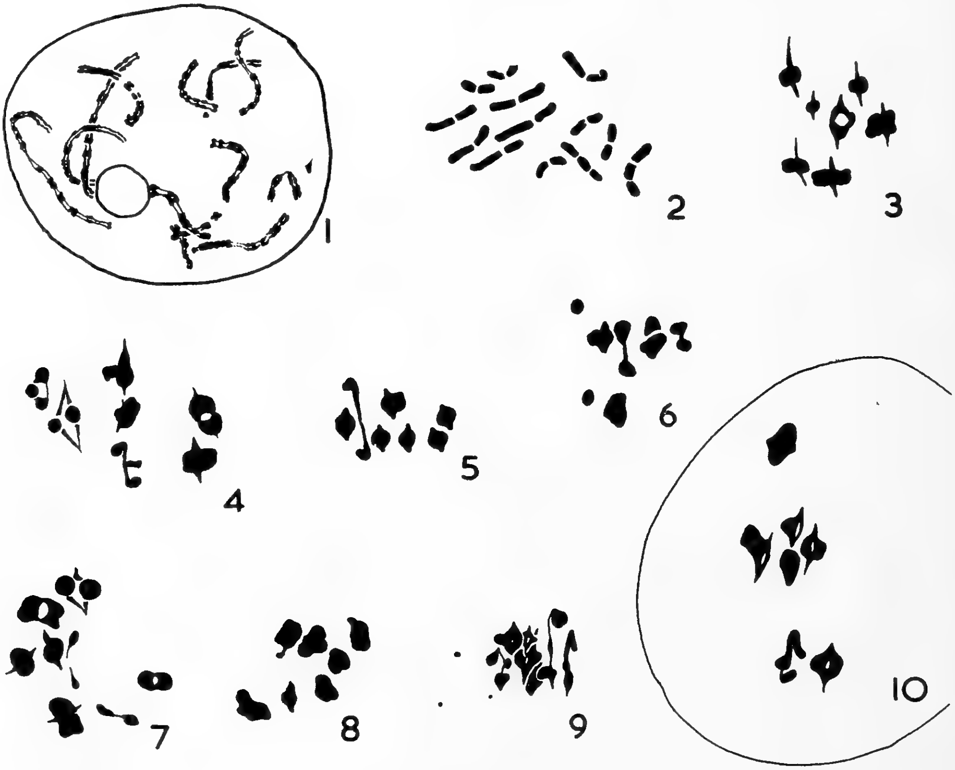
(*b*) *Abnormalities of first metaphase.*

In many plants, and possibly in all, there is heterozygosity for a small terminal knob on one chromosome (Text-figures 8, 13; Plate i, figure 4). Owing to its small size, consistent observations of its presence have not been possible, but it is present in at least ten plants of the Oatley locality.

In from 1% to 10% of mother cells in different plants the congression of bivalents to the metaphase plate may be imperfect (Text-figure 10; Plate i, figure 5). The plate may be loose, with the bivalents spread over the middle quarter or half of the spindle, or bivalents may be excluded altogether from the spindle. Such bivalents are often retarded in phase when the spindle has passed into anaphase. Text-figure 11 illustrates a particularly large mother cell in which there has been almost complete disruption of the division.

Failure of congression at metaphase must occasionally result in the loss of whole chromosomes from the daughter nuclei. However, in plant 057/5, which has an unusually high proportion (10%) of mother cells affected in this way, the exclusion of whole chromosomes from the interphase nuclei is much less frequent, and many of the misplaced chromosomes must ultimately regain their correct positions.

A third condition consistently visible at first metaphase, and throughout the first division, is a lateral displacement of the spindle. This displacement is probably present in all mother cells, but is apparent only with suitable orientations of the cells relative to the optical axis of observation. The displacement suggests the presence of cytoplasmic differentiation, and the possible relationship between cytoplasmic polarity and VPT production in *Acrotriche fasciculiflora* has been briefly considered elsewhere (Smith-White, 1959*b*). However, lateral spindle displacement is generally characteristic of other species of the Styphelieae, both in association with regular monad and regular full tetrad production, and it cannot be the immediate or direct cause of VPT production.



Text-figures 1-10.

1. Somatic prophase in ovary wall tissue. 2. Somatic metaphase, ovary wall tissue after cold starvation. 3-10. First metaphase in P.M.Cs: 3, 4. Strong centromere action and the presence of proximal and distal chiasmata are indicated. 5. A single chiasma in one bivalent allows precocious separation. 6. Two univalents, probably due to precocious separation. 7. Univalent misdivision. 8. Heterozygosity for a terminal knob. 9. Minute fragments and possible errors of chromosome splitting. 10. Three bivalents are off the spindle plate. (× *ca.* 2500.)

Other abnormal conditions which are infrequently seen at first metaphase include the presence of small or minute fragments, configurations suggesting errors in chromosome splitting (both illustrated in Text-figure 9), and neocentric activity (Text-figure 13). Neocentrics are also visible at second metaphase. Most cases of neocentrics which have been reported occur in the Gramineae (e.g., in Rye, by Praaken and Muntzing, 1942; Ostergren and Praaken, 1946; Rees, 1955; in Maize, by Rhoades and Vilkomerson, 1942, and Rhoades, 1952; in *Bromus* species hybrids by M. S. Walters, 1951, 1952, and in *Phalaris* by Hayman, 1955). However, Peacock (unpublished data) has observed strong neocentric activity at second metaphase in *Brunonia* in the family Goodeniaceae.

This and the present case are the first two examples of neocentric activity known to us outside the Gramineae.

(c) First anaphase.

The comparative regularity of first metaphase contrasts with the extreme irregularity of anaphase. Whilst 90% or more of the mother cells possess a normal metaphase plate, 95% or even 100% of cells at anaphase exhibit chromosome or chromatid fragments, and there is an appreciable frequency of bridges and associated abnormalities.

Fragments vary in number and size, and in arrangement in the cell. In number they range from one to as many as twelve, but numbers in excess of eight are infrequent (Text-figures 14–21). Significant differences occur in mean fragment frequency per mother cell between plants from the same population (Table 1), and there is very probably a real difference between populations, although more data would be required to establish this point.

The data in Table 1 also show that there is a positive correlation between fragment frequency and pollen death. Thus, loss of fragments must often be lethal. The correlation is not exact, however, and a simple relationship between fragmentation and pollen fertility may not operate.

TABLE 1.

The Relationship between Pollen Fertility and Fragment Frequency.

Plant.	Pollen Fertility.		Mean Fragment Frequency per Mother Cell.
	%	N.*	
O57/5	47·9	25864	1·22 ±0·15
O57/1	38·4	37696	2·96 ±0·28
O57/6	36·1	36004	1·58 ±0·16
R57/6	27·1	61136	3·35 ±0·62
O57/2	26·5	30176	2·87 ±0·28
R57/11	23·3	36392	3·74 ±0·26
R57/15	23·3	37556	2·95 ±0·18
R57/7	12·5	51012	4·44 ±0·32
LP57/4	8·3	18604	4·13 ±0·25
R57/8	7·3	38380	3·15 ±0·28

* N is the number of pollen grains on which the estimate of pollen fertility was made. It is equal to the number of tetrads scored in tetrad analysis, multiplied by 4.

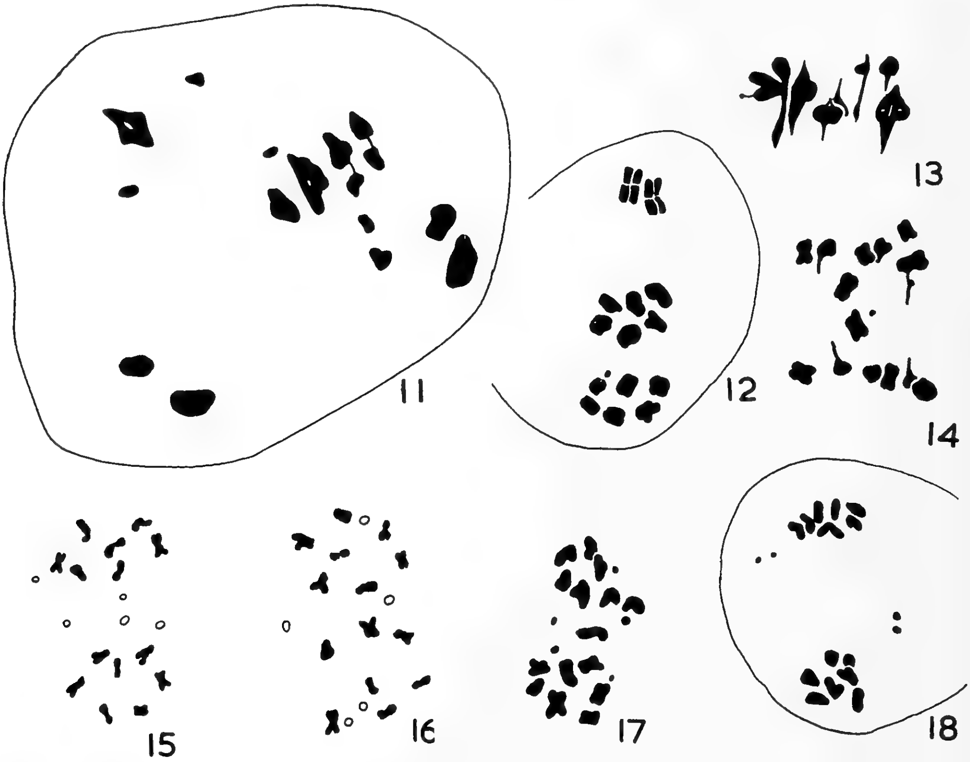
Most fragments are small or minute, and spherical in shape, with a diameter equal to or less than that of chromatids. Larger fragments are rod-shaped, and may have a diameter equal to that of whole chromosomes. Rarely, large fragments may approximate in size to whole chromosome arms (Text-figure 19). It has not been possible to demonstrate any discontinuity in the range of fragment size among the smaller fragments, but there must be a much greater prospect of fragmentation near the ends of the chromosomes than near the centromeres.

Fragments are most often single, but may be double, or they may occur in more or less closely associated pairs (Text-figures 18–20, Plate i, figures 9, 10), as though sister acentrics have separated. Such paired fragments are usually similar in size, but they may be slightly or grossly unequal (Text-figure 21).

In plant R57/15, with a mean fragment frequency of 2·95 fragments per cell, most mother cells can be classified into one of six categories having (i) no fragments, (ii) one fragment, (iii) two unpaired and unequal fragments, (iv) one pair of fragments, (v) three fragments, with two paired, and (vi) two pairs. Both larger and smaller pairs can be recognized (Text-figure 18). Although a few mother cells in this plant contain five or six fragments, there are probably two main loci susceptible to breakage.

The behaviour of the fragments during anaphase is consistent with their acentric nature. They usually lag in the mid-region of the spindle (Text-figures 15, 18, 19), and are often at its extreme edges. With the disappearance of the spindle at telophase they are usually excluded from the interphase nuclei, and may drift to the periphery of the cell (Text-figure 33). They may sometimes be included in the anaphase groups, apparently by chance circumstances (Text-figures 16, 17).

As a result of breakage, damaged chromatids must often be present in the first anaphase and second metaphase groups. Such damage can be recognized when the anaphase chromosomes are heterozygous (Text-figures 22, 23, 24, 35), but is unrecognizable when the chromosomes are homozygous for damage.

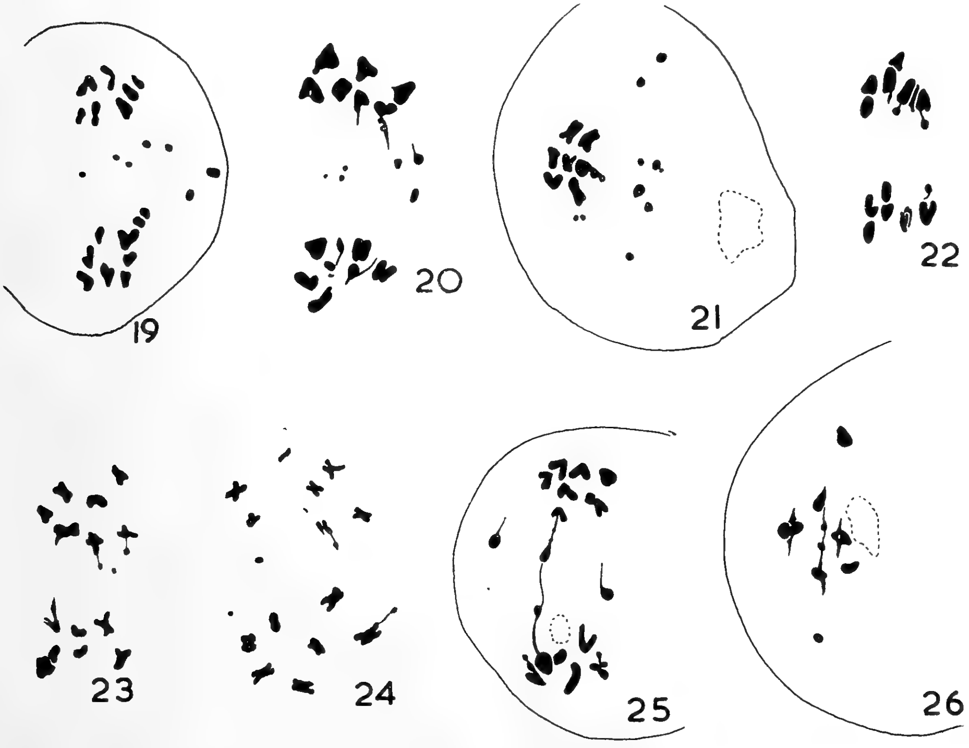


Text-figures 11-18.

11. First metaphase with extreme breakdown, in a mother cell of unusually large size. 12. First anaphase, with two chromosomes off the spindle. 13. First metaphase, showing neocentric activity and heterozygosity for a terminal knob. 14. A.1, the cell illustrated in Plate i, figure 6. 15-17. A.1, with numerous fragments. 18. A.1, with two pairs of associated fragments. (× *ca.* 2500.)

The presence of small chromatid segments which remain attached to the anaphase chromosomes by extremely fine chromatin threads (Text-figures 22–24) is obviously associated with and related to the occurrence of fragments. Following the usage of Levan and Tjio (1948), these will be referred to as "attached fragments". Most often anaphase chromosomes are heterozygous for such attached fragments, and it is occasionally possible to match homologous chromosomes at opposite poles (Text-figure 22). At other times an attached fragment at one pole can be matched with a free fragment in the spindle (Text-figure 23). Attached fragments may lag in the spindle, the connecting filament being greatly attenuated, or there may be a fine chromatin strand stretching from the attached fragment towards or across the equator of the spindle, suggesting a remnant of a chromatin bridge.

A second feature which must be associated with breakage is the occurrence of chromatin bridges. Bridges, however, are much less frequent than fragments, and occur in less than 10% of mother cells. Types of bridge configurations are illustrated in Text-figures 25 to 30, and Plate i, figures 11 and 12. In most cases they consist of fine chromatin threads joining anaphase chromatids. They may be uniformly fine throughout their length, or apparently broken in the mid-region (Text-figures 14, 20, 27, 29), or may have one or two unstretched chromatin blocks attached at the centre (Text-figures 25, 26). Breakage may leave them with the appearance of tandem attached fragments (Text-figure 29), or there may be two "opposed" knobs stretching out from the telophase nuclei (Plate i, figure 12). Some bridge configurations are extremely complex and difficult to interpret (Text-figure 30).



Text-figures 19-26.

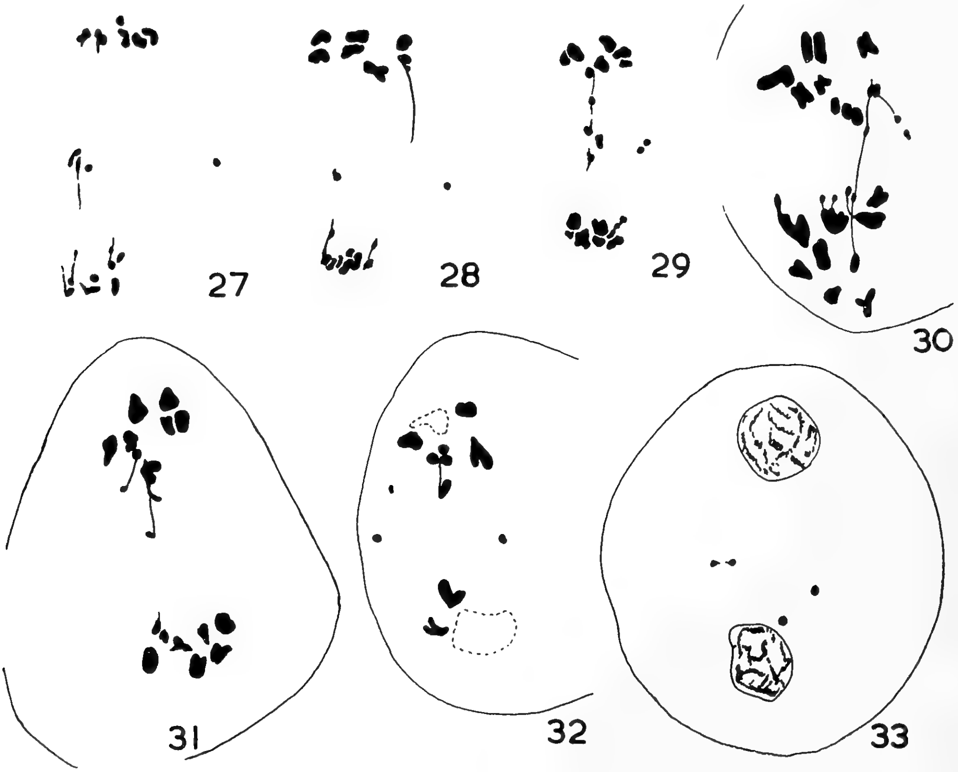
19. A.1, with large and small fragments. 20. A.1, with fragments and broken subchromatid (?) bridges. 21. A.1, with many fragments, including an unequal pair. 22. A.1, with attached chromatid fragments, two evidently being homologous. 23, 24. A.1, with free and attached fragments. 25, 26. A.1, with two-side-arm bridges probably due to subchromatid errors. (× *ca.* 2500.)

(*d*) *Interphase and the second division.*

Fragments which are excluded at telophase remain condensed throughout interphase (Text-figure 33). They may retain their arrangement in associated pairs, or may move apart. They drift to the periphery of the cell, and lie outside the second division spindles (Text-figure 34).

At second metaphase and anaphase, the following abnormalities can be recognized: (i) fragments in the spindles in addition to those in the outer cytoplasm (Text-figure 37); (ii) telocentric or near-telocentric half-chromosomes; (iii) chromosomes heterozygous for the loss of terminal segments (Text-figure 35); (iv) residual first division bridges; (v) second division dicentric and sticky bridges (Text-figure 36); (vi) neocentric activity; and (vii) misdivision (Text-figure 38). Some of the fragments which occur within the spindles will be those which were included in the interphase nuclei, but others may be the results of additional breakage during interphase, or may be consequences of secondary breakage following reunion and bridge formation. A detailed study of fragment frequencies at first and second anaphases is needed to clarify this point.

Fragments remain condensed and visible in the cytoplasm during second telophase and the four-nucleate stage (Text-figure 39). After the formation of the microspores they degenerate.



Text-figures 27-33.

27-31. Late A.1, with remnant bridges and fragments. In 30 the bridge is complex, and there are several attached fragments. 32. A.1, showing misdivision at or close to the centromere, and several fragments. 33. Interphase, with fragments excluded from the nuclei. (× *ca.* 2500.)

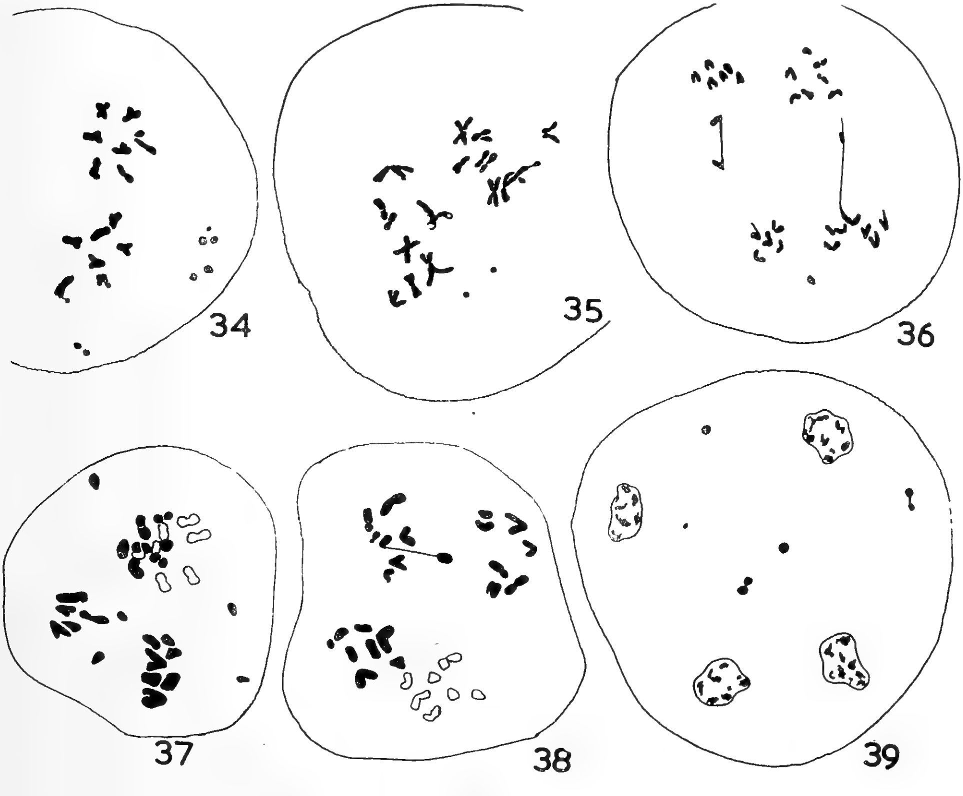
Discussion.

1. *Spontaneous Chromosome Breakage.*

Spontaneous chromosome breakage has been found most frequently either in temporary tissues such as anther tapetum (Cooper, 1933) and endosperm (Clark and Copeland, 1940; Brock, 1954; Rutishauser and La Cour, 1956), or in abnormal clones, wide species hybrids, or artificially inbred lines of outbreeding species.

Spontaneous meiotic breakage has been reported in horticultural clones in *Lilium* (Darlington and Upcott, 1941), *Trillium* (Sparrow and Sparrow, 1950), *Scilla* (Rees, 1952), *Paris* (Haga, 1953), *Dahlia* (Dowrick, 1953) and *Allium* (Darlington and Haque, 1955); in genetic mutants in *Zea* (Beadle, 1932, 1933; McClintock, 1950, 1951, 1953); in inbred *Secale* (Lamm, 1936; Muntzing and Akdik, 1948; Rees, 1955; Rees and Thompson, 1955); and in *Bromus* species hybrids (M. S. Walters, 1950, 1951). In none of these cases does the material constitute part of a natural population. Marquardt (1952) and J. L. Walters (1956), however, have reported spontaneous breakage in natural populations of *Paeonia*. In *Paeonia californica* there is a high frequency of interchange hybridity, and Walters has suggested that fragmentation may be a byproduct of a system where the relatively frequent origin of new structural arrangements has been favoured by selection. Spontaneous breakage must be determined by genotypic unbalance, or by unbalance between the chromosomes and the cytoplasm. It occurs more frequently in meiosis than in mitosis, and Swanson (1958) has suggested that this may be due to a greater vulnerability in meiosis.

We are not aware of any previous records of regular chromosome breakage in a vital germ-line tissue in a sexual perennial species lacking any means of vegetative reproduction. In *Astroloma pinifolium* chromosome diminution must constitute a significant characteristic of the genetic system, and must be balanced against selection. The evolution of such a system must have involved very unusual circumstances, and these have been examined elsewhere (Smith-White, 1960, in press).



Text-figures 34-39.

34, 35. M.2, showing free paired and unpaired fragments, attached fragments, and damaged chromatids. 36. A.2, with a dicentric bridge in one spindle and a sticky (subchromatid?) bridge in the other. 37. A.2, with fragments in the spindles as well as in the outer cytoplasm. 38. A.2, showing misdivision close to a centromere. 39. T.2, with single and paired (dividing?) fragments in the cytoplasm. (× *ca.* 2500.)

2. *The Nature and Time of Breakage.*

Darlington and Haque (1955) point out that the occurrence of free fragments at first metaphase indicates breakage before pachytene, in the premeiotic resting stage, or even in the premeiotic mitoses. Following breakage at pachytene in *Secale* and

Scilla (Rees, 1952, 1955), fragments are held in close association with their parent chromosomes by chiasmata or by coiling. In *A. pinifolium*, free fragments at first metaphase are rare. Most become free only at anaphase, and breakage during or after pachytene must be inferred. Some fragments which appear during the second division may be secondary consequences of other kinds of error, particularly from the formation of partial chiasmata (Darlington and La Cour, 1953).

In *Scilla* (Rees, 1952), *Secale* (Rees, 1955; Rees and Thompson, 1955) and *Allium* (Darlington and Haque, 1955), most, if not all, breakage is B″. In *Vicia* (McLeish, 1953), chemically induced breakage at mitosis is also B″, and is localized in regions of heterochromatin. It is almost always difficult to distinguish between whole chromosome breakage, B″, and isolocus chromatid breakage, 2B′. Darlington and La Cour (1945) and Darlington and Koller (1947) believed that all isolocus sister chromatid breaks result from presplit whole chromosome breakage. Thoday (1953), however, has shown that true isolocus chromatid breakage does occur in mitoses in *Vicia* roots following irradiation.

In *Astroloma pinifolium* most of the fragments visible at first anaphase are single, and their diameters are only equal to or less than that of normal anaphase chromatids. B′ must be inferred. Additional evidence of B′ is found in the occurrence of unequal fragment pairs and in the association of attached and free fragments (Text-figures 21, 23). Where there are paired fragments of equal size, or where homologous chromosomes at opposite spindle poles are both heterozygous for attached fragments (Text-figure 22), it is impossible to distinguish the three theoretical possibilities of B″, isolocus sister chromatid 2B′, or isolocus non-sister homologous chromatid breakage. However, with a high frequency of B′ and with localization of breakage such as is suggested by the fragment characteristics in plant R57/15 (*v. supra*), both sister and non-sister isolocus breakage is to be expected.

The occurrence of B″ or of B′ is related to the time of breakage, the former occurring before, and the latter after pachytene splitting. In *A. pinifolium* most breakage must occur later than the two-strand stage, but the appreciable frequency of isolocus breaks suggests that it may occur at or very close to the moment of splitting. It may therefore be related to errors in chiasma formation. Oehlkers (1953) denies any relationship between chemically induced breakage and chiasma formation, and this must be generally true for breakage of the B″ type. Revell (1953), however, concludes that diepoxide causes breakage at the time of chromosome splitting by a process related to normal chiasma formation. Such breakage might well be restricted to non-sister chromatids.

3. *The Interpretation of Bridge Configurations.*

The bridges which have been observed are clearly not due to inversion hybridity. Some are of simple dicentric structure (Text-figures 27, 36), and are probably due to sister chromatid breakage followed by SR, with either reductional or equational first division chromatid separation, to give first or second division bridges. They could also be due to non-sister breakage and reunion. The infrequency of fragment (i.e., distal) reunion suggests that both SR and NSR proximally may also be rare, contrary to the behaviour demonstrated by Rees and Thompson (1955) in inbred rye. Differences in the frequency of proximal and distal reunion, however, are not uncommon and, together with restriction of neocentric activity to centric chromosomes, have led Darlington (1951, 1956), Rhoades (1951) and Rees (1953) to the view that there is centromere control of both these types of behaviour.

If breakage is related to chiasma formation, some bridges may be due to partial or subchromatid crossing over. Partial chiasmata have been described in *Uvularia* (Darlington and La Cour, 1953) and in *Scilla* (Rees, 1953). Subchromatid chiasmata or subchromatid breakage and reunion could yield two-side-arm bridges similar to those figured in irradiated pollen mother cells in *Trillium* by Wilson, Sparrow and

Pond (1959). In the *Trillium* material there can be no suggestion that the subchromatid breakage is related to chiasma formation, since it can be induced by irradiation at diplotene. In *A. pinifolium* bridge configurations which are suggestive of partial chiasmata or of subchromatid breakage and reunion are illustrated in Text-figures 25 and 26 and in Plate i, figure 11. The "opposed knobs" illustrated in Plate i, figure 12, may be due to breakage of two-side-arm subchromatid bridges. It is possible that some of the bridges in *Astroloma* may be of the subchromatid pseudo-bridge types illustrated for *Trillium*, in which case they could finally separate under anaphase tension without secondary damage. Text-figures 32 and 38 illustrate cases of subchromatid splitting errors close to the centromeres, which support this interpretation.

Attached fragments at first anaphase and at second metaphase may be interpreted as fragments still held in sticky contact with their parent chromosomes, or more probably, as consequences of subchromatid breakage, as described by Levan and Tjio (1948), Kihlman (1951, 1952) and McLeish (1953).

Bridges due to partial chiasmata and to subchromatid breakage and reunion, with the exception of the pseudo-bridges illustrated by Wilson, Sparrow and Pond, and the attached fragments due to subchromatid breakage, would all lead to fragmentation in the pollen grain mitoses. Unfortunately, the cytoplasm in pollen grains of *A. pinifolium* is extremely granular, and the identification of small fragments would be virtually impossible.

4. *Meiotic Irregularities and Variable Pollen Tetrads.*

Where pollen grains remain together in tetrads at maturity, any causes of appreciable pollen death will result in the production of variable tetrads. It is perhaps surprising that, whilst many cases of partial pollen sterility are known, and tetrad pollen occurs in many families, very few examples of variable tetrads are known.

The trinomial square frequency distributions of the five tetrad categories, which is a feature of the behaviour of *A. pinifolium* (Smith-White, 1959*b*), suggests that there is a relationship between VPT production and meiosis. The loss of whole chromosomes, which is an important contributory cause of comparable behaviour in *Leschenaultia* (Martin and Peacock, 1959), is much too infrequent to be a serious cause. Chromosome breakage with the loss of chromatid fragments, on the other hand, is a constant feature of all east coastal plants which have been examined, and most of the pollen mother cells are affected. Fragment loss is obviously associated with VPT production, and a clear but probably not a simple relationship has been demonstrated between fragment frequency and pollen fertility. The nature of this relationship will be considered elsewhere (Smith-White, 1960, in press).

The diversity of kinds of irregularity which occur in the pollen mother cells of *A. pinifolium* suggests that there may be a lack of balance between the chromosomes in division and their immediate environment. There is in fact a very considerable variation in pollen mother cell size at first metaphase, which may indicate a lack of efficient control in the timing of prophase. Darlington and Haque (1955) have shown that change of timing of prophase in *Allium ascalonicum* is responsible for a syndrome of abnormalities including chromosome breakage.

SUMMARY.

Astroloma pinifolium has a pattern of distribution which indicates a relict condition. It has a secondary polyploid genome compared with the basic chromosome number of the genus.

It produces variable tetrad pollen, in which the frequencies of the tetrad categories often conform to the terms of trinomial squares.

Meiosis in the pollen mother cells is abnormal. Failure of bivalent congression, loss and misdivision of univalents, and neocentric activities, are occasionally seen. A regular spindle eccentricity at first metaphase, which is usual in the Styphelieae, is indicative of cytoplasmic polarity.

The most significant irregularity is the presence of chromosome fragments at first anaphase and later stages. There is also a variable frequency of chromatin bridging at both meiotic divisions.

Analysis of fragment characteristics and bridge configurations suggests that (i) fragmentation is due to chromatid breakage, (ii) breakage occurs at or soon after the time of chromosome splitting in pachytene, (iii) some bridges are the result of reunion or of sister reunion, but others are due to subchromatid breakage and reunion or perhaps to errors in chiasma formation, (iv) attached fragments, which are frequent at first anaphase, are also probably the results of subchromatid errors, and may lead to undetected errors in the pollen grain mitoses.

Chromatid breakage is associated with the production of variable tetrad pollen. A comparison of fragment frequency and pollen fertility data indicates a complex rather than a simple relationship. It will be necessary to reconcile the consequences of chromosome breakage with the VPT frequency distributions which are characteristic of the species.

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EXPLANATION OF PLATE I.

1. Mitosis in leaf initial. 2-12. Meiosis in P.M.Cs: 2. Diakinesis, illustrating the lateral displacement of the nucleus. 3. M.1, with two univalents at the upper pole. 4. M.1, showing a bivalent heterozygous for a terminal knob. 5. M.1. Two bivalents and two univalents off the plate. 6. A.1, with laggard chromosomes, a fragment, and a broken bridge. 7. A.1, with one bivalent off the spindle still undivided. 8. One pole of A.1, showing a chromosome heterozygous for an attached fragment. 9. T.1, with one pair of fragments in the equator of the spindle. Other fragments are present, but are out of focus. 10. M.2, with a pair of fragments in the cytoplasm. 11. T.1, with a two-side-arm bridge The connection between the two side arms is extremely thin. Bridges of this type are probably derived from subchromatid breakage and reunion. 12. T.1, with "opposed knobs", or an incomplete bridge. This type of configuration is probably related to the subchromatid bridging illustrated in figure 11. (× *ca.* 2000.)

A NEW TREE-FROG (GENUS *HYLA*) FROM QUEENSLAND.

By Stephen J. Copland.

[Read 27th April, 1960.]

Synopsis.

A new species of the genus *Hyla* is described from south-eastern Queensland, bringing the total number of known forms of Australian hylids to about 45.

Thanks to the courtesy of Dr. J. C. Pearson, Lecturer in Helminthology in the University of Queensland, I have received three specimens of a tree-frog, which appears to be new, and which I accordingly describe as *Hyla pearsoni*, sp. nov.

Hyla pearsoni, sp. nov.

Diagnosis.—Most closely resembles *Hyla gracilenta*, from which it may be distinguished by the following character differences: smaller and much more slender, width of body to total length of head and body, *pearsoni* 24%, *gracilenta* 38%; upper arm coloured, *gracilenta* white; forearm normal, *gracilenta* with large granular plaque-like shield; much smaller finger discs; less webbing between fingers 38%, *gracilenta* 68%; skin smooth, *gracilenta* uniformly and finely granulate and covered with minute pores; dorsum with black flecks, *gracilenta* uniform; thighs brown, *gracilenta* thighs white with purple. These are perhaps the more obvious differences, but the two species differ in a considerable number of other characters.

Description of the Holotype, No. A.C.7043: a male, not quite adult; collected on a branch of Cedar Creek, east of Mt. Glorious, about 20 miles north-west of Brisbane, Queensland, by J. C. Pearson, 8.ix.1958; *c.* 2,000 ft.

Habitus quite slender, triangular, tapering from a broad head to a narrow waist, maximum width of body 7 mm., 24% of total length of head and body (29 mm.), waist 4 mm.; a rather small frog, although only males have been seen and these are almost certainly not quite adult; head subtriangular, a trifle broader than long (10 × 9 mm.); snout short (4 mm.), equal to diameter of eye, sharply truncate when seen from above, almost vertical in profile, extending hardly at all beyond lower lip; canthus rostralis fairly straight and slightly rounded; lores rather convex near lower jaw and mildly concave against canthus rostralis; interorbital width about 1·4 times that of an upper eyelid (3·5 to 2·5 mm.), top of head flat between rather distinct eye bulges; internasal space 2 mm.; diameter of eye distinctly greater than its distance from nostril; tympanum sharply distinct, smooth and almost flush, tilted slightly upward, contained in diameter of eye between two and a half and three times (1·5 to 4 mm.), distance from eye 1 mm.; a sharp, but rather low slightly undulating supratympanic ridge.

Skin of head and body and all exposed dorsal surfaces of limbs practically smooth with a few large scattered warts up to 0·5 mm. in diameter, only about 20 altogether, shared equally over body, head and limbs; there are also a few smaller projections; underside of lower jaw finely granulate with five large warts; belly coarsely granulate with about a dozen quite large warts, a few to 1 mm. across; ventral surfaces of limbs smooth with a very occasional smoothed wart; a small shagreened area under each tympanum; no or only the slightest trace of pectoral fold; anal area granulated with a small flap.

Forelimb inclined to slightness, moderately long (19 mm.), 61% of length of head and body; upper arm distinctly thinner than lower (but nothing to the extent found in *Hyla gracilenta*); a distinct and wide web in the angle of elbow, tapering to wrist, but not far along upper arm; hand 7·5 mm.; finger discs small, elongated, about 0·5 × 1 mm., smaller than tympanum; fingers in ascending order of length, 1, 2, 4, 3; extent of webbing between fingers, 46, 33, 34%, average 38%; no or narrow fringes to fingers; thumb much thickened basally, the second finger also slightly swollen; both the thumb which is opposed and the finger together may be regarded as a unit forming a clasping organ; subarticular tubercles small but fairly distinct; palm shallowly divided.

Hindlimb long and slender, length (45 mm.) 155% of head and body; femur 12 mm., tibia 14 mm., foot 19 mm.; heel reaches to between eye and nostril; toe discs small, about equal to those of fingers, slightly elongated, only about half size of tympanum (0·75–1 to 1·5 mm.); toes in increasing order of length, 1, 2, 3 = 4, 5; extent of webbing between toes, 70, 50, 63, 50%; web does not reach or closely approach any disc; no or extremely narrow fringes to toes; subarticular tubercles small and low, but distinct; sole shallowly divided longitudinally; a small, marginal inner metatarsal tubercle.

Vomerine elevations paired, small, rounded, distinctly separated from each other, and twice more widely from the choanae which they equal in size, each about two-thirds behind line joining posterior borders of choanae; tongue elongated, heart-shaped, shallowly indented posteriorly and grooved dorsally, free behind, rather small, about half width of mouth at angle of jaws; a large opening behind the tongue at each side of the mouth near the angles of the jaw leads into a wide subgular vocal sac.

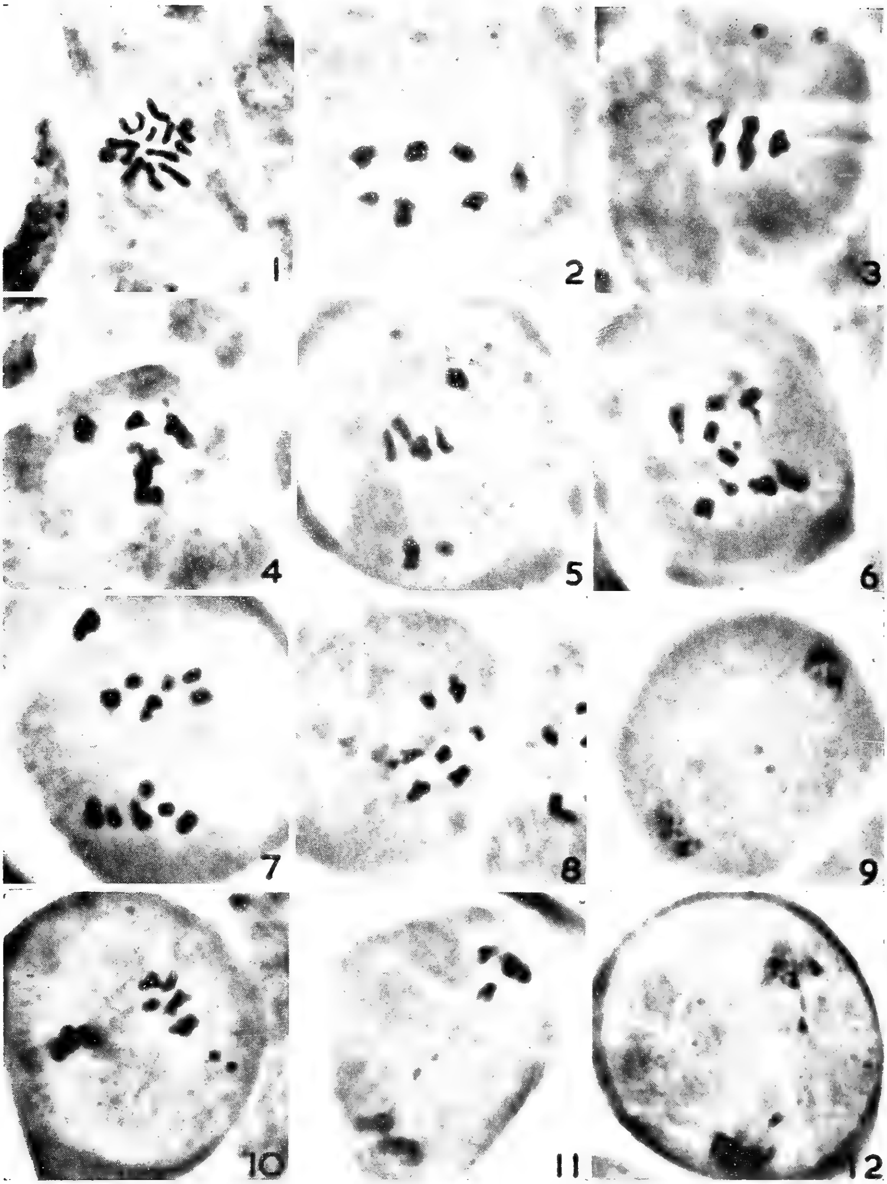
Dorsal surface of body and other exposed surfaces a light leaden blue, sparingly flecked with black; all ventral surfaces whitish, but a wide margin of lower jaw suffused with darker giving a speckled appearance; posterior surfaces of thighs and to some extent those of all limbs bluish-brown; sides brown speckled with white; a wide, more or less uniform, brown line runs from the snout to the eye and is continued back behind the eye to include the tympanum and ends just behind the forelimb; there is a bar of the same colour under the eye; an obscure thin light line runs above the long brown one, and light spots margin the upper jaw.

Variation in Paratypes.—Two paratypes, Nos. A.C.7044–5, locality as holotype, J. C. Pearson, 8.ix.1958, closely resemble the holotype in body proportions and other details. Total lengths 30, 28 mm., maximum body widths 8, 7 mm., waists both 4 mm. A.C.7045 is somewhat smoother and less warty than the other two specimens. The extent of webbing between fingers in both paratypes is barely 33%. Vomerine elevations are much as in the holotype, but nearly entirely behind the choanae in A.C.7044, and only about one-third in A.C.7045. Coloration is fairly uniform, but both paratypes have less black flecking than the holotype.

Field Notes.—Pearson has supplied the accompanying notes with his specimens: "It looks superficially like a small *gracilenta*, and its song is a softer version of that of *bicolor*. I've found it frequently along rainforest streams, but not elsewhere. All of the several dozen frogs which I examined for parasites were males. It appears that both sexes live away from streams between rains, that breeding occurs during or soon after periods of rain, and that the females leave the stream immediately after breeding, while the males hang around for several days. Frogs range from uniform pale green above, through blotchy (freckled) to a uniform sandy brown. The call which I associate with them—I have not seen one singing—is a lower, rustier version of *H. bicolor*—which I have seen singing. In life, the tadpoles are jet black, very plump, and without any markings. Results of field observations in stream in rainforest at Mt. Glorious: 2.ii.1958, no adults, eggs or tadpoles found; 7.iii.1958, egg masses on rocks in stream, tadpoles and a few adults, six collected—five males and one immature female; 2.viii.1958, tadpoles and adult males found; 8.ix.1958, egg masses, well developed tadpoles and many males found; 11.xii.1958, egg masses and well developed tadpoles found; 2.ii.1959, egg masses and tadpoles with hind legs, but no adults; 22.iv.1959, egg masses only found. Laboratory observations: Egg masses collected 1.xii.1958 and brought to laboratory. First tadpoles undergoing metamorphosis by 4.ii.1959, that is 54 days later at summer temperatures. However, tadpoles develop faster in the field, as on 5.ii.1959 there were no tadpoles left in the stream where the eggs were collected."

Pearson also mentions an adult caught in Coomera Creek, at the foot of the Lamington Plateau, in October, 1957.

Remarks.—This inconspicuous little frog falls within the group of Hylidae, AA, with vomerine elevations and fingers at least one-third webbed as defined by Copland (1957—PROC. LINN. SOC. N.S.W., 82 (1): 9–108). The new species has also been compared with actual specimens or descriptions of all species dealt with in the above paper, but does not appear to have close affinity with any one of them. To complete the key given in the paper mentioned above, the diagnosis of *Hyla pearsoni* should be inserted under *H. gracilenta* on page 11.



Astroloma pinifolium. Mitosis in leaf initial.

STUDIES ON THE MODE OF INHERITANCE OF HAJIRA TYPE STEM RUST RESISTANCE AND VICTORIA TYPE CROWN RUST RESISTANCE AS EXHIBITED IN CROSSES INVOLVING THE OAT VARIETY GARRY.

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[Read 25th May, 1960.]

Synopsis.

Studies on the mode of inheritance of stem rust and crown rust resistance to certain races of the pathogens in crosses involving the resistant oat variety Garry and various susceptible varieties showed that Garry comprised a heterogeneous mixture of genotypes. Three factor pairs conditioning stem rust resistance were identified, designated as Rd_1, an independent gene operative against races 2 and 12, and the linked genes Hj_1 and Hj_2 (with a recombination value of 26·69 ± 2·29 crossover units) conditioning seedling resistance to races 2, 10 and 12 and field inoculum. In all, six factor pairs were concerned with crown rust resistance and these were in three linkage groups. Group 1 comprised three genes with the following estimated linkage values:

$$\underset{9{\cdot}59 \pm 1{\cdot}68 \qquad 10\ \text{approx.}}{\underline{Vc_a \qquad Vc_b \qquad V\bar{c}_1}}$$

. Vc_a and Vc_b were complementary genes for seedling resistance, whilst $V\bar{c}_1$ conditioned adult plant resistance only. Linkage group 2 comprised the two genes Vc_2 and IVc_2 with an estimated recombination value of 10 crossover units between them. Vc_2 conditioned seedling as well as adult plant resistance, but was inhibited by IVc_2. Thirdly, $V\bar{c}_3$ was an independent dominant gene for adult plant resistance only. The genes conditioning stem rust resistance were genetically independent of those for crown rust resistance.

Introduction.

Hajira has been used as a source of resistance to oat stem rust, *Puccinia graminis avenae* E. & H., since 1926. The variety was introduced into North America from Egypt (Welsh and Johnson, 1951). This source of resistance has assumed particular importance since it has conferred resistance against all the existing races in North America and Australia.

Originally Hajira was believed to be resistant only to races 1, 2, 3, 5 and 7, and subsequently also to race 12, which was discovered later. In 1936, however, certain advanced generation lines from the cross Hajira × Joanette were tested in the glasshouse to race 6 and certain other races (Welsh, 1936). Resistance to race 6 was observed at low and intermediate temperatures in a few lines. These lines were uniformly resistant to race 8 also and this resistance was thought at that time to have been obtained through transgressive segregation. History of the utilization of this source of resistance has been reviewed by Welsh and Johnson (1951, 1954). Their studies in 1951 indicated that Hajira itself contributed genes for resistance to all the races of stem rust. Four hundred single plant selections of Hajira were tested and 12% showed resistance to all the known races in Canada.

Victoria was introduced into the United States from South America in 1927 (Stanton and Murphy, 1933) and its resistance was incorporated into economic varieties by 1940 (Stanton and Coffman, 1943). To combine both stem rust and crown rust resistances into one variety, Hajira and Victoria were used in a three-way cross, Victoria × (Hajira × Banner) × Victory, made in 1930 in Canada. Promising rust resistant selections were made and of them a few, viz., R.L.1681, R.L.1692 and R.L.2123, are worthy of mention in the present connection. R.L.1692 and R.L.2123 were later named Garry and Rodney respectively.

The variety Garry was originally introduced into Australia under the designation R.L.1692 and later as Garry. Both strains proved to be resistant to all the known races of stem rust in Australia and to all the races of crown rust until 1952, when a race attacking Victoria was identified (Baker and Upadhyaya, 1955). Workers abroad found that the crown rust resistance of Victoria type was associated with susceptibility to Victoria blight. This disease has been reported in Queensland (Miles and Rosser, 1954) but has not assumed any serious proportions in Australia. Due to its resistance to all the races of stem rust Garry still remains a valuable source of rust resistance.

Associated with a sound breeding programme, a knowledge of the mode of inheritance of rust resistance is very essential. The present studies were undertaken with this object in view.

LITERATURE REVIEW.

Studies on the mode of inheritance of Hajira type of stem rust resistance have been reported by Welsh (1931), Gordon and Welsh (1932), Litzenberger (1949), Kehr and Hayes (1950), Kehr *et al.* (1950), Welsh and Johnson (1951, 1954) and Osler and Hayes (1953).

Welsh (1931) and Gordon and Welsh (1932) reported a monofactorial inheritance of stem rust resistance to races 1, 2, 3, 5 and 7. This was independent of the Joanette factor for resistance to race 4. Foote (quoted by Kehr *et al.*, 1950) and Osler and Hayes (1953) reported that a single factor governed resistance to races 7 and 8 in selections from the crosses Hajira × Joanette and Victoria × (Hajira × Banner). Kehr and Hayes (1950) had indications of the presence of more than one factor for resistance to race 6 in the cross Hajira × Joanette. They obtained a near 13:3 ratio of resistant and segregating to susceptible F_3 families. Litzenberger (1949) found a trigenic segregation in the cross Hajira × Joanette selection × Mindo, against race 8. One of these genes was allelic with the White Russian factor for resistance to races 2 and 8. All the three factors were independent.

Welsh and Johnson (1951) obtained divergent results with different selections from crosses involving Victoria × (Hajira × Banner). Resistance to race 8 in Garry and Canuck was conditioned by a single factor. In the cross of Canuck it was revealed that the same factor conditioned resistance to other races also. Two independently inherited genes in R.L.1681 conditioned resistance to race 8. In the field, one of these genes conditioned resistance to all the twelve races of stem rust, viz., 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12 and 13. Later studies in 1954 revealed the presence of three independent genes in Garry. Gene "A" conditioned resistance to races 1, 2, 3, 5, 7, 7A and 12; gene "B" to the same races as above except 7A; and gene "C" to races 4, 6, 8, 10, 11 and 13. Other varieties supposed to possess these various factors were: gene "A"—Ajax, Richland, Green Russian and R.L.1574 (selection from Victoria × (Hajira × Banner); gene "B"—Canuck, R.L.1225 (sister selection of R.L.1574), R.L.1574 and Rodney (R.L.2123) and gene "C"—Canuck, R.L.1225, R.L.1574 and Rodney.

The inheritance of the crown rust resistance of Victoria or its derivatives has been studied by Smith (1934), Waterhouse (1939), Weetman (1942), Murphy and Meehan (1946), Litzenberger (1949), Poehlman and Kingsolver (1950), Griffiths (1953) and Welsh, Peturson and Machacek (1954).

The studies by Smith revealed that either more than a single factor was involved or that susceptible types were eliminated due to some type of sterility. From the F_2 studies in the cross Algerian × Victoria against race 6, Waterhouse (1939) concluded that three independent factors governed resistance to this race. Weetman (1942) observed that resistance to races 1 and 45 in Victoria was governed by a single factor. Murphy and Meehan (1946) and Litzenberger (1949), working with highly rust resistant derivatives of Victoria, found only one gene to be responsible for resistance. Griffiths (1953) also reported the presence of only one gene in Victoria for its hypersensitive type of reaction. The observations of Poehlman and Kingsolver (1950), however, indicated the operation of a second factor conditioning an intermediate type of resistance to races 1 and 45. These lines were resistant to Victoria blight. Welsh, Peturson and Machacek (1954) studied crosses involving Garry and R.L.1987 and concluded that the hypersensitive reaction to races 4, 5, 34A and 57 was governed by a single dominant factor. This was linked with susceptibility to Victoria blight.

Resistance to races 1, 2, 3, 6, 24, 34, 38 and 45 was conditioned by three dominant factors. Gene "A" was epistatic to gene "B" and conditioned strong resistance. Gene "B" conditioned susceptibility and was epistatic (inhibitor) to gene "C" which produced a weaker type of hypersensitive reaction and was associated with susceptibility to Victoria blight.

Independence of the factors for stem rust resistance both in Laggan and in Hajira × Joanette selection and Victoria type of crown rust resistance was reported by Waterhouse (1939) and Litzenberger (1949) respectively.

EXPERIMENTAL PROCEDURE.

(*a*) *Materials.*

In 1953 F_2 embryos from certain F_1 plants of the 1952 harvest were made available. Twenty F_1 plant progenies of the cross Algerian × Garry and fifteen of the cross Fulghum × Garry were included. A further four F_0 seeds were from the cross Burke × Garry. The former crosses were made with Garry accession No. O.259 and the latter with No. O.288.[1] Further crosses were attempted by the senior author in 1953 between Laggan and Garry, Gothland and Garry and Joanette and Garry. A history of the parents other than Garry is as follows:

Algerian (O.9)—a selection made by Pridham in 1918 from a hybrid between Algerian and Red Rustproof.

Fulghum (O.54)—an introduction from North America.

Burke (O.106)—a selection from Kherson by Pridham.

Laggan (O.78)—a selection from Kelsall by Pridham.

Gothland (O.230)—introduced from the U.S.A. as an oat smut differential variety.

Joanette (O.233)—introduced from the U.S.A. as an oat smut differential variety. This variety gave a susceptible reaction to races 8 and 10, instead of the "X" type of mesothetic reaction characteristic of Sevenothree and another Joanette strain (O.45) at low temperatures.

The crosses of Garry with Laggan, Gothland and Joanette were made on single plant selections of Garry. Rust races used were:

Stem rust races—2, 10 and 12.

Crown rust races—203Anz.1, 226Anz.1, 230Anz.1, 237Anz.1, 237Anz.4 and 286Anz.1.

The races used in the present studies were either maintained at Sydney University or isolated from field collections. The position with regard to the races of crown rust present in Australia has been discussed by Baker and Upadhyaya (1955). The races of crown rust mentioned above correspond to races 57, 6, 46 (or 103), 1, 6 and 6 respectively on the old set. Since all the races of crown rust, except race 237Anz.4, were classified as Anz.1 types, it is proposed to denote them in subsequence reference by their international numbers only. Race 237Anz.4 will be denoted as 237–4.

(*b*) *Methods.*

The Technique of Inoculation.—F_1 and F_2 seedlings were inoculated by means of an inoculating needle. In F_2 and F_3 tests occasionally heavily rusted pots were brushed onto moistened and rubbed seedlings. The period of incubation varied from about 20 hours in summer to 36 hours in the winter months.

Data on reaction type were usually recorded after 8 to 10 days in the summer and after about 15 days in the winter. When the same hybrid material was studied to more than one race the seedlings were clipped back to about 2½ inches in height and all the leaves showing any pustule development were removed. After 3–4 days with the emergence of the new leaves, inoculation with a second race was carried out. Sometimes a mixture of races was used on the secondary leaves. The mixture of races involved using heavily infected pots of each race and dusting the spores onto the leaves of the hybrid material.

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[1] Numbers refer to Sydney University Oat Variety Collection Number.

During the summer months the temperature in the glasshouses frequently reached as high as 90–95°F. During the winter months the temperatures were occasionally as low as 40°F. To overcome these extremes use was made of a light and temperature controlled room from time to time. Also in the winter months the glasshouses were heated to raise the temperature. The temperature in the control room was kept constant at 68 ± 2°F.

In the adult stage in the field, multiplication of the inoculum of stem rust was done by the hypodermic syringe method and that of crown rust by brushing heavily infected leaves of natural inoculum present in the field. On differential tests this natural inoculum during the 1953 and 1954 seasons showed the presence of races 203, 226 and 237 and some of their subraces. Race 10 of stem rust was found to be the prevalent one during this period. Inoculations in the evening followed by overhead irrigation in the morning usually secured a heavy infection of the hybrid material.

In all tests use of spreader rows of Algerian and Burke for crown rust and of Bond and Victoria for stem rust was made. Tests on the adult plants in the F_1 generation in some of the crosses were undertaken in the University plot where natural infection was not found to any appreciable extent. The plants were hypodermically injected with the inoculum of each appropriate race separately and rust reactions recorded on different tillers.

Recording of Rust Reactions.—In the seedling stage reaction types were recorded according to the scales suggested by Stakman, Levine and Bailey (1923) for stem rust and by Murphy (1935) for crown rust. In all tests parental lines were also inoculated; this permitted more critical classification of the intermediate types of reactions in the hybrid material. The different reaction categories designated were as below.

Reaction.	Infection Type.		Symbol.
	Seedling.	Adult.	
Immune	0;	0	I
Highly resistant	; to 1=	1−, 1	R
Resistant	1, 1n, 1+, 2−	1+, 2	R
Moderately resistant	2n, 3–cn	1 to 3c	MR
Moderately susceptible	2+, 2++, 3	3c to 3+	MS
Susceptible	3+c, 4	3+, 4	S

In the F_3 generation, lines were noted as pure breeding or segregating. In the segregating lines, in some cases there was preponderance of susceptible plants and such lines were designated as S:R; others were written as R:S where the number of resistant plants were in excess. In the seedling stage an average of 20 plants in each F_3 line were tested and in the adult stage an average of 40 plants were tested in rows 4′–6′ long sown one foot apart.

In some cases in order to study the F_3 behaviour of F_2 plants only representative samples from each class of F_2 reactions were tested. In order to calculate the expected frequencies in the F_3 in such cases the observed frequencies were calculated to the original F_2 class frequencies.

Designation of Factors for Resistance.—The following method of gene nomenclature was followed in the present paper. Two letters were taken to abbreviate the name of the variety originally found to possess the particular gene (or the most common variety possessing the gene). Complementary factors were symbolized by alphabetical suffixes and individual genes by numerical suffixes. Inhibitor factors were indicated by use of "I" with the suffix of the gene it inhibited. Genes for adult plant resistance only were symbolized by a line over the gene symbol.

EXPERIMENTAL RESULTS.

(A) *Studies on Stem Rust Resistance.*

(*a*) F_1 Reactions.

In Table 1 are given the parental and F_1 reactions of the crosses of Garry with Algerian, Fulghum, Burke, Laggan, Gothland and Joanette, in tests against races 2, 10 and 12 in the seedling stage, in the adult stage (where specifically inoculated) and in the field.

From this table it will be seen that certain seedlings of the crosses Algerian × Garry and Garry × Gothland were not infected and gave (0) type reactions. Five seedlings of the cross Algerian × Garry gave a reaction more resistant than Garry, and four gave a susceptible reaction. Similarly three seedlings out of eleven in the cross Fulghum × Garry gave a susceptible reaction. One seedling each in the crosses Garry × Gothland and Garry × Joanette gave a less resistant reaction than Garry. Out of a total of 37 seedlings of the various crosses tested in the seedling stage to any one of the three races 20 seedlings gave reactions of Garry type indicating complete dominance of the resistance of Garry. Variations in reaction types between fleck (;) and (2) were probably due to variation in environmental conditions. In the adult tests also the reaction of Garry type seemed in general to be fully dominant. However, three F_1 plants out of twelve tested gave a less resistant reaction.

TABLE 1.

Reactions Against Races of Stem Rust of the F_1s and the Parents Used in Crosses Involving Garry.

Parent or Cross.	Seedling Reaction Types to Races.			Adult Plant Reactions to Races.			Field Reactions.
	2	10	12	2	10	12	
Garry[1]	(1 – 2 –) (98%)	(1 – 2 –) (90%)	(1 – 2 –) (98%)	R	MR	R	R (90%)
Algerian	(3 + c)	(3 + c)	(3 + c)	S	S	S	S
Algerian × Garry F_1	4/5(;) 1/5(3 +)	1/5(0) 1/5(;) 3/5(1)	1/5(0) 1/5(1) 3/5(3 +)	—	—	—	—
Fulghum	(3 + c)	(3 + c)	(3 + c)	S	S	S	S
Fulghum × Garry F_1	3/3(1)	2/4(1) 2/4(4)	3/4(1) 1/4(4)	—	—	—	—
Burke	(1)	(4)	(1)	—	—	R	S
Burke × Garry F_1	—	2/2(2 –)	—	—	—	—	4/4R
Laggan	(1)	(4)	(1)	R	S	R	S
Laggan × Garry F_1	—	2/2(2 –)	2/2(2 –)	R	1/2R 1/2MR	R	1/2R 1/2MR
Gothland	(3 + c)	(3 + c)	(3 + c)	S	S	S	—
Garry × Gothland F_1	—	1/2(0) 1/2(2)	1/1(2 –)	R	—	—	—
Joanette	(3 + c)	(3 + c)	(3 + c)	S	S	S	S
Garry × Joanette F_1	1/1(2)	—	1/1(2 –)	R	2/2R	1/2R 1/2MR	—

[1] Garry O.259 was heterogeneous against these races. Garry O.288 was resistant. Garry single plant selections 3 and 8 were resistant ((1) type) and moderately resistant ((2 –) type) to race 10, respectively.

(*b*) F_2 Segregation.

Since certain F_1 seedlings gave a susceptible reaction, progenies of the different F_1 plants were tested separately in the F_2. Progenies of F_1 plant nos. 5, 7, 8, 9, 12, 13, 19 and 20 of the cross Algerian × Garry and nos. 7 and 10 of the cross Fulghum × Garry gave only 11 resistant plants out of 1,019 tested to any one of the three races used. Progenies of some of these F_1 plants segregated for resistance to crown rust, and the F_1 plants were morphologically alike indicating their hybrid nature. This small percentage of resistant plants observed could, therefore, be due to natural crossing.

Data on the progenies of other F_1 plants indicating the presence of one or more dominant genes are presented in Tables 2, 3 and 4.

It will be seen from Table 2 that the families of these F_1 plants were susceptible to race 10 but segregated for behaviour to races 2 and/or 12. This indicated the operation of a factor for resistance to races 2 and/or 12 only. Out of a total of 463 plants tested against these races (91 plants tested to race 2 in the cross Fulghum × Garry were also tested to race 12 and are not taken into account) 136 were found to be susceptible. A fit to a 3:1 ratio was not very satisfactory (Chi-square for 1 d.f. = 4·700; P value = 0·05–0·02). Later studies, however, confirmed the operation of a single gene against these races. In the field race 10 was most prevalent.

TABLE 2.

Segregation in the Progenies of Certain F_1 Plants of the Crosses Algerian × Garry and Fulghum × Garry, Indicating the Operation of a Single Factor for Resistance to Races 2 and 12 Only.

F_2 Reaction.	Algerian × Garry. F_1 plant no. 1.		Fulghum × Garry.					
			F_1 plant no. 5.			F_1 plant no. 11.		
	Race 2	Race 10	Race 2	Race 12	Field.	Race 2	Race 12	Race 10
Resistant	29	0	98	131	0	66	69	2
Susceptible ..	14	60	39	54	53	25	29	79
Total	43	60	137	185	53	91	98	81

Certain progenies of F_1 plants indicated the operation of linked genes against all the races and in the field. These data are presented in Table 3.

From the data presented in Table 3 it will be seen that out of a total of 3,096 plants tested to the different races 423 were found susceptible. This gave an over-all ratio of 6·32 resistant to 1 susceptible. A heterogeneity test by the method of Brandt and Snedecor (Fisher, 1936) indicated that the data were homogeneous. Chi-square

TABLE 3.

Segregation in the Progenies of Certain F_1 Plants in Crosses Involving Garry Indicating the Operation of Duplicate Linked Factors Against Races 2, 10, 12 and for Field Behaviour.

Cross and F_1 plant no.	Race Used.	F_2 Reaction.		Ratio of R : S.	Chi-square $\left(\frac{D^2}{I}\right)$	Probability.
		Resistant.	Susceptible.			
Algerian × Garry—						
2	2	96	11	8·73 : 1	0·9966	0·5 –0·3
	12	237	38	6·24 : 1	0·0341	0·9 –0·8
	10	175	18	9·72 : 1	3·1313	0·1 –0·05
	Field	184	21	8·76 : 1	1·9556	0·2 –0·1
4	2	208	37	5·62 : 1	0·5604	0·5 –0·3
	12	60	11	5·45 : 1	0·2450	0·7 –0·5
	10	122	17	7·18 : 1	0·1792	0·7 –0·5
	Field	111	25	4·44 : 1	2·5385	0·2 –0·1
6	2	53	5	10·60 : 1	1·3186	0·3 –0·2
10	10[1]	11	3	3·67 : 1	0·2852	0·7 –0·5
11	2	77	8	9·63 : 1	1·3223	0·3 –0·2
14	Field	58	11	5·27 : 1	0·3501	0·7 –0·5
15	Field[1]	16	2	8·00 : 1	0·0032	0·98–0·95
17	Field	47	3	15·67 : 1	2·9281	0·1 –0·05
18	Field[1]	13	2	6·50 : 1	0·00001	1·00–0·99
Fulghum × Garry—						
3	Field[1]	20	3	6·67 : 1	0·0031	0·98–0·95
6	12	54	6	9·00 : 1	0·6685	0·5 –0·3
9	10[1]	15	2	7·50 : 1	0·0194	0·9 –0·8
12	2 & 12	38	7	5·43 : 1	0·1653	0·7 –0·5
	10	198	35	5·66 : 1	0·4837	0·5 –0·3
13	Field	63	15	4·20 : 1	1·9552	0·2 –0·1
14	Field	44	4	11·00 : 1	1·2370	0·3 –0·2
15	10	68	13	5·23 : 1	0·4456	0·7 –0·5
	Field	158	29	5·85 : 1	0·2070	0·7 –0·5
Garry × Gothland						
2	10	183	35	5·29 : 1	1·2042	0·3 –0·2
5	2	78	11	7·09 : 1	0·0912	0·9 –0·8
Garry × Joanette						
2 and 3	10	159	26	6·12 : 1	0·3656	0·7 –0·5
3 and 4	10	127	25	5·08 : 1	1·0993	0·3 –0·2
Total	.. ..	2673	423	6·32 : 1	0·1295	0·8 –0·7

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[1] Yates' correction factor applied.

values for a monogenic and a digenic segregation (3:1 and 15:1) were 212·3 and 272·1 respectively, indicating very large deviations. This intermediate ratio, therefore, suggested the operation of linked duplicate factors.

The operation of a gene for resistance to races 2 and 12 only has already been indicated in the progenies of certain F_1 plants. Further evidence of the presence of this gene was obtained from the segregations in the progenies of certain other F_1 plants. The data are presented in Table 4.

Progenies of three F_1 plants of the cross Fulghum × Garry showed ratios highei than 6·32:1 or 15:1. An aggregate of these three plants, viz., 3, 8 and 15, gave a ratio approximating 31·6:1. Based on the expected segregation of two linked factors and the third factor for resistance to races 2 and 12, the observed ratio was close to the expected ratio of 28·8:1. The expected ratio of 15:1 in the case of F_1 plant 1 was deduced from F_3 studies made later. This ratio indicated the operation of only one of the two linked duplicate factors independent of the factor for resistance to races 2 and 12.

TABLE 4.

Segregation in the Progenies of Certain F_1 Plants in Crosses Involving Garry Indicating the Operation of the Gene for Races 2 and 12 Only in Addition to the Gene or Genes for Resistance to All the Races.

Cross and F_1 plant no.	Race Used.	F_2 Reaction.		Ratio of R : S.	Expected Ratio.	Probability.
		Resistant.	Susceptible.			
Fulghum × Garry						
1	2	171	18	9·50 : 1	15 : 1	0·1–0·05
3	2[1]	97	1	97·00 : 1	96·64 : 3·36	0·5–0·3
8	12	140	7	20·00 : 1	96·64 : 3·36	0·3–0·2
15	12[1]	79	2	39·50 : 1	96·64 : 3·36	0·9–0·8
Burke × Garry	12	354	—		No seg.	
	10	96	26	3·70 : 1	3 : 1	0·5–0·3
	Field	188	63	2·98 : 1	3 : 1	1·0–0·99

[1] Yates' correction factor applied.

In the cross Burke × Garry it will be observed that there was no segregation against race 12 and monogenic segregation against race 10 and in the field. This indicated the presence of a common factor in Garry and Burke for resistance to races 2 and 12 (since Burke was resistant to these two races). A monogenic segregation ratio against race 10 indicated the operation of one of the two linked duplicate factors. In another cross between Garry and Laggan 164 plants were tested against race 12 and of these 10 were found to be susceptible. Since Laggan possessed the gene for resistance against races 2 and 12, Garry single plant selection 8 (which was used in the cross with Laggan) contributed the other gene. F_3 studies to be reported later showed that the gene from Garry conditioned resistance to race 10 also and was independent of the gene in Laggan.

(*c*) Breeding Behaviour in the F_3 Generation.

F_2 progenies of certain F_1 plants indicated the operation of duplicate linked factors for resistance to all three races. F_3 behaviour was studied in the progenies of F_1 plant nos. 6 and 17 of the cross Algerian × Garry and nos. 4 and 8 of the cross Fulghum × Garry. The data are presented in Table 5. Breeding behaviour of 622 resistant plants from F_1 plant progenies indicating operation of duplicate linked factors were also studied to the different races.

In order to calculate the percentage recombination between the linked factors a combined analysis of the F_2 and F_3 data was undertaken utilizing the data presented in Tables 3 and 5. The derived maximum likelihood expression was 2673 Log. $(3+2p-p^2)$ + 455 Log. $(1-2p+p^2)$ + 110 Log. $(1+2p-p^2)$ (Mather, 1938).

Maximization with respect to "p" gave a value of 0·266884 and the variance of "p" calculated from the equation $\frac{1}{s^2p} = \frac{d^2L}{dp^2}$ was ± ·0229. Thus a recombination value of 26·69 ± 2·29 was indicated. On this basis the expected frequencies in the F_2 generation

TABLE 5.

F_3 Reactions of F_2 Plants from the Progenies of Certain F_1 Plants in the Crosses Algerian × Garry and Fulghum × Garry Indicating the Operation of Two Linked Duplicate Factors Only.

(Expected behaviour, 36·56 : 50·00 : 13·44 for Res. : Seg. : Sus. respectively.)

Cross and F_1 plant no.	Race Used.	F_3 Reactions.			Total.	Probability.
		Resistant.	Segregating.	Susceptible.		
Algerian × Garry						
6	12	33	43	11	87	0·98–0·95
17	10	21	22	3	46	0·3–0·2
Fulghum × Garry						
4	10	21	31	7	59	0·9 –0·8
8	10	35	39	11	85	0·7– 0·5
Total	..	110	135	32	277	0·5 –0·3
Lines from resistant F_2 plants only	..	285	377	—	622	0·7 –0·5

were 86·56:13·44 (6·44 Res.:1 Sus.) and in the F_3 were 36·56:50·00:13·44 (Res.:Seg.:Sus.). The repulsion phase heterozygotes were included in the segregating class. For determining the heterogenity Chi-squares for the combined data the equation Chi-square $= \frac{D^2}{I}$ was used. Here "D" was the deviation from the expected and "I" the information about "p". "I" was calculated as the second derivative of the logarithmic likelihood expression. The total Chi-square value was 26·8087 for 30 d.f. The probability value between ·5 and ·3 indicated a good agreement of the data with the hypothesis.

It was observed that the segregation of some progenies in F_2 indicated the additional operation of the factor for resistance to races 2 and 12 only. The breeding behaviour of such progenies is given in Table 6.

It will be seen from Table 6 that in F_1 plant nos. 1 and 2 of the cross Fulghum × Garry and in the crosses Burke × Garry and Laggan × Garry a single gene was responsible for resistance to race 10. In the former two F_1 plants two factors conditioned

TABLE 6.

F_3 Reactions in the Crosses of Garry Indicating the Presence of the Additional Gene for Resistance to Races 2 and 12, and of One or Both Factors for Resistance to Race 10.

Cross and F_1 plant no.	Race Used.	F_3 Reactions.			Total.	Expected Ratio.	Probability.
		Resistant.	Segregating.	Susceptible.			
Fulghum × Garry							
1 ..	12	25	32	—	57	7 : 8	0·7 –0·5
	10	6	13	6	25	1 : 2 : 1	0·98–0·95
2 ..	2	14	20	1	35	7 : 8 : 1	0·7 –0·5
	12	11	16	—	27	7 : 8 : 1	0·5 –0·3
	10	13	23	10	46	1 : 2 : 1	0·9 –0·8
3 ..	2	33	15	2	50	(*a*)[1]	0·98–0·95
	12	99	36	3	138	(*a*)	0·5 –0·3
	10	19	28	6	53	(*b*)[1]	0·9 –0·8
8 ..	2	18	9	2	29	(*a*)	0·9 –0·8
	12	17	10	2	29	(*a*)	0·9 –0·8
	10	35	39	11	85	(*b*)	0·7 –0·5
9 ..	2	10	6	—	16	(*a*)	0·98–0·95
	12	11	6	—	17	(*a*)	1·0 –0·99
	10	6	8	2	16	(*b*)	1·0 –0·99
Burke × Garry							
1 and 2 ..	10	50	104	47	201	1 : 2 : 1	0·9 –0·8
Garry × Laggan							
1 and 2 ..	10	19	46	20	85	1 : 2 : 1	0·8 –0·7

---

[1] The ratios expected in (*a*) and (*b*) were 65·55 : 31·09 : 3·36 and 36·56 : 50·00 : 13·44 respectively.

resistance to races 2 and 12. In the F_2 segregation reported earlier in the crosses of Garry with Laggan and Burke the operation of the gene for resistance to races 2 and 12 was evident.

F_3 reactions in the F_1 plant progenies 3, 8 and 9 of the cross Fulghum × Garry clearly indicated the operation of three factors against races 2 and 12 and of two linked factors against race 10. Since for reactions to races 2 and 12 the plants heterozygous for the three factors (both in coupling and in repulsion phases), which are about 37·5% of the lines heterozygous for reactions to race 10, are expected to show less than one susceptible plant in 30 plants, such lines may not be realized in F_3 tests with about 20 seedlings. This class was, therefore, included with the resistant class for working out the expected ratio against races 2 and 12.

TABLE 7.

Relationship between Reactions to Different Races on Identical F_2 Seedlings.

Reactions to Race 12.	Reactions to Race 2.		Reactions to Race 10.		Field Reactions.	Reactions to Race 10.	
	Resistant.	Susceptible.	Resistant.	Susceptible.		Resistant.	Susceptible.
Resistant ..	337	2	217	3	Resistant ..	94	—
Susceptible	3	53	—	27	Susceptible	—	24

(*d*) Relationship of Reactions to Different Races.

(i) F_2 vs. F_2: In Table 7 are given the reactions against two races obtained on the same F_2 plants of the various crosses combined together.

It will clearly be seen from the data presented in Table 7 that the reactions to races 2, 10 and 12 were governed by the same gene. Out of 642 plants studied to these races, only eight plants did not conform to their original reactions. They were resistant to one race, but susceptible to the other. They were probable errors in classification or tagging. The reactions to race 10 and reactions in the field were also perfectly correlated, indicating the operation of the same factor. In the progeny of F_1 plant no. 15 of the cross Fulghum × Garry it was observed that out of 78 plants resistant to race 12, 11 plants were susceptible to race 10. Two plants were susceptible to both races. This indicated the operation of the additional factor for resistance to races 2 and 12 only.

TABLE 8.

Breeding Behaviour of F_3 Lines from F_2 Plants Classified for Behaviour to Different Races of Stem Rust.

F_3 Behaviour to Races 2 or 12.	F_2 Reaction to Races 2 or 12.		F_2 Reaction to Race 10 or in the Field.	
	Resistant.	Susceptible.	Resistant.	Susceptible.
Resistant	194	(1)	31	3
Segregating ..	146	(1)	19	11
Susceptible	(1)	37	—	4
Race 10.				
Resistant	61	(1)	40	—
Segregating ..	82	(1)	44	(1)
Susceptible	16	7	—	10

Lines shown in brackets were those not expected.

(ii) F_2 vs. F_3: Progenies of a few selected F_1 plants were used for the study of their correlated F_2 and F_3 reactions. The results are presented in Table 8.

It will be seen from Table 8 that only progenies of 6 F_2 plants out of 711 classified did not behave as expected. These were almost certainly errors in classification or labelling. Similar minor errors were noticed in the behaviour of the F_2 generation. The operation of the gene for resistance to races 2 and 12 only was again noticed. Out of 18 plants classified as susceptible to race 10, 3 gave fully resistant progenies, 11 gave segregating progenies and 4 gave susceptible progenies. A good fit to a 1:2:1 ratio was obtained. Similarly 16 plants classified as resistant to race 2 or 12 gave susceptible progenies to race 10 and 7 were susceptible to both. A fit to a 3:1 F_2 ratio was good.

(iii) F_3 vs. F_3: It was indicated earlier that, due to the operation of three factors for resistance to races 2 and 12 in some lines, less than one plant in 30 was expected to be susceptible. In tests with the two races on separate seedlings such lines may show susceptible reactions to one or other race. Out of 125 lines tested to both races from such material, 56 were resistant to both, 46 were segregating and 6 were susceptible. However, 8 lines resistant to race 12 showed segregation to race 2 and 9 lines showed a reciprocal behaviour. From the progenies of certain F_1 plants showing the presence of the gene for resistance to races 2 and 12 and also genes for resistance to race 10, 32 lines susceptible to race 10 were tested for their reactions to races 2 and 12. In these, 8 resistant, 17 segregating and 7 susceptible lines were observed. The good fit to a 1:2:1 ratio indicated the independence of this factor from the factors for resistance to all races.

Notes taken on the F_3 lines for stem rust reactions in the field were not satisfactory because of a low incidence of stem rust in this material. It was, however, observed that all lines giving a susceptible reaction to race 10 were susceptible in the field with about 15% infection. These results with earlier reported F_2 studies indicated the operation of the same linked factors for adult plant resistance.

(*e*) Designation of Factors for Resistance to Stem Rust.

It has been shown that Garry possessed a gene for resistance to races 2 and 12 only, which was common with the factor in Burke. Since Burke is a sister selection of Richland (a widely cultivated variety known to possess this factor) it is proposed to designate this factor as "Rd_1". The variety Laggan also possessed the same gene. The two linked factors possessed by Garry for resistance to races 2, 10 and 12 were derived from Hajira and it is proposed therefore to designate them as "Hj_1" and "Hj_2". A recombination value of 26·69 ± 2·29 crossover units was calculated between these genes.

(B) *Studies on Crown Rust Resistance.*

(*a*) F_1 Reactions.

In Table 9 are given the reactions of the F_1 plants of the crosses of Garry when tested with different races of crown rust. The parental reactions are given below the F_1 reaction types. Reactions to the different races in the adult stage and in the field are also given in the table.

One seedling in the cross Burke × Garry tested against race 226 and two seedlings in the cross Garry × Joanette tested against race 203 did not show any infection. In other cases either full or partial dominance of resistance was noted in the seedling as well as the adult stage, with the exception of two seedlings of the cross Algerian × Garry and one seedling of the cross Fulghum × Garry. These three seedlings gave a moderately susceptible reaction of (2+) type.

(*b*) F_2 Segregation.

It was observed from the behaviour of certain progenies of F_1 plants in tests against stem rust that different genotypes operated, thereby indicating genetic diversity in different single plant selections of Garry. Seedling tests with different races of crown rust and field behaviour showed that all the F_2 progenies of F_1 plant nos. 5, 8 and 9 of the cross Fulghum × Garry and plant no. 19 of the cross Algerian × Garry were susceptible. In the seedling stage progenies of F_1 plant nos. 1, 7, 11 and 15 of the cross Fulghum × Garry and of F_1 plant nos. 1, 4 and 14 of the cross Algerian × Garry were all susceptible. Of these, however, plant nos. 4 and 14 of the latter cross and no. 15 of the former segregated for crown rust behaviour in the field. The data for seedling and adult plant tests are presented in Tables 10 and 11 respectively.

From the F_3 behaviour of certain F_2 plants reported later it was concluded that an inhibitor factor suppressed the dominant action of a factor for resistance and that these were linked with approximately 10% recombination. On this assumption and with the operation of another single factor, the expected ratio of resistant to susceptible plants was 3·2:1. Although the presence of the inhibitor group could not be ascertained in the progenies of all F_1 plants shown in the table, comparisons of observed and expected figures are based on its presence. It will be observed that a satisfactory fit to a 3·2:1 ratio was not obtained in all individual cases and was particularly very poor for the aggregate of all crosses. The overall ratio of R:S plants observed was 2·62:1, which was less than a monofactorial ratio and greater than a bifactorial ratio of complementary dominant factors. This suggested a linkage between two such complementary factors in coupling phase. A heterogeneity test gave a Chi-square value of 12·38 for 20 degrees of freedom between individual segregations within crosses and of 3·69 for 5 d.f. between crosses. The probability was in no case less than ·5, indicating homogeneity of the data. In the last column of the table are given the probabilities for the different F_2 populations and totals based on the assumption of the action of two complementary dominant factors linked with a recombination value of 9·59%. This value was derived as later reported from the combined analysis of F_2 and F_3 data by the method of maximum likelihood. In no case was the probability less than ·10, indicating good agreement between observed and expected results.

TABLE 9.

Reactions of F_1s and Parents Used in Crosses Involving Garry Tested Against Different Races of Crown Rust.

Parent or Cross.	Seedling Reactions to Races.		Adult Plant Reactions to Races.				Field.
	203	226	203	226	237	237–4	
Algerian × Garry ..	—	3/5 (1n) 2/5 (2+)	—	—	—	—	—
Fulghum × Garry ..	—	3/4 (1n) 1/4 (2+)	—	—	—	—	—
Burke × Garry ..	2/2 (3c)	1/4 (0) 1/4 (1n) 2/4 (1+n)	—	—	—	—	4/4 R
Laggan × Garry ..	—	2/2 (3−c)	R	R	R	R	Int. R
Garry × Gothland ..	—	2/2 (2−n)	—	Int. R	Int. R.	—	—
Garry × Joanette ..	2/2 (0)	—	MR	MR	—	R	—
Garry	(1n)	(1n)	R	R	R	R	I (98%)
Other parents ..	(4)	(4)	S	S	S	S	S

Data on F_2 segregation in the field are given in Table 11.

It has been mentioned earlier that certain progenies of F_1 plants indicated the operation of the inhibitor group. With the operation, therefore, of an additional factor for adult plant resistance the expected ratio was 3·2:1 and with additional duplicate factors the expected ratio was 15·7:1. In the absence of the inhibitor group the expected ratio was 3:1 in the former case. In the seedling stage, plant nos. 4, 14 and 20 of the cross Algerian × Garry and plant no. 15 of the cross Fulghum × Garry did not show any resistant plants in their progeny tests, indicating the absence of the inhibitor and its linked factor. It will be observed from the table that these plants gave a number of resistant and intermediate type of resistant adult plants. Except for plant no. 15 of the cross Fulghum × Garry the other three indicated the operation of a gene for adult plant resistance. Plant nos. 2, 6, 13 and 18 of the cross Algerian × Garry, nos. 2, 4, 12 and 14 of the cross Fulghum × Garry and no. 3 of the cross Burke × Garry clearly indicated the operation of a factor for adult plant resistance in addition to the inhibitor group. Whereas plant nos. 16 and 17 of the cross Algerian × Garry indicated the operation of two factors for adult plant resistance, plant nos. 3 and 13 of the cross Fulghum × Garry showed a poor fit to the expected ratio of 15·7:1. There was an excess of moderately susceptible plants. In this cross it will be observed, in general, that the number of highly resistant plants was lower in comparison with the other crosses. This indicated the probable operation of minor modifying factors. These assumptions were confirmed from the F$_3$ behaviour presented later.

(*c*) F$_3$ Breeding Behaviour.

To confirm the hypothesis of linked factors, random F$_3$ lines from the progenies of certain F$_1$ plants and also lines from classified F$_2$ material were tested to different races

TABLE 10.

Segregation for Crown Rust in the Progenies of Certain F$_1$ Plants of Crosses Involving Garry, Indicating the Operation of Two Linked Dominant Complementary Factors (Recombination Value, 9·59±1·68) and of an Inhibitor and its Linked Inhibited Dominant Factor (Recombination Value, approx. 10).

Cross and F$_1$ plant no.	Race Used.	F$_2$ Reaction.				Ratio of R : S.	Probability.	
		Res.	MR.	MS.	S.		3·2 : 1.	71·9 : 28·1.
Algerian × Garry								
2	226	124	18	23	21	3·2 : 1	0·5 –0·3	0·2 –0·1
	226	22	53	27		3·1 : 1	0·7 –0·5	0·8 –0·7
5	237–4	23	28	21		2·4 : 1	0·3 –0·2	0·95–0·9
6	226	42	—	12	4	2·6 : 1	0·5 –0·3	0·7 –0·5
	203	46	24	8	18	2·8 : 1	0·5 –0·3	0·7 –0·5
9	237–4	25	22	21		2·2 : 1	0·2 –0·1	0·7 –0·5
11	203	46	8	19	11	1·8 : 1	0·02–0·01	0·2 –0·1
12	237–4	131	3	39	11	2·7 : 1	0·3 –0·2	0·8 –0·7
	203	56	21	19	13	2·4 : 1	0·3 –0·2	0·8 –0·7
13	237–4	62	9	18	4	3·2 : 1	0·99–0·95	0·5 –0·3
16	203	29	23	16	10	2·0 : 1	0·05–0·02	0·5 –0·3
17	226	86	11	40	1	2·7 : 1	0·2 –0·1	0·7 –0·5
Total ..	..	912		356		2·6 : 1	0·01–0·001	0·95–0·9
Fulghum × Garry								
2	226	47	4	10	14	2·1 : 1	0·1 –0·05	0·5 –0·3
3	203	85	41	32	16	2·6 : 1	0·3 –0·2	0·9 –0·8
10	226	11	43	20	5	2·2 : 1	0·1 –0·05	0·5 –0·3
	237–4	17	18	19		1·8 : 1	0·1 –0·05	0·3 –0·2
Total ..	..	266		116		2·3 : 1	0·01–0·001	0·5 –0·3
Burke × Garry								
1	203	183	27	42	32	2·8 : 1	0·5 –0·3	0·5 –0·3
2	226	43	73	4	44	2·4 : 1	0·2– 0·1	0·8 –0·7
	203	38	73	37		3·0 : 1	0·8 –0·7	0·5 –0·3
3	237	142	2	45	2	3·1 : 1	0·8 –0·7	0·3 –0·2
Total ..	..	581		206		2·8 : 1	0·2 –0·1	0·3 –0·2
Laggan × Garry								
3	203	127	23	59		2·5 : 1	0·3 –0·2	0·95–0·9
4	203	64	108	71		2·4 : 1	0·05–0·02	0·8 –0·7
Total ..	..	322		130		2·5 : 1	0·02–0·01	0·8 –0·7
Garry × Gothland								
1–6	226	16	81	28		3·5 : 1	0·7 –0·5	0·2 –0·1
	203	7	126	5	47	2·6 : 1	0·3 –0·2	1·0 –0·99
Total ..	..	230		80		2·9 : 1	0·5 –0·3	0·5 –0·3
Garry × Joanette								
4	226	14	—	3	—	4·7 : 1	0·7 –0·5	0·5 –0·3
1–4	203	56	10	1	22	2·9 : 1	0·7 –0·5	0·7 –0·5
Total ..	..	80		26		3·1 : 1	0·95–0·9	0·5 –0·3
Grand total	..	2391		914		2·62 : 1	<0·001	0·7 –0·5

in the seedling and in the adult plant stages. The observations on F_3 reactions are presented in Tables 12 and 13. Some lines in each cross showed the presence of moderately resistant plants in the resistant, segregating and susceptible lines. When such plants were found in the susceptible class the reaction was indicated as S:R. The expected behaviour indicated a ratio of 20·53 (R & R, R^-) : 51·35 (R, R^-, S & R^-, S) : 28·11 (S, R^- & S) in the seedling stage.

TABLE 11.

F_2 Segregation for Crown Rust in the Field in the Progenies of Certain Crosses Involving Garry.

Cross and F_1 plant no.	Field Reactions.			Total.	Expected Ratio.	Probability. (Chi-square.)
	Re-sistant.	Inter-mediate.	Sus-ceptible.			
Algerian × Garry						
2	12	159	38	209		
6	5	18	9	32		
13	1	1	1	3		
18	2	10	3	15		
Total	208		51	259	3·2 : 1	0·2– 0·1 (2·44)
4	12	97	27	136		
14	17	41	11	69		
20	7	12	8	27		
Total	186		46	232	3·0 : 1	0·1-0·05 (3·31)
16	2	8	0	10		
17	9	38	3	50		
Total	57		3	60	15·7 : 1	0·8–0·7 (0·106)
Fulghum × Garry						
2	—	9	6	15		
4	—	3	1	4		
12	6	133	46	185		
14	3	36	9	48		
Total	190		62	252	3·2 : 1	0·8–0·7 (0·088)
3	—	11	12	23		
13	9	42	27	78		
Total	62		39	101	15·7 : 1	<0·001
15	2	113	70	185	3·0 : 1	<0·001
Burke × Garry						
3[1]	83	108	60	251	3·2 : 1	0·99–0·95 (0·0009)

[1] This cross was tested in the winter of 1954, whilst others were tested in 1953 winter.

In Table 12 wherever tests were carried out with more than two races the same F_3 lines were tested. In the above tests the ratio ranged between 2·3 to 3·5 segregating lines for each resistant line. The average for all lines was 1 resistant : 2·9 segregating. For a single major gene segregation the expected ratio was 1:2. The observed ratio was greater than this and less than 1:8, as expected for complementary factor pair segregation.

It will further be observed that certain lines showed segregation with the majority of plants susceptible. The reactions in the F_3 lines derived from random F_2 plants of F_1 plant 8 of the cross Fulghum × Garry when tested against race 226 showed that out of 58 lines none were fully resistant and only four segregated with a preponderance of resistant plants. Twelve lines were S:R and the remainder gave a susceptible reaction. Lines showing a majority of resistant plants indicated the operation of a dominant factor for resistance, and S:R segregation either a recessive factor for resistance or an inhibitor factor for the dominant factor mentioned above. The operation of the latter was considered to be more likely. If it is assumed that the inhibitor factor was independent of the dominant factor an F_3 behaviour of 1R; 2R:S; 6S:R; 7S was expected in the progenies of F_1 plant no. 8. Out of 58 lines tested none were resistant and only 4, as against 7 expected, were found to segregate R:S. Among the lines segregating S:R one-third were expected to segregate 3S:1R. Of the 12 lines of this class three lines were found to segregate 3:1. A critical examination of the lines derived from susceptible F_2 plants revealed that out of 190 lines classified as S:R or S, 42 lines segregated S:R and of these 15 lines gave a 3:1 ratio (this excludes the data from the crosses of Garry with Laggan and Burke, which were studied later). Instead of obtaining a 13S:3R ratio in the other lines, only 1 or 2 resistant plants were noted amongst about 20 plants per line. The number of susceptible lines observed was far greater in proportion to the segregating lines, when compared with the expected proportion of 7 out of every 13. In all, 95 lines gave a S:R reaction to one or other race, and of these only 15 lines segregated S:R to all four races 203, 226, 237–4 and 286.

TABLE 12.

Crown Rust Reactions of F_3 Lines in the Seedling Stage Indicating Operation of Linked Genes in Various Crosses Involving Garry.

Cross and F_1 plant no.	Race Used.	F_3 Reactions.						Total.	P Value (greater than).
		Resistant.	R, R^-.	R, R^-, S.	R^-, S.	S : R^-.	Susceptible.		
Algerian × Garry									
2	226	19	10	88	4	1	35	157	0·1
	203	29	6	82	8	1	34	160	0·2
6	Field collection	6	9	53	—	3	21	92	0·3
17	Do	—	8	24	1	2	8	43	0·5
Fulghum × Garry									
2	203	2	12	25	11	13	15	78	0·2
	286	2	11	32	6	11	17	79	0·3
3	203	11	2	43	3	11	12	82	0·5
	226	3	9	35	—	9	11	67	0·8
	286	5	6	34	3	5	14	67	0·5
4	203	11	3	30	2	4	10	60	0·5
	226	2	10	27	5	3	13	60	0·95
	286	6	5	25	5	2	14	57	0·95
Laggan × Garry									
8[1]	226	—	—	4	—	12	42	58	0·3
1[2]	203	6	8	10	9	6	26	85	0·2
Burke × Garry									
3[2]	230	51·6		125·1		74·3		251	0·8

[1] Expected segregation in this plant was 0·25 (R) : 5·0 (R : S) : 45·0 (S : R) : 49·75 (S).

[2] Random lines and/or lines from F_2 progenies classified in the field were used. The data on these crosses were not utilized in calculating the linkage values.

A further study of 159 lines from the F_1 families of plants 4 and 14 of the cross Algerian × Garry and of plants 5 and 15 of the cross Fulghum × Garry did not show any resistant plant in any lines except for two plants in each of two lines. This clearly excluded the possibility of natural crossing as an explanation for the occurrence of 1 in 20 plants as resistant. Calculations based on the occurrence of 15 lines segregating approximately 3S:1R, and 31 out of 95 lines segregating to any one of the four races and also on the segregation observed in the F_3 of the progeny of F_1 plant 8 of the cross Fulghum × Garry, indicated an approximate linkage value of 10 units between the inhibitor factor and the dominant gene it inhibited. Calculating the expected F_3 behaviour on this assumption would give 0·25 line resistant, 5·0 lines segregating R:S, 4·5 lines segregating 3S:1R, 40·5 lines segregating with 1 resistant plant in about 20 and 49·75 lines fully susceptible. The lines showing 1 in 20 plants as resistant may not be observed to be segregating in tests against all the races. The F_3 behaviour observed in plant 8 of the cross Fulghum × Garry fitted closely the expectation with a probability value greater than ·3.

The data in F_2 and F_3 studies in the seedling stage indicated linkage between two complementary dominant factors and in calculating the recombination value of these factors the above observations were considered. The combined logarithmic likelihood expression for the F_2 and F_3 data thus derived was: $2391 \text{ Log.}(1221-758p+379p^2) + 1050 \text{ Log. } 379\ (1+2p-p^2) + 91 \text{ Log.}(403-758p-399p^2) + 286\ (818+40p-20p^2)$.

The classes S:R and S for F_3 reactions were combined. Maximization with respect to "p" gave a value of ·0959 ± ·0168. Thus a recombination value of 9·59% ± 1·68% was obtained.

In the F_2 the ratio of resistant to susceptible seedlings was 71·9:28·1 on this basis and in the F_3 20·5:51·4:28·1 for resistant : segregating : susceptible lines. The susceptible class included lines segregating S:R, with a preponderance of susceptible plants. All the individual single F_1 plant progeny segregations obtained in F_2 and F_3 showed good agreement. In the F_2 the various Chi-square values were: (*a*) for deviation 0·3445 (1 d.f.), (*b*) for heterogeneity within crosses 10·718 (20 d.f.) and (*c*) for heterogeneity between crosses 3·6704 (5 d.f.). Probability of chance deviation in every case was not less than 50%, indicating good agreement between observed and expected results and homogeneity of the data.

The behaviour in the field of certain F_1 plant progenies is given in Table 13.

TABLE 13.

Adult Plant Behaviour of Certain F_3 Lines in the Crosses Algerian × Garry and Fulghum × Garry at Castle Hill Farm in 1954.
(Expected values in brackets.)

Cross and F_1 plant no.	F_4 Reactions.						Expected Ratio.	Probability.
	R.	R, R^-.	R, R^-, S.	R^-, S.	S : R^-	S.		
Algerian × Garry								
2	15	28	74	4	22	6	25·2 : 51·2 : 23·6	
6	4	14	32	—	14	2		
Fulghum × Garry								
2	6	6	28	3	14	6		
4	5	7	23	5	1	10		
Total	85 (83·4)		169 (169·9)		78 (78·7)			0·9–0·8
Algerian × Garry								
11	6	4	11	2	1	—	43·8 : 50·2 : 5·9	
17	16	43	71	6	6	3		
Fulghum × Garry								
3	29	22	55	9	5	7		
Total	120 (127·7)		159 (146·0)		22 (17·3)			0·3–0·2

It will be observed from Table 13 that also in the field certain F_2s from these F_1 plants gave progenies which segregated with a preponderance of susceptible plants. This indicated that the inhibitor factor and its linked dominant factor for resistance were operative in the field also. In the table it again will be seen that F_3 families of some F_1 plants indicated the operation of a single major factor for adult plant resistance whilst others suggested duplicate factors. These results substantiated some of the observations made in F_2 on adult plants. Due to the operation of the inhibitor group the ratio of 1:2:1 or 7:8:1 was changed slightly as indicated in the table. The probability values were greater than ·8 for monogenic segregation and greater than ·2 for the duplicate factor segregation, indicating a good fit. The S:R class was included with the susceptible class. When the expectancies were calculated with the S:R class taken separately, the probability values were greater than ·02 in the former and greater than ·3 in the latter case.

In the summer of 1955, 278 lines from the crosses Algerian × Garry (F_1 plant nos. 4 and 14), Fulghum × Garry (F_1 plant no. 15) and Burke × Garry (F_1 plant no. 1) were sown in the field, but due to the predominance of race 259 all the lines gave a susceptible reaction.

(*d*) Relationship of Reactions to Different Races.

F_2 plants classified to one race were studied for their F_3 behaviour to the same or a different race. The breeding behaviour is presented in Table 14.

It will be observed from the data presented in Table 14 that F_3 lines derived from resistant F_2 plants were either fully resistant or segregated with a preponderance of resistant plants. Similarly the lines derived from the susceptible F_2 plants were either susceptible or segregated with susceptible plants preponderant, except for one line which was fully resistant. In the intermediate classes, however, several lines were found to behave differently from the expected ratio. Nine lines from the MR F_2 reaction type class gave lines that were either susceptible or segregated with a preponderance of susceptible plants and, similarly, 14 lines derived from MS plants gave fully resistant progenies or segregating R:S progenies. This aberrant behaviour of certain F_2 plants of the intermediate classes, particularly to the same race in F_3, indicated errors in classification or labelling. Corrections in the F_2 data were made on this basis wherever possible.

TABLE 14.

F_3 Breeding Behaviour of the Progenies of Classified F_2 Plants in the Seedling Stage.

F_2 Reactions to Race.	F_3 Reactions to Race.				Total.
	Resistant.	Segregating R : S.	Segregating S : R.	Susceptible.	
226	203				
R	3	19	—	—	22
MR	2	6	—	1	9
MS	1	—	5	20	26
S	—	—	—	1	1
203	Composite field inoculum				
R	10	31	—	—	41
MR	3	17	—	1	21
MS	—	4	1	7	12
S	1	—	2	12	15
203	203				
R	13	22	—	—	35
MR	2	6	3	4	15
MS	1	1	1	2	5
S	—	—	—	10	10
203	226				
R	14	17	—	—	31
MR	4	6	—	—	10
MS	2	4	1	—	7
S	—	—	—	5	5

F_3 seedling vs. F_3 seedling comparison to different races is presented in Table 15.

It will be seen from reactions presented in Table 15, for behaviour against paired races, that the majority of lines gave identical reactions. Four hundred and eighty-two lines gave resistant and segregating reactions to both races and only 17 gave a resistant reaction to one race but segregated to the other. Twelve lines showing segregation gave either a S:R behaviour or were homozygous susceptible to the other race. These discrepancies suggested some errors in classification. From among the susceptible and S:R lines 181 gave identical reactions and 35 gave a S:R reaction to one race, but were susceptible to another. In the S:R class, as already mentioned, it was expected that certain lines would give about 1 in 20 plants with a resistant reaction. Such lines may not have shown identical reactions to the paired races and, as such, the observed behaviour of these lines was not unexpected. In general, analysis of reactions clearly indicated that the same factors conditioned resistance to races 203, 226, 237, 237–4 and 286.

Seedling reactions vs. adult plant reactions: Relationship between seedling reactions and adult plant reactions were studied in the F_2 of the cross Garry × Gothland, between adult plant reactions in the F_2 and seedling reactions in the F_3 in the cross Burke × Garry and between F_3 reactions in the two stages in the cross Fulghum × Garry and Algerian × Garry. The appropriate data are presented in Tables 16 and 17.

TABLE 15.

Relationship of F_3 Behaviour to Different Races of Crown Rust in Certain Crosses Involving Garry.

F_3 Reactions to Race.	F_3 Reactions to Race.			
	Resistant.	Segregating R : S.	Segregating S : R.	Susceptible.
203	226			
Resistant	73	11	—	—
Segregating				
(R : S)	2	199	1	4
(S : R)	—	2	19	16
Susceptible	—	2	2	74
286	226			
Resistant	37	1	—	—
Segregating				
(R : S)	1	106	1	—
(S : R)	—	1	9	6
Susceptible	—	1	7	47
203	237–4			
Resistant	7	1	—	—
Segregating				
(R : S)	1	21	—	—
(S : R)	—	—	24	3
Susceptible	—	—	1	7
203	237			
Resistant	10	—	—	—
Segregating				
(R : S)	—	28	—	—
(S : R)	—	—	1	—
Susceptible	—	—	—	—

In Table 16 the expected frequencies of the susceptible class, indicated in brackets, were calculated on the assumption that two factors conditioned adult plant resistance in this cross with one showing linkage with the two complementary factors for seedling resistance, approximately 10 units away from the gene proximal to it. This inference was obtained from F_3 studies in the seedling as well as adult stage of the same lines. The data are presented in Table 17.

In the cross Burke × Garry 201 lines were studied from an F_2 population of 251 plants classified in the adult stage in the field for crown rust behaviour; therefore the observed frequencies in the table were adjusted on the basis of the original F_2

TABLE 16.

Relationship between F_2 Seedling and Adult Plant Reactions in the Cross Gothland × Garry.
(Expected values in brackets.)

Adult Plant Reactions.	Seedling Reactions.			Total.
	Resistant.	MR.	Susceptible.	
Resistant	32	24	13	69
MR	—	—	1	1
MS–S	— (1·1)	—	9 (3·8)	9 (4·8)
Probability[1] ..	0·7–0·5		0·01–0·001	0·1–0·05

[1] Yates' correction factor applied.

TABLE 17.

Relationship between Adult Plant Reactions and Seedling Reactions in F_3 in Certain Crosses Involving Garry. (Expected values in brackets.)

Cross and F_1 plant no.	Adult Plant Reactions.	Seedling Reactions in F_3.				Total.
		Resistant.	Segregating (R : S).	Segregating (S : R).	Susceptible.	
	F_2					
(*a*) Burke × Garry	Resistant ..	50·2 (51·1)	111·2 (116·7)	29·6 (23·8)		191 (191·6)
	Susceptible ..	1·4 (0·48)	13·9 (12·2)	44·7 (46·7)		60 (59·4)
	Total ..	51·6 (51·6)	125·1 (128·9)	74·3 (70·6)		251
	Seedling (F_3).	Adult plant reactions (F_3) (indicating the operation of one factor for adult plant resistance)				
(*b*) Algerian × Garry F_1 plant nos. 2 and 6 and Fulghum × Garry F_1 plant nos. 2 and 4	Resistant ..	44 (48·0)	7 (10·9)	0 (0·56)	0	51 (59·5)
	Segregating (R : S) ..	29 (22·5)	123 (112·3)	5 (14·1)	1	158 (148·9)
	(S : R) ..	1	2	8	6	81
	Susceptible ..	1 (2·3)	13 (25·2)	30 (54·0)	20	(81·5)
	Seedling (F_3).	Adult plant reactions (F_3) (indicating the operation of two factors for adult plant resistance)				
(*c*) Algerian × Garry F_1 plant no. 17 and Fulghum × Garry F_1 plant no. 3	Resistant ..	37 (39·1)	10 (6·6)	1 (0·1)	0	48 (45·8)
	Segregating (R : S) ..	34 (41·6)	69 (70·1)	1 (2·7)	0	104 (114·4)
	(S : R) ..	4	13	0	1	71
	Susceptible ..	9 (17·0)	26 (35·3)	8 (10·4)	10	(62·7)
			(*a*)	(*b*)	(*c*)	
Chi-square for seedling reactions			0·3 (P= 0·9 –0·8)			
Chi-square for adult plant reactions			0·003 (P= 0·99–0·9)			
Chi-square for association			2·39 (P= 0·8–0·7)	15·3 (P= 0·1–0·05)	12·8 (P= 0·2–0·1)	

frequencies. It will be observed from the behaviour of the classified plants that the majority of plants classified as resistant gave either fully resistant F_3 lines or gave lines segregating R:S. Several lines were also susceptible. Similarly, from susceptible F_2 plants the majority of the lines derived were susceptible and a few lines were either fully resistant or were segregating R:S. Observations made on the F_3 lines in the two stages also indicated similar patterns. A test of independence clearly indicated association between seedling resistance and adult plant resistance since the probability was less than ·001 in every case.

If it is assumed that one of the two factors for seedling resistance governed adult plant resistance as a single dominant factor, then from the class of lines segregating R:S in Table 17 (*b*), 9% or only 14·2 lines were expected to be homozygous resistant in the field. The observed number was 29. Similarly from the lines susceptible in the seedling stage 1% or 0·89 line would be resistant and 9·6% or 7·9 lines segregating. The observed numbers were 2 and 15 respectively. The deviations were therefore large. Similar deviations were noted in the other two parts of the table.

An alternate assumption on the basis of another factor linked with the two complementary factors for seedling resistance and showing approximately 10% crossing over offered a more satisfactory explanation and gave closer fits to the expected frequencies. Expected frequencies on the basis of this assumption are shown below.

Seedling Reactions in F_3, Indicating the Operation of $\underline{IVc_2\ Vc_2}$ and $\underline{Vc_a\ Vc_b}$	Adult Plant Reactions in F_3 (Indicating the Operation of $\underline{IVc_2\ Vc_2}$).						Total.
	And single dominant factor linked with seedling resistance.			And two dominant factors, one linked with seedling resistance.			
	Resistant.	Segregating (R : S).	Susceptible including S : R.	Resistant.	Segregating (R : S).	Susceptible including S : R.	
Resistant ..	16·556	3·784	0·191	17·550	2·944	0·048	20·53
Segregating ..	7·769	38·728	4·851	18·664	31·472	1·213	51·35
Susceptible (including S : R)	0·803	8·678	18·630	7·630	15·826	4·658	28·11
	25·128	51·190	23·670	43·844	50·242	5·919	100·00

For calculating the F_2 frequencies the resistant and the segregating classes are combined.

The data presented in Tables 16 and 17 show a close fit to the expected frequencies, calculated from the figures given above. In Table 17 (*b*) the deviation was not significant at the 5% level of significance. In the cross Garry × Gothland (Table 16) two factors for adult plant resistance operated and in the cross Burke × Garry only the factor linked with the complementary factors for seedling resistance operated. In the latter cross 11 lines in the susceptible class of F_3 reactions were found to give a S:R reaction.

The recombination value was assumed to be approximately 10% because the segregating ratios to the different races in the seedling stage varied slightly and a very accurate estimation was not possible.

(*e*) Designation of Factors for Crown Rust Resistance.

On the basis of the scheme for gene designation outlined earlier, the complementary factors were designated Vc_a and Vc_b, the dominant factor as Vc_2 and its inhibitor as IVc_2. The two factors for adult plant resistance were designated $Vc_{\bar{1}}$ and $Vc_{\bar{3}}$, $Vc_{\bar{1}}$ being linked with the two complementary factors thus:

$$\begin{array}{ccc} Vc_a & Vc_b & Vc_{\bar{1}} \\ \hline \multicolumn{2}{c}{9{\cdot}59 \pm 1{\cdot}68} & 10 \text{ approx.} \end{array}$$

Vc_2 and IVc_2 were also 10 units apart.

(C) *Relationship between Factors for Stem Rust Resistance and Crown Rust Resistance.*

Chi-square values were calculated for independence of crown rust reactions and stem rust reactions in the F_2 and F_3 generations involving the different factors. A tabular statement of the information is presented in Table 18. Since Vc_a, Vc_b and $V\bar{c}_1$ were linked as were Hj_1 and Hj_2, independence was calculated for only one of the factors in each case.

The test for independence of stem rust resistance and crown rust reactions clearly indicated their independent inheritance, both in seedling and adult plant tests.

TABLE 18.

Chi-square Test for Independence of Stem Rust and Crown Rust Resistant Factors.

Generation Studied.	Factors.	N.	D.F.	Probability.
F_2	$\underline{Hj_1\ Hj_2}$ vs. $\underline{Vc_a\ Vc_b\ Vc_1}$, $\underline{IVc_2Vc_2}$	106	2	0·2 –0·1
F_3	As above	596	6	0·5 –0·3
F_3	Rd_1 vs. as above	22	6	0·98–0·95
F_3	Rd_1, $\underline{Hj_1\ Hj_2}$ vs. $V\bar{c}_3$	36	6	0·5 –0·3
F_2	Hj_1 or Hj_2 vs. $V\bar{c}_1$	251	1	0·99–0·95

DISCUSSION.

The variety Garry, when tested as seedlings to different races or in the field, showed heterogeneity. The fact that this was not due to mechanical mixture was evident from the present studies. The heterogeneous character of Garry was particularly expressed in its crosses with Algerian and Fulghum in the F_1, F_2 and F_3 generations. Twenty F_1 progenies of the cross Algerian × Garry, 15 of the cross Fulghum × Garry, 4 of the cross Burke × Garry, 4 of the cross Laggan × Garry, 6 and 5 respectively of the crosses Gothland × Garry and Joanette × Garry were utilized in the present studies. Due to the heterogeneous nature of the parent Garry, certain F_1 plants and/or their progenies differed in behaviour to both stem rust and/or crown rust races.

In the present studies three factors were identified conditioning stem rust resistance. One common factor in Garry and Burke (and indirectly Laggan) conditioned resistance to races 2 and 12. This factor was possibly the same as that in Richland and reported by workers in other countries. The other two factors were found linked with a recombination value of $26{\cdot}69 \pm 2{\cdot}29$ and conditioned resistance against races 2, 10 and 12. Workers in North America identified four factors, derived from the variety Hajira, in Garry or its sister selections. One was the same as the Richland factor, two independent factors conditioned resistance to race 8 (a race closely allied to race 10) and one was similar to the Richland factor except that it did not condition resistance to race 7A. Probably one of the two linked factors against Australian races was identical with one of the factors conditioning resistance to race 8 in North America. The present investigations, therefore, added one more factor to the gene pool of sources of resistance to stem rust.

Waterhouse (unpublished) studied crosses of R.L.1692 (Garry O.259) with Fulghum, Algerian and Adonis and studied the segregation to stem rust races 2, 7 (allied to race 12) and 8 (allied to race 10). A population of 1,054 F_2 plants from 20 different F_1 plants, studied against races 2 and 7, showed 46 susceptible. A fit to the ratio of 96·64:3·36 shows no significant deviation at the 5% level of probability. From 484 plants studied for behaviour to race 10, 93 were susceptible. An excess of 28·5 plants was therefore shown in the susceptible class in this case, indicating a significant deviation. However, it was noted that some of the F_1 progenies gave a good fit to the expected ratio of 86·6:13·4 and that the over-all ratio of 4·2:1 indicated an intermediate ratio between monogenic and digenic segregation. The operation of linked factors was thus suggested.

These crosses were made in 1946 and 1948 and the crosses of the same Accession Number O.259 with Fulghum and Algerian made in 1951 were studied by the present authors.

The studies on crown rust inheritance in Garry revealed its complicated nature against Australian races. In all, six factors were identified. Two major dominant complementary linked factors conditioned seedling resistance only and similarly two independent factors conditioned adult plant resistance only. An additional factor conditioned resistance both in the seedling and in the adult plant stage. The resistance due to this factor was, however, inhibited by the action of another gene linked with it and separated by approximately 10 crossover units. One of the genes for adult plant resistance was further found linked with the two complementary factors for seedling resistance. No previous report has been made of linkage between the factors of the Victoria type. Usually only a single factor has been reported or wherever more than one factor was reported (e.g., Welsh *et al.*, 1953) the factors were considered independent. The identification of the numerous factors for crown rust resistance in Garry was made possible because of different types of segregation in the progenies of different F_1 plants. Progenies of 54 F_1s were studied. Some of them possessed factors for resistance to stem rust only, others to crown rust only. Again, among these types, some showed segregation of one or both factors for seedling resistance and others for factors for adult plant resistance. The identification of the factor inhibiting the action of a dominant factor would not have been possible except for the F_3 segregation of these factors only in the progeny of F_1 plant number 8 of Fulghum × Garry, where these two factors were also indicated as linked.

The results with the Australian races differed greatly from those where the same races (on the conventional international set designation) of another country were used. This indicates that the identification of the races on the international set of differentials does not necessarily help in the utilization of information available for resistance against any particular race in another country. This is in agreement with observations made by Watson and Waterhouse (1949) concerning race 34 of wheat stem rust.

The results indicated that the factors conditioning seedling resistance did not confer resistance against the same races in the field. This was clear from the F_3 studies carried out using composite inoculum collected from the field for seedling tests in the glasshouse. The factors for seedling resistance operated against this inoculum in the usual manner and the reactions were identical with those when race 203 was used in the seedling stage. In the field, however, two different factors conferred resistance. These observations make it necessary for the breeder to study his breeding material carefully before incorporating resistance into any economic variety.

The fact that a single race, 259Anz.1, made all the factors for crown rust resistance in Garry and Victoria ineffective stresses the need for introducing more factors for crown rust resistance from diverse sources. Studies assessing the possibility of introducing diverse genes into Garry or Victoria have been carried out by the senior author and will be reported in a series of subsequent papers.

SUMMARY.

Studies on the inheritance of stem rust resistance and crown rust resistance were carried out in various crosses involving the variety Garry. It was clear that Garry was a heterogeneous mixture of types. Studies on the progenies of 54 F_1 plants from the crosses of Garry with Algerian, Fulghum, Burke, Laggan, Gothland and Joanette revealed the operation of the following six factors for crown rust resistance and three factors for stem rust resistance:

$\dfrac{Vc_a \qquad Vc_b \qquad V\bar{c}_1}{9{\cdot}59 \pm 1{\cdot}68 \quad 10 \text{ approx.}}$ in linkage group 1. Vc_a and Vc_b were complementary factors for seedling resistance to races 203, 226, 230, 237, 237–4 and 286. $V\bar{c}_1$ conditioned adult plant resistance only.

$\frac{Vc_2\ IVc_2}{10\ \text{units}}$ in linkage group 2. Vc_2 conditioned seedling as well as adult plant resistance, but was inhibited by IVc_2.

Vc_3—independent dominant factor for adult plant resistance only.

Rd_1—independent factor for resistance to races 2 and 12 of stem rust.

$\frac{Hj_1\ \text{and}\ Hj_2}{26{\cdot}69 \pm 2{\cdot}29}$ in linkage group 3 conditioning seedling resistance to races 2, 10 and 12 of stem rust and field resistance.

The factors for crown rust resistance were independent of the factors for stem rust resistance.

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THE SUBGENUS OCHLEROTATUS IN THE AUSTRALIAN REGION (DIPT.: CULICIDAE). IV.

REVIEW OF SPECIES OF THE FLAVIFRONS SECTION.

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(Three Text-figures.)

[Read 27th July, 1960.]

Synopsis.

Males and larvae of *Aëdes clelandi* (Taylor) and *Aëdes purpuriventris* Edwards and larvae of *Aëdes flavifrons* (Skuse) are described for the first time; the pupae of these species are figured. An account is given of their biology and distribution. New records of distribution of *Aëdes calcariae* Marks are reported.

INTRODUCTION.

The Flavifrons Section of the subgenus *Ochlerotatus* was established by Marks (1957) to accommodate four southern species: *flavifrons*, *purpuriventris*, *clelandi* and *calcariae.* Up to this time *purpuriventris* and *clelandi* had been known only from the females and their relationships to other species were obscure. Thus Edwards (1926) expressed the opinion that *purpuriventris* was closely allied to *burpengaryensis* (Theobald) and was possibly conspecific with *nigrithorax* (Macquart).

In an earlier paper (Edwards, 1924) he had supposed that *clelandi* was close to *nivalis* Edwards, but Mackerras thought that it was a variant of *burpengaryensis.* The confusion was resolved by the discovery of the males of these two species: the recognition of the Flavifrons Section by Marks (1957) was based on similarity of the male terminalia. The structure of the terminalia suggests that the Flavifrons Section is closer to the Burpengaryensis Section than to any others of the sections.

Three members of the Section, *flavifrons*, *purpuriventris* and *calcariae*, are bush mosquitoes which, in Victoria, are found in the eastern and southern parts of the State and on the Dividing Range, though not at higher altitudes. Of the three, *flavifrons* is by far the most common species; *calcariae* and *purpuriventris* have a discontinuous distribution determined by their restricted choice of breeding sites. *Aëdes clelandi* is a coastal species; it has been recorded from only two localities in Victoria, but has been found in many localities in South Australia and in the south-western part of Western Australia and Flinders Islands. *Aëdes flavifrons* is distributed in New South Wales, Victoria, South Australia, Bass Strait islands and Tasmania, *Aë. purpuriventris* in Victoria, South Australia and Tasmania. *Aë. calcariae* has been recently fully described by Marks (1957), so the present paper will deal with the remaining three species of the section; full descriptions of them are given.

AËDES FLAVIFRONS (Skuse).

Culex flavifrons Skuse, 1889, PROC. LINN. SOC. N.S.W., 3: 1735. *Culicada vandema* Strickland, 1911, *Entomologist*, 44: 202. *Culicada vandema* var. *variegatans*, *ibid.*: 204. *Culicada flavifrons* Taylor, 1914, PROC. LINN. SOC. N.S.W., 38: 751. *Aëdes flavifrons* Edwards, *Bull. ent. Res.*, 14: 374.

Distinctive Characters. Adult: Femora and tibiae mottled; all tarsi banded; hind tarsi with basal bands. Wings mottled with creamy scales only slightly broader than dark ones; membrane with dark blotch in middle. Tergites unbanded. Male terminalia: similar to *Aë. calcariae*, but coxite tergally has only a few fine setae along inner aspect

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and lacks group of long setae near base. Harpago with strong preapical seta as in *calcariae*. *Larva*: Head seta 5, 3–4-branched; 6, single. Lateral comb of 35–53 coarsely fringed scales. Siphon index 3·0–3·6. Seta 1 of segment VIII, 4–5-branched.

Description of Adult.

Male. Head: Vertex clothed with curved pale golden scales, and darker forked upright ones. Proboscis mottled. Palps longer than proboscis, with patches of white scales at base of segments 4 and 5. Thorax: Integument reddish-brown. Scutum uniformly clothed with pale golden scales, with some admixture of black scales in fossa. Scutellum with pale narrow curved scales and strong black border bristles. Anterior pronotum with dark scales, some pale elongate ones and bristles. Posterior pronotum with small patch of broad pale scales below, elongate black scales in middle and narrow pale scales above. Pleura with patches of broad pale scales. Lower mesepimeral bristles absent. Knob of halteres dark with pale scales. Legs: Femora and tibiae violet black, mottled with pale scales. Tarsi (Fig. 1, *d*, *e*, *f*) of fore and mid legs with 2–3 white basal bands, hind tarsi with 5 bands. Fore tarsal claws unequal, anterior claw with two teeth, posterior with one; mid claws unequal, anterior claw long, simple, posterior small, toothed; hind claws small equal, simple. Wing length: 4·1–4·9 mm. Membrane with dark blotch in middle. Scales of wing violet-black with scattered creamy scales, only slightly broader than the dark ones. Abdomen: Tergites and sternites violet-black; tergites with white basal bands, sternites with large lateral patches of white scales. Terminalia (Fig. 1, *a*, *b*, *c*): Coxite scaled with violet-black scales sternally and laterally. Sternal aspect of coxite with dense, long yellowish setae mesially on distal half. Tergally coxite bears sparse fine setae along its inner aspect; laterally and apically with long, strong setae. Apical lobe of coxite bears several fine short setae and some stronger, longer ones. Basal lobe rounded plate with numerous setae, including 2–3 longer ones arising on tergal side of lobe. Style slightly more than half length of coxite, curved, swollen about mid length; apical third slender with 2 fine setae; appendage one-quarter length of style. Harpago stout, curved, with one strong, long preapical seta; appendage almost as long as harpago, fimbriated and with curved tip. Paraproct with one tooth. Lobes of the IXth tergite with 3–6 strong setae.

Female. Females differ from males as follows: Palps with black and ochreous scales about one-fifth length of proboscis. Mesepimeron with 2–5 lower bristles; rarely they are absent. Fore and mid tarsal claws toothed, hind simple, equal (Fig. 1, *g*, *h*). Wing length: 3·7–5·1 mm. Cell R_2 about twice length of stem. Tergites unbanded; VIth with admixture of ochreous scales, VIIth predominantly ochreous. Sternites mottled with ochreous and violet-black scales; white lateral basal spots on all segments.

Variation. Aë. flavifrons is a very variable species; this is particularly true of the female. Dark specimens have the proboscis and palps black-scaled, with only a few pale scales. The integument is dark brown. The scutum is clothed with black scales, with only a few pale golden ones which are mostly around the bare prescutellar area. The intensity of mottling of the legs and wings may be greatly reduced. On the sternites the ochreous scales may be reduced to basal lateral patches with only a few scattered ones in the black area; only sternites VI and VII have the ochreous scales dominant. There are in Victoria intermediates between the typical form and the dark one, which are similar to var. *variegatans* described by Strickland (1911) from Tasmania; the fossa, of these intermediates, is clothed entirely with black scales to form distinct black lateral patches on the light-coloured scutum. In some specimens the tergites are more or less mottled with ochreous scales.

Pupa. Details shown in Figure 1, *i*, *j*.

Larva (Fig. 1, *k*, *l*). Head, siphon and saddle light brown. Head: Head about two-thirds as long as broad. Antennae about half length of head, with scattered spicules; seta 1 arising at about two-thirds length from base, 3–5-branched. Head seta 4, tiny, 2–4-branched; 5, 3–4-branched; 6, single; 7, 8–10-branched; 8 and 9, 2-branched. Mentum with 13–14 lateral teeth on each side. Thorax: Prothoracic setae: Seta 3, 2-branched or single; 7, 2–3-branched; 1, 2, 4, 5 and 6, single. Abdomen: VIIIth segment: Lateral comb patch of 35–53 coarsely fringed scales. Seta 1, 4–5-branched; 2 and 4, single; 3, 8–10-branched; 5, 6–7-branched. Siphon slightly tapering towards apex, index 3·0–3·6. Pecten of 15–18 spines. Seta 1, 5–6-branched, arising halfway along siphon. Anal

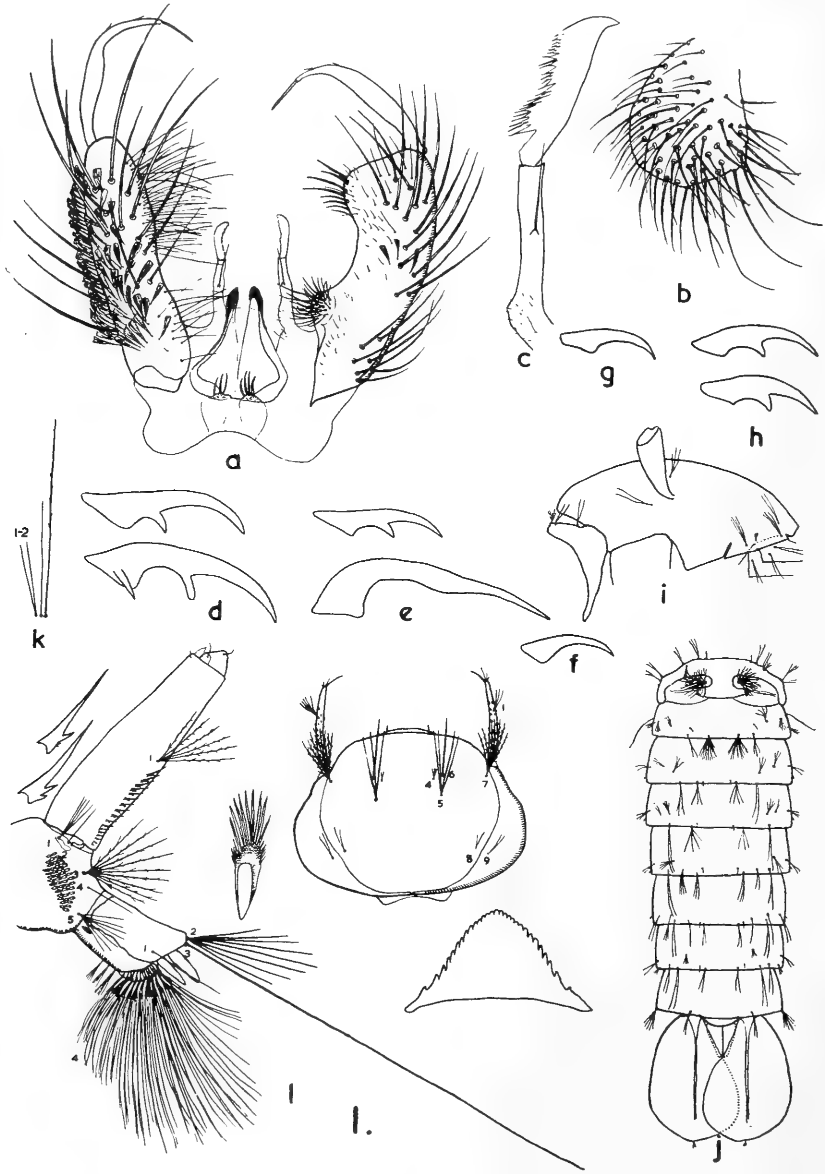

Fig. 1.—*Aëdes flavifrons* (Skuse). *a-c*, ♂ terminalia: *a*, left coxite sternal aspect, right tergal aspect; *b*, basal lobe; *c*, harpago; *d-f*, ♂ tarsal claws: *d*, fore; *e*, mid; *f*, hind; *g-h*, ♀ tarsal claws: *g*, hind; *h*, fore and mid; *i-j*, pupa: *i*, cephalothorax and metanotum; *j*, abdomen; *k-l*, larva: *k*, prothoracic setae 1-3; *l*, head, mentum and terminal segments.

segment: Saddle covering dorsal two-thirds of segment; a small separate sclerotized plate lies near proximal angle of saddle. Setae 1 and 3, single; 2, 7–8-branched; 4 (ventral brush) of 16 tufts, usually 3 of them precratal. Anal papillae pointed, about one-third length of saddle.

Biology. *Aë. flavifrons* is one of the most common spring mosquitoes in Victoria. It breeds in ground pools, up to two feet in depth, containing leaves and twigs, and usually without vegetation. The pools may be exposed to the sun for a part of the day or completely shaded; pits, sometimes 2–3 feet deep, at the base of uprooted trees are favoured breeding sites.

In Victoria, *flavifrons* is confined to woodland at low altitudes; it has not been collected above 2,000–3,000 feet.

Larvae have been found in association with those of *Aë. queenslandis* (Strickland), *Aë. calcariae* Marks, *Aë. purpuriventris* Edwards and *Theobaldia inconspicua* Lee.

Biting Habits. It is a day biting mosquito, attracted to man; it remains active in the shade during the day even in the summer.

Distribution. Specimens have been examined from the following localities: NEW SOUTH WALES: Colo Vale (H. Blatch); VICTORIA: Cabbage Tree Creek, Combienbara, Orbost, Cranbourne, Nowa Nowa, Wilson's Promontory, Lower Tarwin, Maroondah, Yellingbo, Marysville, Ringwood, Kilmore, Ararat, Grampians, Lorne, Cape Otway, Lyonville, Carpendeit, Homerton, Milltown (N. V. Dobrotworsky). SOUTH AUSTRALIA: Robe, Lake Bonney, Narraburra, Millicent (E. W. Lines). FLINDERS ISLAND: Lady Barron (F. N. Ratcliffe), Razorback (J. H. Callaby and D. L. McIntosh). It also has been reported from Tasmania by Strickland (1911) and Lee (1948), but has not been collected in Western Australia.

AËDES PURPURIVENTRIS Edwards.

Aëdes purpuriventris Edwards, 1926, *Bull. ent. Res.*, 17: 113.

Distinctive Characters. Adult: Posterior pronotum with broad scales below, narrow curved scales above. Wings unmottled. Femora and tibiae unmottled; hind femora dark on apical quarter or half anteriorly and posteriorly. Tarsi unbanded. Post-spiracular area with patch of broad scales. Tergites unbanded with small basal lateral patches of white scales. Typical specimens can be easily recognized by purple sternites. Male terminalia: Tergally coxite bears numerous short fine setae along inner aspect; setae on apical lobe longer and stronger than in related species. Harpago without pre-apical seta, but with 4–5 short setae on basal half. *Larva*: Antennae long, thin, curved, almost as long as head. Head seta 5, 2–4-branched; 6, 4–6-branched, plumose. Pecten of close-set spines paler towards tip. Lateral comb patch of 28–35 coarse fringed scales. Siphon short; index 2·3–3·0.

Description of Adult.

Male. Head: Curved and forked scales on vertex pale. Proboscis and palps purplish-black. Palps slightly shorter than proboscis without labella. Thorax: Integument dark brown. Scutum uniformly clothed with brown scales, becoming pale round front margin and a round bare prescutellar area; scutellum pale-scaled. Anterior pronotum with broad flat and narrow curved pale scales. Posterior pronotum with broad pale scales below, narrow dark scales above. Pleura with patches of broad white scales. Lower mesepimeral bristles absent. Legs purplish-black; fore and mid femora white beneath. Hind femora dark on apical quarter or half anteriorly and posteriorly. All claws (Fig. 2, *d*, *e*, *f*) simple except anterior one of fore legs, posterior also may be toothed. Wing membrane with faint blotch in middle. Wing length: 3·9–5·0 mm. Abdomen purplish-black-scaled, with basal lateral patches of white scales on tergites. Terminalia (Fig. 2, *a*, *b*, *c*): Coxite with purplish-black scales sternally and laterally and several strong setae. Some long yellowish setae mesially on sternal aspect, particularly on distal half. Tergally coxite bears numerous fine small setae along its inner aspect, long strong setae laterally. Apical lobe bears several short, and a few longer, setae. Basal lobe rounded plate with numerous setae. Style about half length of coxite, curved and swollen for about half length; apical third slender with 2 fine setae; appendage about one-fifth of length of style. Harpago stout curved, with 2–3 long setae and numerous fine ones on basal half; appendage as long as harpago, fimbriated and with curved tip. Lobes of IXth tergite with 3–5 strong setae.

Female. Female differs from male as follows: Palps about one-fifth length of proboscis. Mesepimeron usually with one strong dark lower bristle, and one small paler; sometimes three bristles or none. All claws equal simple or toothed (Fig. 2, *g*). Wing length: 4·4–5·2 mm. Cell R_2 about 2·4 times its stem. Blotch on wing membrane more conspicuous. Abdomen: First segment with white scales, sixth sternite mottled, seventh ochreous, all others purplish scaled.

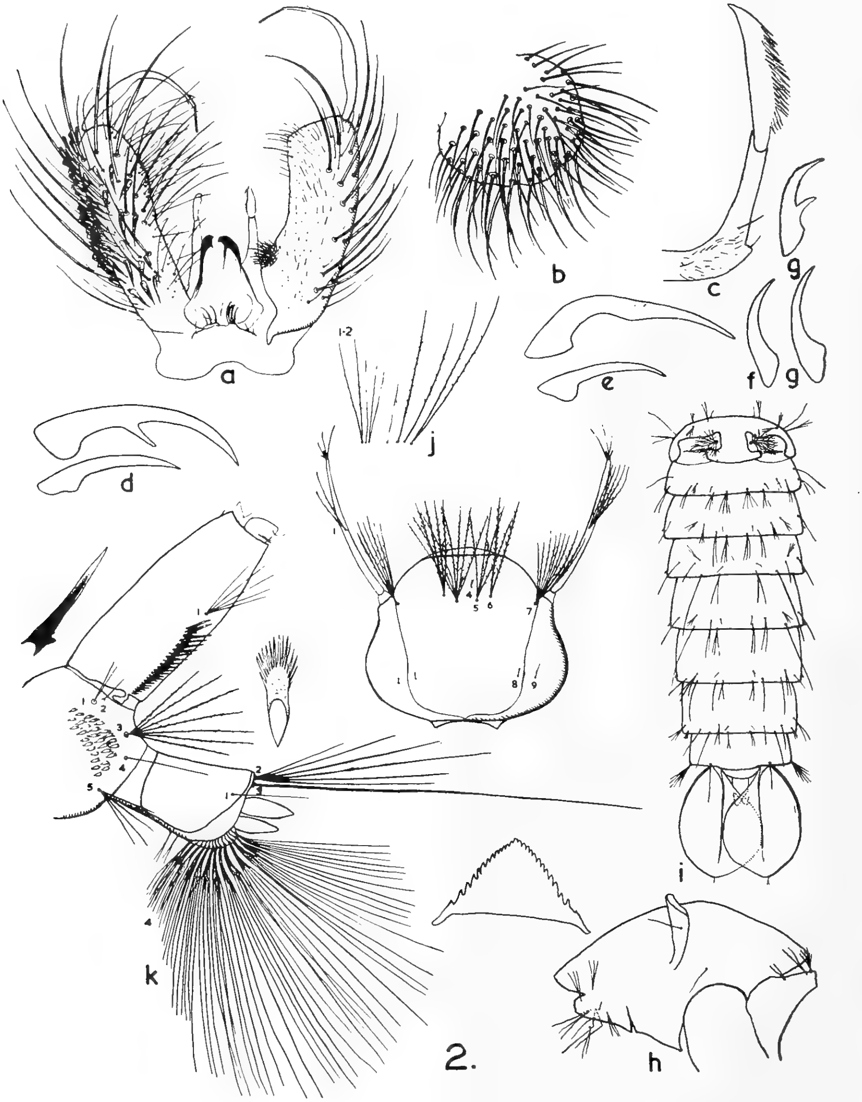

Fig. 2.—*Aëdes purpuriventris* Edwards. *a-c*, ♂ terminalia: *a*, left coxite sternal aspect, right tergal aspect; *b*, basal lobe; *c*, harpago; *d-f*, ♂ tarsal claws: *d*, fore; *e*, mid; *f*, hind; *g*, ♀ tarsal claw; *h-i*, pupa: *h*, cephalothorax and metanotum; *i*, abdomen; *j-k*, larva: *j*, prothoracic seta; *k*, head, mentum and terminal segments.

Variation. *Aë. purpuriventris* collected at Lorne, Victoria, were fairly uniform, but those from Robe, S.A., show a few variations: females often have the second sternite pale-scaled and segments 6 and 7 of abdomen purple-black-scaled. A great deal of variation is found in specimens from Lyonville, Victoria. Some have lighter integument and dark goldish scales on scutum, others have large curved pale scales, instead of broad ones on the lower part of the posterior pronotum. Tergite 5, mottled; 6 and 7 may be ochreous-scaled. Sternites may be ochreous with more or less black mottling. Tarsal claws of all legs toothed or simple; there are specimens which have both types of claws. In males there may be narrow basal bands on tergites.

Pupa. Details shown in Figure 2, *h*, *i*.

Larva. Head, siphon and saddle light brown. Head about six-sevenths as long as broad. Antennae long, thin, curved, slightly shorter than length of head. Seta 1 arising near mid-length, 2–5-branched. Head seta 4, 2–3-branched; 5, 4–6-branched; 6, 2–4-branched; 7, 6–11-branched; 8 and 9, 2-branched. Thorax: Prothoracic setae: 1 and 3, 1–2-branched; 2, 4, 5 and 6, single; 7, 2-branched. Abdomen: VIIIth segment: Lateral comb patch of 28–35 coarsely fringed scales. Seta 1, 3–4-branched; 2, single or 2-branched; 3, 7–8-branched; 4, single; 5, 3–5-branched. Siphon short with index 2·3–3·0. Pecten of 18–23 close-set dark spines distinctly paler towards tip and with one large stout, and 1–3 small, denticles at base. Seta 1, 4–6-branched arising about mid-length of siphon. Anal segment: Saddle almost complete ring; small separate elongate sclerotized plate at lower proximal angle of saddle. Seta 1 and 3 single; 2, 6–8-branched; 4 (ventral brush) of 16–17 tufts, 2–3 of which are precratal. Anal papillae equal, pointed, about half length of saddle; lower pair shorter than upper one.

Biology. *Aë. purpuriventris* is a spring species. It breeds in shaded ground pools and shows a preference for pits 2–3 feet deep; larvae are also commonly found in pools under uprooted trees. In South Australia larvae have been found breeding in flooded rabbit burrows. Adults have not been collected later than the end of January.

Larvae have been found in association with those of *Aë. queenslandis*, *Aë. calcariae*, *Aë. flavifrons* and *T. inconspicua*.

Biting Habits. During the spring and early summer it is a day biting mosquito, but on hot days in December or January it bites only after sunset. It does not bite man as readily as does *Aë. flavifrons*.

Distribution. Specimens have been examined from the following localities: VICTORIA: Baxter, Maroondah, Ballan, Lyonville, Lorne, Cape Otway (N. V. Dobrotworsky); Maryvale (G. W. Douglas). SOUTH AUSTRALIA: Robe, Shellbank, El Cantara, L. Eliza (E. W. Lines). It also has been recorded in Tasmania (Edwards, 1926); it has not been recorded from New South Wales or Western Australia.

AËDES CLELANDI (Taylor).

Culicada clelandi Taylor, 1914, *Trans. ent. Soc. Lond.*, 1913: 690. *Aëdes clelandi* Edwards, 1924, *Bull. ent. Res.*, 14: 379.

Distinctive Characters. Adult: Posterior pronotum with narrow curved scales only. Post-spiracular area mostly with narrow curved scales. Wings unmottled. Femora and tibiae unmottled; hind femora dark on apical quarter or half anteriorly. Tarsal segments with some pale scales at base. Tergites usually with basal bands. Male terminalia: Apical lobe of coxite with small setae only. Harpago with large thumb near base. *Larva*: Head seta 5, 2-branched; 6, single. Siphon short with index 2·0–2·5. Lateral comb patch of 19–21 fringed scales with central tooth twice as long as nearest one. Saddle complete ring. Ventral brush without precratal tufts.

Description of Adult.

Male. Head: Vertex clothed with pale curved, and brown upright, scales. Proboscis and palps black-scaled. Palps longer than proboscis. Thorax: Integument reddish-brown. Scutum clothed with golden scales and some scattered black ones. Scutellum with narrow pale scales. Anterior pronotum with narrow pale scales. Posterior pronotum with narrow curved scales pale below, black above. Pleura with patches of broad flat scales, except scales on post-spiracular area which has patch of narrow and only a few elongate scales. Lower mesepimeral bristles usually absent, rarely 1–2 present. Knob of haltere dark with pale scales. Legs: Fore and mid femora, and tibiae dark-scaled above, pale beneath. Hind femora dark on apical quarter or half anteriorly, a few paler scales on dark distal part of femur. Hind tibiae and first tarsal segment of all legs with pale scales beneath and some on black dorsal side. Tarsi unbanded, but with some pale scales at base of first 2–3 segments. Claws (Fig. 3, *c*, *d*, *e*) of fore and mid tarsi toothed, of hind tarsi simple. Wing length: 3·5–4·7 mm. Tergites black-scaled with basal bands. Sternites black-scaled with white lateral basal patches. Terminalia (Fig. 3, *a*, *b*): Coxite dark-scaled sternally and laterally, with several strong

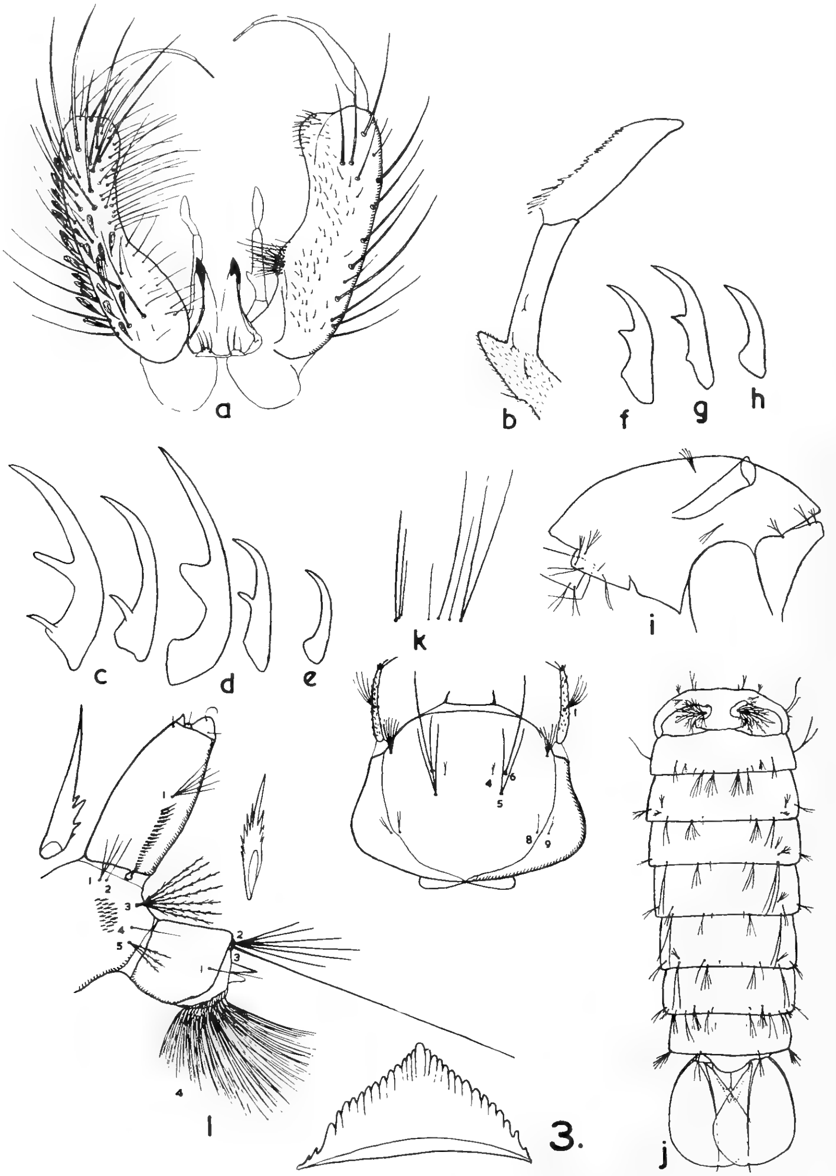

Fig. 3.—*Aëdes clelandi* (Taylor). *a-b*, ♂ terminalia: *a*, left coxite sternal aspect, right tergal aspect; *b*, harpago; *c-e*, ♂ tarsal claws: *c*, fore; *d*, mid; *e*, hind; *f-h*, ♀ tarsal claws: *f*, fore; *g*, mid; *h*, hind; *i-j*, pupa: *i*, cephalothorax and metanotum; *j*, abdomen; *k-l*, larva: *k*, prothoracic setae; *l*, head, mentum and terminal segments.

setae. Tergal aspect of coxite with small setae along its inner side and long strong setae laterally and apically. Sternally coxite has long goldish setae mesially on apical half. Apical lobe with about 20 short fine setae. Basal lobe rounded plate with numerous moderately long setae. Style about half length of coxite, curved and swollen at about mid length; apical third slender. Appendage about one-quarter length of style. Harpago stout, curved, with prominent thumb near base; basal third with numerous fine setae and 3–4 larger ones; appendage almost as long as harpago, fimbriated; tip blunt. Paraproct with single tooth. Lobes of IXth tergite with 3–5 strong setae.

Female. Female differs from male as follows: Palps about one-fifth length of proboscis. 1–3 strong, pale lower mesepimeral bristles. Claws (Fig. 3, *f*, *g*, *h*) of fore and mid tarsi equal toothed, of hind tarsi simple. Wing length: 3·4–4·9 mm. Cell R_2 about 2·7 times its stem. Abdomen: Tergites violet-black-scaled, with basal creamy-white bands which may be reduced to a few pale scales and lateral patches; seventh tergite may be mottled. Sternites ochreous-scaled; black scales may form central patch, may be scattered, giving a mottled appearance, or may be few in number.

Pupa. Details shown in Figure 3, *i*, *j*.

Larva (Fig. 3, *k*, *l*). Head, siphon and saddle light brown. Head about three-quarters as long as broad. Antenna short and stout, less than half length of head; seta 1 arising near mid-length of antenna, 4–5-branched. Head seta 4, 2–3-branched; 5, usually 3-branched; 6, single; 7, 6–8-branched; 8, 1–2-branched; 9, 2-branched. Mentum with 14–15 small lateral teeth. Thorax: Setae 1–6 single; 7, 2–3-branched. Abdomen: VIIIth segment: Lateral comb of 19–21 scales fringed at base, and with central tooth twice as long as nearest lateral one. Seta 1, 3-branched; 2 and 4, single; 3, 7–8-branched; 4, 3–4-branched. Siphon short, with index 2·0–2·5. Pecten of 19–21 spines, with one large, stout denticle and 1–3 small ones. Seta 1, 5-branched, arising about mid length of siphon. Anal segment: Saddle complete ring. Separate small, elongate sclerotized plate ventro-laterally near saddle. Seta 1 and 3, single; 2, 6–7-branched; 4 (ventral brush), of 16 tufts. Anal papillae short, pointed, upper pair less than half length of saddle, lower pair shorter.

Biology. Aë. clelandi is a spring species. Larvae have not been found in the field in Victoria, but presumably the breeding sites are similar to those recorded elsewhere. In Western Australia *clelandi* breeds in freshwater pools with or without vegetation (Britten, 1955); in South Australia larvae have been found with those of *Aë. calcariae* in flooded rabbit burrows where the water may be two feet below ground level and heavily contaminated with rabbit faeces (Marks, 1957). Adults have been collected as early as July (Britten, 1955), but in Victoria they are most common during September–November. On Phillip Island they occur in numbers in the tea-tree scrub adjoining the shore.

Biting Habits. It is a day biting species which attacks man.

Distribution. Specimens have been examined from the following localities: Victoria: Phillip Island, Lower Tarwin (N. V. Dobrotworsky). South Australia: Calcaria, Robe, Cantara, L. Eliza (E. W. Lines); Warren R. (W. D. Dodd). Western Australia: Cowdale (F. N. Ratcliffe); Janangara, Emu Pk., Albany, Forestdale, Bullsbrook, Canning Bridge, Darkan, Dale River (McIntosh); Lancilia, Albany, Denmark, Karagullen (E. J. Britten). Flinders Island: Lady Barron (F. N. Ratcliffe); Vinegar Hill (J. H. Calaby). *Aë. clelandi* has not been recorded in New South Wales or Tasmania.

Aëdes calcariae Marks.

Aëdes calcariae Marks, 1957, *Pap. Dep. Ent. Univ. Qd.*, 1 (5): 74.

The additional records are: Victoria: Yellingbo, Sylvan, Grampians, Gorae West, Homerton.

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FLORAL STRUCTURE AND ANATOMY IN THE FAMILY STYLIDIACEAE SWARTZ.

By R. C. Carolin, University of Sydney.

(Twenty-three Text-figures.)

[Read 27th July, 1960.]

Synopsis.

The floral structure and anatomy of species of all genera in the family are described. The floral structure seems quite different from that found in Goodeniaceae, although some similarities are noted. Various phylogenetic trends within the family are suggested and its inclusion within the Campanales is questioned.

Introduction.

Although Mildbraed has dealt with the gross morphology of the flowers of this family fairly exhaustively, little has been published on the microscopic structure. Morren (1838) dealt with the structure of the gynostemium in relation to the trigger movement. Saunders (1939) gives a rather superficial account. Subramanyam (1950, 1951) gives an account of the floral structure of *Levenhookia dubia* and *Stylidium graminifolium*, but he does not deal with vasculation in either.

Details of the techniques used in this investigation will be found in Carolin, 1959.

Observations.

Donatia.

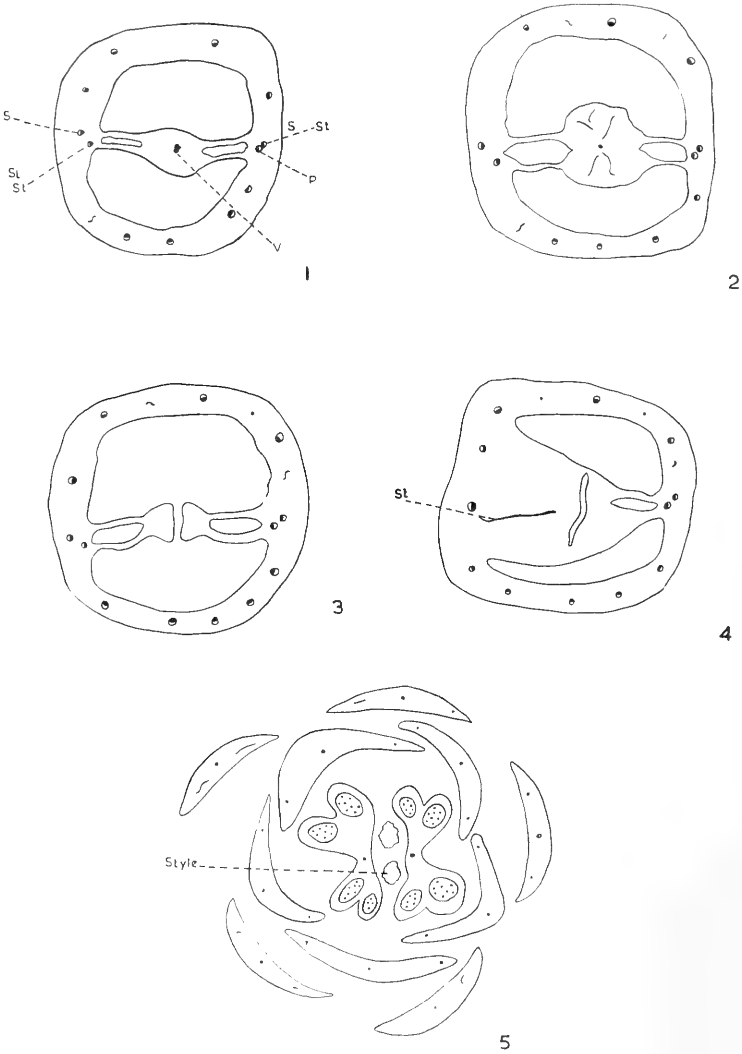
Two species are recognized; in both, the stamens are free from the style except just at the ovary dome. *D. fascicularis* is a South American species possessing three stamens. Unfortunately no suitable material was available for examination.

D. nova-zelandiae Hook. f. This species has two stamens only. The divergence of bundles from the receptacular stele may be somewhat irregular. Generally two series of five bundles diverge, one series on the sepal radii somewhat lower than the second on the petal radii. These may branch later so that smaller bundles are found in the pseudo-ovary wall in addition to the ten main cords. Quite low in the pseudo-ovary wall two bundles diverge from the main cords on petal and sepal radii at the junction of the ovary septum and the pseudo-ovary wall (Figs 1, 22). These eventually pass into the stamens. The main cords pass on into the free regions of the floral parts, branching only when these become free from one another. The petal lateral bundles are derived from the petal main bundles and likewise the sepal laterals from the sepal mains (Fig. 5). The stamens are shortly united to the stylar base and become free almost immediately. There is apparently no vascular supply in the style itself which bifurcates near the ovary dome.

After the divergence of the main cords to the pseudo-ovary wall the receptacular stele is resolved into a single bundle with a central xylem mass and irregular patches of phloem surrounding it. This passes into the ovary septum which consists of two sheets of parenchymatous tissue on either side of a solid core of placentae and connecting this latter to the ovary wall (Figs 1, 2). Thus the ovary is bilocular in this region, where the ovules are attached. The vascular strand in the placental axis is completely used up in supplying the ovules. Just above the highest ovule insertions a split appears in the central (sterile) axis and the ovary appears unilocular (Fig. 3). Immediately beneath the ovary summit the two halves meet once again to produce another bilocular zone. The ovary dome appears to be generally, although weakly, nectiferous (Fig. 17).

Phyllachne.

P. colensoi Berggren. A varying number of bundles (about ten) separate from the receptacular stele almost together. They pass upwards into the pseudo-ovary wall. The bundles supplying the six petals and six sepals are resolved in no apparently regular order from these cords. In the cortex of the receptacle the two lateral cords divide and the inner members pass upwards into the gynostemium (Figs 6–10). They are, apparently, the staminal bundles, as they supply the two bilocular anthers on either side of the stigmatic lobes. The stigmata receive no vascular strands at all.

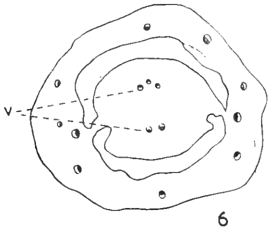


Figs 1-5. *Donatia nova-zelandiae.*—1. Pseudo-ovary, lower zone, below ovular insertion; 2. pseudo-ovary: zone of ovular insertion; 3, pseudo-ovary: "unilocular" zone; 4, pseudo-ovary: upper "bilocular" zone; 5, flower above ovary. × 20.

Above the divergence of the cords to the pseudo-ovary wall, the receptacular stele, consisting generally of five bundles, passes into the enlarged placental axis (Fig. 6). The ovary is bilocular in this zone. Higher up, the septum aborts on either side of the placental axis and the ovules are attached in this unilocular region (Fig. 7). The vascular tissue is completely used up in supplying the ovules inserted on this free central placenta. Above the ovular insertions the axis splits into two halves (Fig. 8). These strands are unvasculated and they eventually join together, and to the ovary wall, to regenerate an apparently bilocular condition (Fig. 9). There is a double, somewhat irregularly lobed nectary at the base of the gynostemium on the ovary dome. No vascular bundles were observed to enter it.

FORSTERA.

Similar in all respects to *Phyllachne*.



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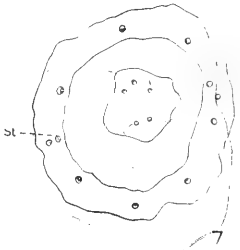

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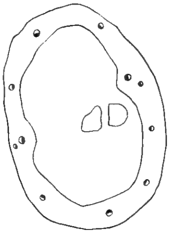

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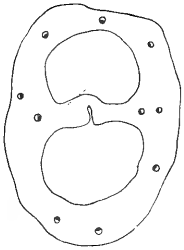

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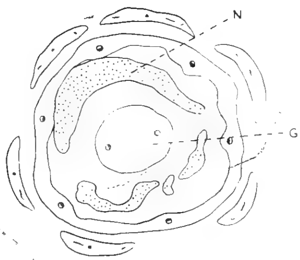

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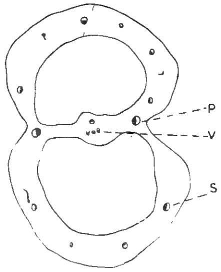

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Figs 6-10. *Phyllachne colensoi.*—6, Pseudo-ovary: lower "bilocular" zone below ovular insertion; 7, pseudo-ovary: "unilocular" zone showing free central placentae; 8, pseudo-ovary: upper zone of ovary showing sterile parenchymatous strands; 9, pseudo-ovary: uppermost "bilocular" zone; 10, flower above ovary. × 20.

Fig. 11. *Stylidium graminifolium.*—Pseudo-ovary: lowermost zone below ovular insertion. × 16.

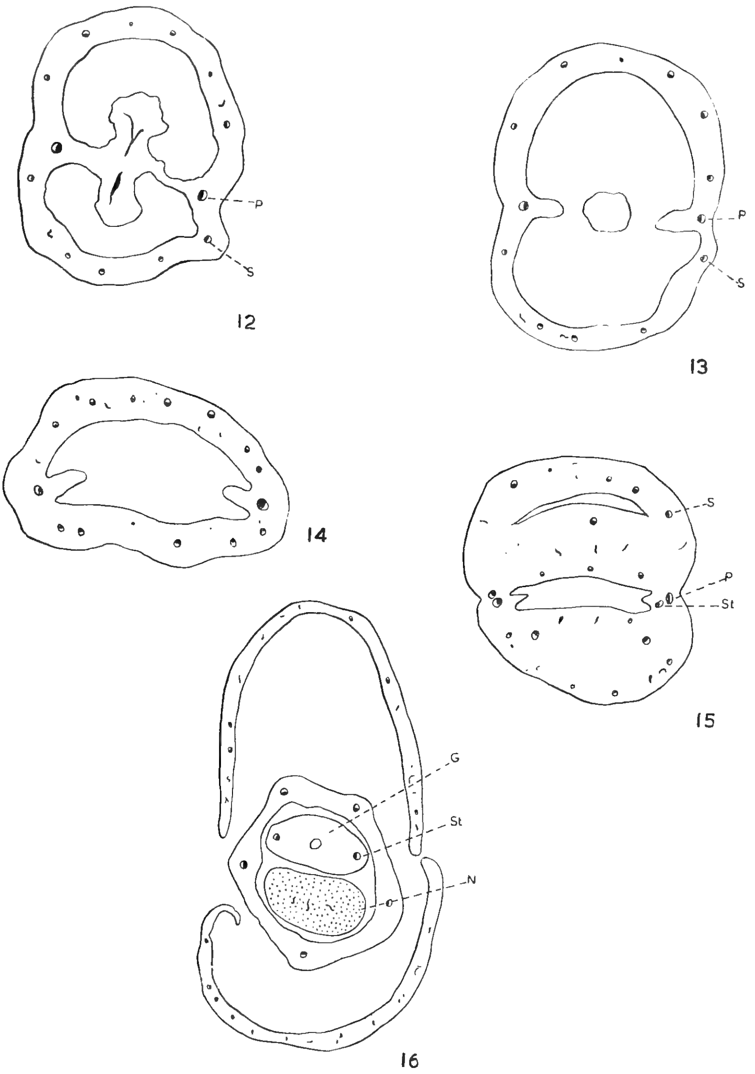
OREOSTYLIDIUM.

Similar to *Phyllachne* except for the absence of the sterile strands connecting the placental axis to the ovary summit and the apparently bilocular condition in the region of ovule insertion.

STYLIDIUM.

Unfortunately no species of the section *Forsteropsis* were available for study. Mildbraed (1908), however, gives fairly clear illustrations of some of the member species. The gynostemium is of a rather specialized type, whereas the ovary shows some features which can be considered primitive. Notable in this respect are the two parenchymatous strands attached to the placental axis, as in *Phyllachne*, but apparently free from the ovary summit.

S. graminifolium Swartz. In the receptacle ten bundles diverge from the central stele, five on the sepal radii somewhat lower than the other five on the petal radii. The residual stele also consists of five bundles. The ten main cords in the pseudo-ovary wall give off smaller branches irregularly, which form a network throughout the wall, but the number of main cords remains constant (Figs 12–14). At the ovary dome most of these outer bundles give off weak strands which converge upon the base of the gynostemium. Those strands in the posterior position fade out, whereas those in the

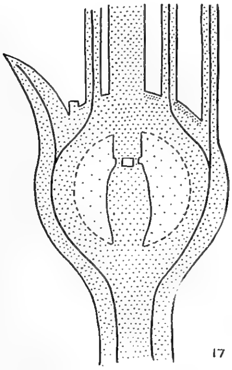


Figs 12-16. *Stylidium graminifolium.*—12, Pseudo-ovary: zone of ovular insertion; 13, pseudo-ovary: "unilocular" zone showing (sterile) free central placentae; 14, pseudo-ovary: upper zone; 15, ovary dome; 16, flower above ovary. × 16.

Key to Figures 1-16—S, Sepal main bundle or cord in pseudo-ovary wall on sepal radius. P, Petal main bundle or cord in pseudo-ovary wall on petal radius. St, Staminal bundle. G, Gynostemium. V, Placental bundle(s). N, Nectary.

anterior position are diverted into the large nectary at the base of the gynostemium (Figs 15, 16). Also at the ovary dome the bundles supplying the anterior-lateral petals distribute one large trace each into the gynostemium. This represents the sole supply to the anthers; no vascular tissue, apparently, is distributed to the stigmata (Figs 15, 16, 21, 23).

The placental supply is derived from the five bundles remaining in the receptacle after the divergence of the cords to the pseudo-ovary wall. The anterior two and the posterior three amalgamate, in that combination, to form two strands which pass into the placental axis. These bend horizontally into the two swollen placentae, branch profusely, and are totally used up in supplying the ovules. Throughout most of the region of ovular insertion the septum and placental axis divides the ovary into two loculi. At the upper part of this region the septa part from the placental axis on either side, leaving a free central column which is sterile in its upper part and free from the ovary summit (Figs 12, 13, 19). The inturned edges of the abortive septa remain quite apparent (Figs 14, 15).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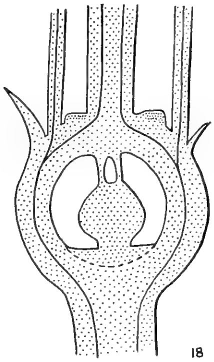
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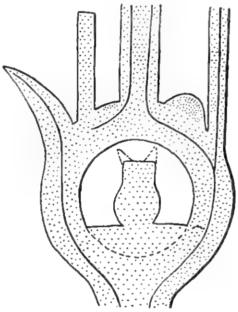
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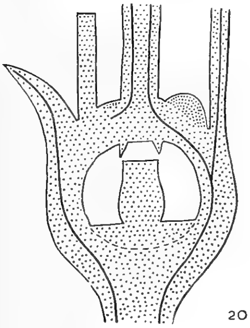
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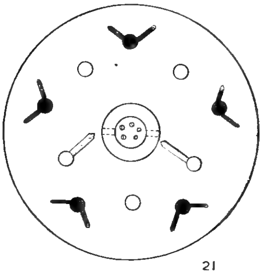
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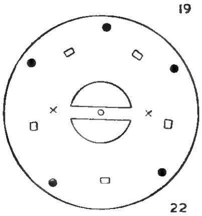
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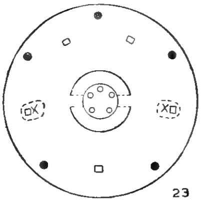
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Figs 17-20.—Diagrammatic, lateral, longitudinal sections of pseudo-ovaries: 17, *Donatia*; 18, *Phyllachne*; 19, *Stylidium*; 20, *Levenhookia*.

Fig. 21.—Generalized plan of the distribution of vascular bundles at the ovary dome of *Stylidium*.

Figs 22, 23.—Diagrammatic transverse sections of pseudo-ovaries: 22, *Donatia*; 23, *Stylidium*.

S. laricifolium Rich. Very similar to the preceding species.

S. adnatum R.Br. This species was not examined in the present investigation, but it is mentioned here as an example in which one of the loculi is almost completely aborted (Saunders, 1939).

In many species illustrated by Mildbraed (1908) the septa have apparently completely aborted and the ovules are borne on free-central placentae. However, he also pictures *Phyllachne* as showing this condition, whereas the septa are present but very low in the ovary. The same situation may apply in some, at least, of the *Stylidium* species so figured.

LEVENHOOKIA.

L. dubia Sond. in Lehm. With regard to vasculation and structure of the ovary this species is similar to *Stylidium.* The septa are complete at the base of the ovary, but almost immediately lose contact with the placental axis. Ovules are inserted in the free-central region only. At the top of the loculus the inturned margins of the abortive septa rejoin, so that it appears that two parenchymatous sheets project downwards from the ovary roof but without making contact with the placental axis. Thus the uppermost, divided region of the ovary is present in this species although absent in *Stylidium.* Subramanyam (1950) figures this, but contents himself with calling it a "structure" and does not attempt to interpret it (Fig. 20).

DISCUSSION AND CONCLUSION.

The family is rather more uniform than the Goodeniaceae. The changes of the floral structure are mainly concerned with the loss of the septa connecting the placental axis to the ovary wall, with the condensation of the vascular supply, and with the union of the stamens and style into a gynostemium. These trends are summed in Figures 17, 18, 19, 20, 22 and 23.

Donatia is clearly the most primitive member of the family. The stamens are free from the style, the ovary septum is complete except for a very small zone near the summit, and the staminal vascular supply is free for the greater part of the length of the pseudo-ovary wall. The ovary, then, is directly comparable with that of the Goodeniaceae, showing the same three vertical zones (Carolin, 1959). It is noted that even in this genus the style is not supplied with vascular tissue.

In all the other genera the stamens and style are united into a gynostemium and staminal strands are united to the adjacent main cords in the pseudo-ovary wall (Figs 18, 19).

The ovary shows a phylogenetic progression to the unilocular condition, but in a different direction from that of the Goodeniaceae. In the latter case it is due to splitting in the axis itself, indicating how parietal placentation may arise from axile, although it does not actually occur (Carolin, 1959). In the former case it is due to the separation of the septum on either side of the swollen placental axis leaving a free-central placenta. In *Phyllachne* this septal abortion leaves two strands connecting the axis with the ovary summit (Fig. 18). These represent the two thickened ends to the septa in the medial zone of *Donatia* (Figs 3, 17). In *Stylidium* sect. *Forsteropsis* these strands have lost their connection with the summit; in other *Stylidium* spp., they have aborted altogether; and in *Levenhookia* they have lost their connection with the placental axis (Figs 19, 20). Through *Stylidium* and *Levenhookia* there is a progressive shortening of the septate zone until the placenta appears quite free, but there seems to be no progression to a reduction in the number of ovules as in Goodeniaceae (Carolin, 1959).

The vascular supply to the placenta of *Phyllachne* (Figs 6, 7) and *Stylidium graminifolium* suggests that the ovary is derived from five carpels, the five central bundles remaining as discrete entities, often into the placental axis (Fig. 11). There are no vascular supplies to the style or stigmata; therefore there is no further evidence in this direction. It can be suggested, then, that the loculi of the ovary, when they are present (pseudo-carpels), are compounded one of two and one of three carpels, although it is impossible to decide the position of these morphologically different carpels due to the absence of carpel dorsal strands (Fig. 21).

The same considerations with regard to the pseudo-ovary wall apply in this case as in the Goodeniaceae (Carolin, 1959).

The nectary, which, as in the case of Goodeniaceae, may be derived from the ovary wall, shows a progressive concentration to an anterior position. In *Donatia* the summit of the ovary is nectiferous and in *Phyllachne* the nectary is a double, irregularly lobed structure in that position (Curtis, 1946). In *Stylidium* there is a large, domed protuberance on the ovary dome in the anterior position and a much smaller one posteriorly. In all species, except one, there is no vascular supply to the nectary, implying that it has no relationship with aborted floral organs. Only in *Stylidium graminifolium* is there a weak and irregular supply of xylem and phloem derived from the network of bundles which passes below the nectary and ends in the base of the gynostemium in other species (see Subramanyam, 1951). A vascular supply may have been diverted from its normal path by some intense gradient operating at the critical time, possibly an increase in sugar and water requirements of the nectary. This may indicate how it is possible for the direction of a bundle to be changed in the phylogenetic sense.

Rapson (1952–1953) has maintained the separation of the Donatiaceae from the Stylidiaceae on the grounds of anatomical differences in parts other than the flower. In view of the plausibility of interpreting the flowers of *Donatia* as the basic type of the family, in the phylogenetic sense, it seems unprofitable to divide the family as recognized by Mildbraed (1908).

Various other authors have suggested that *Donatia* shows affinities with the Saxifragaceae; indeed many systematists have placed it in that family, e.g., Bentham and Hooker in the "Genera Plantarum". Both the superficial construction of the flower and the vegetative appearance point to such a relationship. The family, however, seems to be a natural unit, possibly showing affinities with Campanulaceae or Saxifragaceae (those Saxifragae with an inferior ovary). These two groups are so different that it seems unlikely that a dual relationship is possible. Rapson decided that his anatomical studies indicated a Campanalian affinity, but his evidence is slender and nowhere does he attempt a critical comparison with the anatomy of *Saxifraga*. Mildbraed gives much weight to the occurrence of inulin in *Stylidium* and in many members of the Campanales. But, as Rapson points out, inulin has too wide a distribution in the Angiosperms for its presence to be of much phyletic value.

The structure of the ovary of Stylidiaceae belongs to the same general pattern as that of the Campanales (Carolin, 1959, unpub.), but this pattern is not uncommon in other groups and can be given little weight. Indeed, Saunders (1939) indicates that the ovary of *Saxifraga* is bilocular below and unilocular above. Union of the bases of the styles of this genus would produce the situation found in *Donatia*.

Subramanyam (1951) gives a list of similarities with regard to the embryo-sac and embryo morphology, but most of these characteristics are also widely distributed. He also says: "*Stylidiaceae* . . . resembles *Lobeliaceae* in having zygomorphic flowers and confluent anthers." At least three genera within the family have actinomorphic flowers and the anthers are not strictly connate (certainly not in *Donatia*), but are adnate to the style.

The glandular hairs present in many of the Stylidiaceae are found elsewhere in the Campanales only in Goodeniaceae, although they occur commonly in *Saxifraga* (Engler, 1916–1919). Also tannin cells occur commonly in Stylidiaceae (also see Rapson, 1952–1953) and in Saxifragaceae (Metcalfe and Chalk, 1950), but are uncommon or even absent in Campanulaceae.

The systematic position of the family is obscure. Indeed, a consideration of the pollen-presentation structures, which will be published separately, suggests even more strongly that the affinities may not be with the Campanales. More evidence with regard to the Saxifragaceae is needed before the position of Stylidiaceae can be further determined.

Professor W. R. Phillipson, Professor N. S. Bayliss and Miss B. J. Briggs have collected material which was used in this investigation. The collection of the rest was made possible by a research grant from the University of Sydney.

VOUCHER SPECIMENS EXAMINED.

Phyllachne colensoi (Hook. f.) Berg., Mt Rufus, Tasmania. B. Briggs 1.1958. SYD. *Forstera bellidifolia* collected by Miss B. G. Briggs. No voucher. *Donatia nova-zelandiae* Hook. f., collected by Prof. N. S. Bayliss. No voucher. *Stylidium graminifolium* Swartz, Oatley, W. J. Peacock. Jan. 1958. SYD. *Stylidium laricifolium* Rich., Khyber Pass, N.S.W. R. Carolin, no/389. 6.10.1957. SYD. *Levenhookia dubia* Sond. in Lehm., Triangle Res. Brackleeby, N.S.W. E. J. McBarron, no. 4952, 25.9.1950. SYD.

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THE STRUCTURES INVOLVED IN THE PRESENTATION OF POLLEN TO VISITING INSECTS IN THE ORDER CAMPANALES.

By R. C. Carolin, University of Sydney.

(Plate ii; five Text-figures.)

[Read 27th July, 1960.]

Synopsis.

A comparison of the structures within which pollen is presented to visiting insects in the families Campanulaceae, Goodeniaceae and Stylidiaceae is made. It is shown that the indusium of the Goodeniaceae is not homologous to the pollen collecting hairs of the Campanulaceae. The indusium consists of an upgrowth from the style immediately below the stigmatic branches, variously modified. In *Leschenaultia* the stigmatic function is transferred to the outer surface of the upper lip of this indusium. Furthermore it is noted that in the Stylidiaceae pollen is invariably presented whilst still contained within the anther loculi. The term "pseudo-indusium" is proposed for the compound structure in the Lobelioideae consisting of connate anthers, closed stigmatic branches and stylar hairs. The results suggest that the Order may not be monophyletic. It is suggested that the naked presentation in Campanuloideae developed in drier climates and an intrusion into wetter conditions may have been the selective factor operating to produce the protected presentation of Lobelioideae and Goodeniaceae.

The Order Campanales as constituted by Hutchinson (1926) is characterized by the presentation of the pollen in, or on, certain structures directly associated with the style. The sole exception appears to be *Donatia*, in the Stylidiaceae, in which pollen is presented directly from the anther lobes which are free from the style. It is primarily the similarity in situation of these structures which has been responsible for uniting the three families, usually with the inclusion of Calyceraceae and Compositae, in the Order Campanales (Campanulales or Campanulatae) (see Rendle, 1938).

CAMPANULACEAE.

The pollen-collecting hairs of the Campanulaceae have received considerable attention in the past. These hairs are situated at various positions on the style, the anther lobes, at anthesis, being closely applied to the style. With the growth of the style and the shrinkage of the stamens, or both, pollen is brushed from the anther lobes by the pollen-collecting hairs. These hairs, moreover, at this stage commence to collapse and, in some genera, to invaginate into the large bulbous base. This is particularly marked in *Campanula* (Brongniart, 1839; Hassall, 1842). The latter author has suggested that the collapse, etc., is due to extraction of "juices" (water), and this seems quite feasible. Knuth (1909) remarks that the collapse makes it easier for the pollen grains to be dislodged by visiting insects, and this is the author's experience with *Campanula*, *Wahlenbergia*, *Phyteuma* and *Specularia*. This form of pollen presentation is fairly constant throughout the family with various modifications. The most important point to note is that the pollen collecting hairs are formed from a single epidermal cell (Text-fig. 3, C; Plate ii). The plate shows that in *Campanula* most of the epidermal cells undergo a tangential division to form a hypodermis, those destined to form pollen-collecting hairs do not, however, and subsequently undergo considerable basal enlargement.

The most interesting departure from this general scheme is shown in certain sections of *Phyteuma*; *P. orbiculare* was the species examined. Knuth (1909) states that the pollen is deposited upon the style in the usual manner, but when the filaments shrivel the top of the corolla forms a closed tube around the style. Furthermore, the lower parts of the corolla lobes become free whilst the upper parts remain coherent and pressing the pollen onto the style. It seems that the upper tube and style are stuck very tightly together, and also that the corolla is growing much faster than the style; the consequence is that the lower, free parts of the corolla-lobes bend outwards. Knuth considers that the style now elongates, carrying pollen upwards, scouring it out of the tube. The mechanism, however, is a little more subtle than that. There is a considerable period in the life of each flower when the corolla is retaining the style and the whole structure appears to be in a state of tension. The style is lying loosely in the tube at this stage, probably due to the collapse of the pollen-collecting hairs. Insects, and Knuth cites the fairly heavy bee and bumble-bee, visiting the flower alight or crawl onto the lower curved part of the corolla-lobes. This forces the upper, tubular part downwards, splitting the coherent tips and exposing the pollen-covered closed stigmatic lobes and style. Subsequently the style elongates and the stigmatic lobes recurve and become receptive.

Thus, in those *Phyteuma* species allied to *P. orbiculare*, i.e., sections *Hedranthum* and *Synotoma*, an increase in efficiency of pollen use has been evolved. The pollen is actually retained within a structure until its deposition onto an insect is imminent. This represents a general phylogenetic trend in the Campanales, as will be shown later, and there seems no reason why the term "pseudo-indusium", proposed below for a similar structure, consisting of different morphological units, in the Lobelioideae should not be extended to the corolline "pseudo-indusium" of *Phyteuma*.

In the Lobelioideae the pollen-collecting hairs are concentrated onto the stigmatic branches, often more or less in a ring. In this case the pollen is presented in a structure compounded of the anthers as walls and the hair ring and closed stigmatic branches as the floor. The pollen is shaken out of this structure by agitation of the hairs on the apex of the anthers (Text-fig. 3, D). When the stigmatic branches are opened and are eventually exserted from the anther tube the pollen is probably no longer viable. Thus, in the species that have been examined, *Lobelia syphilitica* L., *L. gracilis* R.Br., *L. alata* Labill., *Laurentia fluviatilis* (R.Br.) E. Wimm., *L. petraea* F. Muell., the hairs do not act strictly as a brush; in fact they form a "pseudo-indusium" (see below and Text-fig. 5).

GOODENIACEAE.

In the Goodeniaceae it is the indusium or pollen-cup at the top of the style in which the pollen is presented to visiting insects. Brough (1927) and Hamilton (1894, 1895) have described the pollinating mechanism. This involves dehiscence of the anthers in the bud and the deposition of the pollen within the indusium as the latter grows upwards between the connivent or coherent anthers. Pollen is pushed out of the indusium as the stigmatic surface grows and matures.

The microscopic structure of the indusium has not previously been described. Four main types of indusium are to be found within the family, based upon cellular type and the presence and position of hairs.

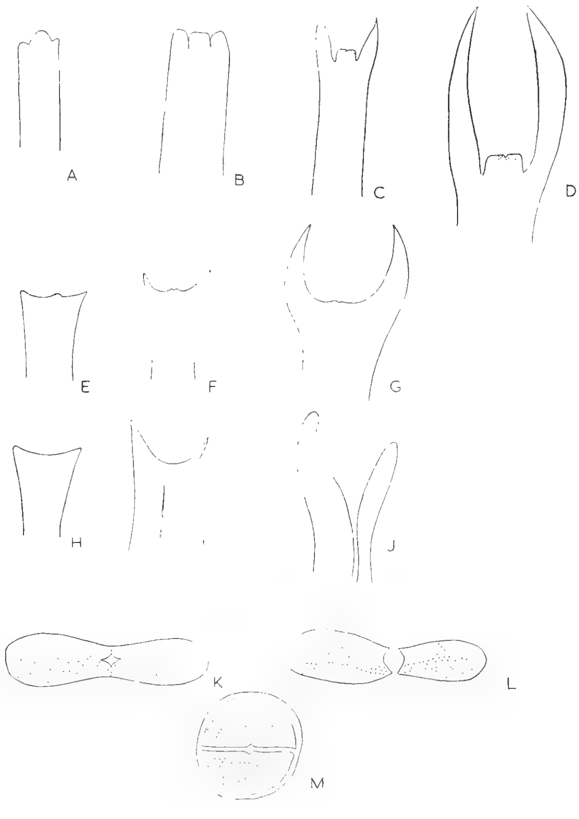
In *Leschenaultia* the two main lips of the indusium consist of somewhat elongated cells with thin walls. These cells are indistinguishable from the other cells of the style by the nature of their cell-walls (Text-fig. 1, B). The elongated cells are surrounded by an epidermis of more or less cubical cells, some of which, on the outer surface, are minutely papillose. The epidermal cells on the margins of the lips project as long hairs which function as a pollen brush, dislodging pollen from the dehisced anther lobes so that the tetrads fall into the indusium. The style has a central canal which is, apparently, always open at its upper end into the indusium and at its lower end into the ovary cavity. The upper opening is usually constricted by two large swellings at the base of the indusium (Plate ii). The position of the stigmatic surface presents a problem. Pollen tetrads, in fact, only germinate when they come into contact with the minutely papillose epidermal cells on the outside of the upper lip (Plate ii). Darwin (1871) was the first to note this and it was confirmed in this investigation for *L. biloba* and *L. formosa*. The indusium develops as a rim around the concave summit of the style. This rim gradually expands into the mature, bilabiate structure. The stylar canal does not become visible until fairly late in development (Text-fig. 2, H-J).

In *Dampiera* and *Anthotium* the indusium consists of an outer layer of relatively thin-walled epidermal cells which do not bear hairs except at the base. Beneath this epidermis there are a number of vertical rows of elongated cells with thick walls and deep pits (Text-fig. 1, A). The stigmatic surface is apparently limited to the edges of a furrow running across the floor of the indusium, morphologically parallel to the position of the ovary septum or its postulated position (see Carolin, 1959, and Brough, 1927) (Text-fig. 2, M; Plate ii). As the stigmatic surface grows it still remains limited

Text-fig. 1.—A, *Dampiera linearis* R.Br. indusium l.s. ×100. B, *Leschenaultia biloba* Lindl. indusium l.s. ×100. C. *Goodenia paniculata* Sm. indusium l.s. ×100.

to the edges of the cleft. In some species of *Dampiera* the indusium is 4-lobed and in others 2-lobed (see Hamilton, 1894, 1895) and in still others entire. It arises as a rim on the concave summit of the young style, in the centre of which is a small protuberance, and grows upwards into the mature structure (Text-fig. 2, E-G). The inner, thickened cells of the indusium are formed by both periclinal divisions of the epidermis and anticlinal divisions of the subsurface layers (see Text-fig. 3, A and B).

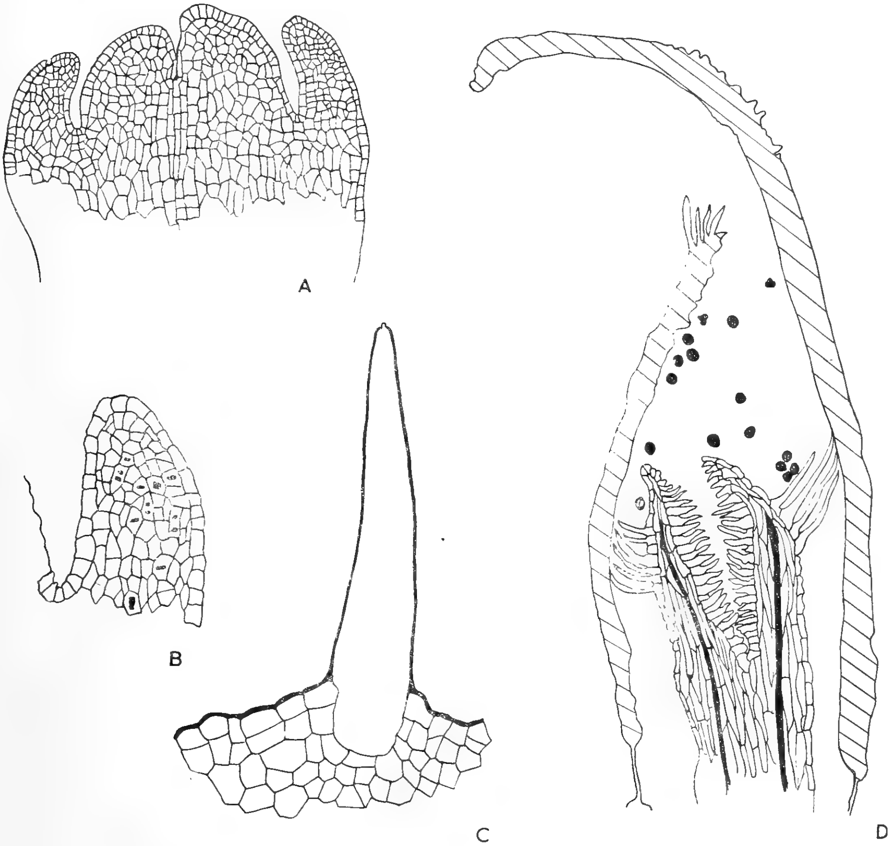
In *Brunonia* the upper part of the indusium has the same cellular structure as that of *Dampiera*, except that the epidermal cells are often projected into long hairs, although these latter do not occur on the margins of the lips. In the lower parts of the indusium the cells are more normally parenchymatous, shorter and with scarcely thickened walls (Text-fig. 1, D); it is bilabiate. The stigmatic surface is apparently limited to the edges of a cleft which extends across the top of the column in the indusium. This cleft is morphologically parallel to the ovary septum. The development of the indusium is similar to that noted in *Dampiera*.



Text-fig. 2.—A-D, Development of the indusium of *Goodenia paniculata* Sm. × 25. E-G, Development of the indusium of *Dampiera stricta* R.Br. × 25. H-J, Development of the indusium of *Leschenaultia biloba* Lindl. × 25. K-M, Surface view of stigmatic surface: K, *Goodenia ovata* Sm.; L, *Goodenia paniculata* Sm.; M, *Dampiera stricta* R.Br.

In the remaining genera that have been studied (*Velleia*, *Goodenia*, *Scaevola*, *Selliera*, *Verreauxia*) the indusia are similar. The epidermis consists of relatively thin-walled cells which are often elongated and which may project into hairs, especially on the margins. The inner cells are elongated, arranged in vertical rows, and have much thickened walls with prominent pits (Text-fig. 1, C). Some cells on the outside near the base may be relatively isodiametric with unthickened walls. The indusia may be

4-partite as in some *Velleia* or 2-partite as in some *Goodenia* or entire (see Krause, 1912). There is often a canal in the stigmatic column the shape of the opening of which gives the impression of the stigmatic surface having been originally 4-lobed (Text-fig. 2, K-L). The union of these four lobes, which may correspond to the postulated ancestral 4-carpellary condition of the ovary, has led to the almost uniform stigmatic surface of many species. In some, however, it is the cleft at right angles to the ovary septum which has become emphasized, e.g., *Goodenia pusilliflora*, *Calogyne berardiana* (Carolin, 1959), *G. paniculata* (Text-fig. 2, L), rather than the one parallel to the septum as in *Dampiera* (Text-fig. 2, M). In this group of genera the indusium first develops as distinct flaps of tissue on either side of the style and somewhat below the summit (Text-fig. 2, A-D). As in *Dampiera* the inner cells of the indusium are developed from both epidermal and subsurface layers (Text-fig. 3, A and B).

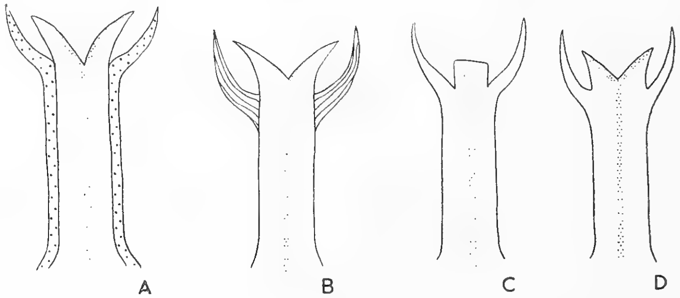


Text-fig. 3.—A, Young indusium of *Goodenia paniculata* Sm. l.s. × 160. B, Young indusium of *G. paniculata* showing cell divisions in upgrowth. × 320. C, Stylar hair of *Campanula*. × 160. D, Pseudoindusium of *Lobelia alata* Labill., stamens cross-hatched. × 80.

It should be noted that the stigmatic areas in all these genera, except *Leschenaultia*, are limited to the uppermost parts of the outgrowth from the floor of the indusium. Pollen grains do not germinate if they are merely in contact with the sides of this column (Text-figs 1, C-D, and 5).

The indusium of this family has attracted much speculation and several interpretations have been put forward, based on macroscopic appearance. Brown (1818) suggested that the indusium is derived from the upgrowth of an epigynous (or hypogynous) disc which he supposed to be modified stamens. He then draws a parallel between this indusium and the anther lobes of the Stylidiaceae, especially the female flowers of *Phyllachne*. This system of homologies is incomplete and confused. Applying the phylogenetic concept to these suggestions there are two separate ideas: (i) a nectary, modified from stamens which the nectary no longer resembles, has grown up and enclosed the style, and (ii) anthers have been modified to form an indusium.

With regard to (i) it would be difficult to eliminate it completely. But first there is a nectary still present in the Goodeniaceae and situated well below the style (Carolin, 1959), and secondly there is no differentiation of an outer layer to the style which may correspond to the upgrown nectary. Thus this derivation seems unlikely. With regard to (ii) one must go rather further than Brown. It must be postulated that the ancestors of both the Stylidiaceae and Goodeniaceae had two whorls of stamens, one whorl with a tendency towards adnation to the style. In the former family the free whorl has been lost, whereas in the latter the inner whorl has been modified into the indusium. But if *Donatia* is included in the Stylidiaceae this seems to be ruled out as it has only one whorl of free stamens and no indusium. In addition the indusium bears no structural relationship to an anther and a more satisfactory explanation can be found elsewhere. Goebel (1899) modified Brown's theory and considered the indusium to be an upgrowth from the receptacle (Text-fig. 4, A).

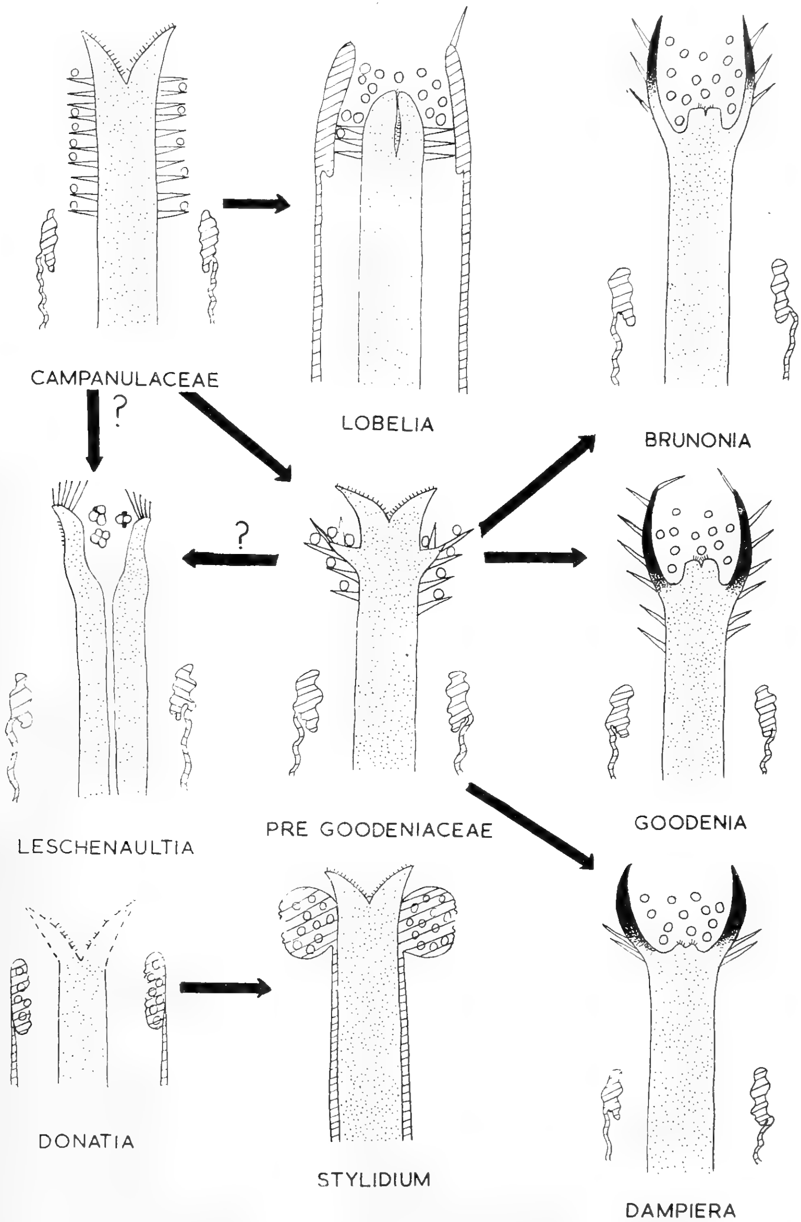


Text-fig. 4.—Interpretations of indusial structure: A, Brown, modified by Goebel; B, Lindley; C, Hanf; D, Author.

Lindley (1836) based his ideas on a rather more rigid system of logic. He suggested that the indusium consisted of a ring of hairs (as found in Lobelioideae) consolidated into a cup (Text-fig. 4, B). His thinking, however, was strictly typological and not phylogenetic. There are a number of reasons why the Lobelioideae cannot be the direct ancestors of the Goodeniaceae (Carolin, 1959), and from both typological and phylogenetic angles the indusium cannot be morphologically equivalent to the pollen collecting hairs of the Campanulaceae. If it were so, one would expect the indusium to consist of a series of elongate cells, continuous from base to the top, and the hairs projecting from it to be simply continuations of these cells. In addition one would expect the epidermis, as such, not to be continuous over the surface of the indusium, and the inner cells of the indusium to be derived from the epidermal cells of the young style as are the stylar hairs in Campanulaceae (Text-fig. 3, C). In fact none of these conditions are fulfilled (see above).

Hanf (1936) has put forward another view after extensive investigations of stylar structure in a number of families. In effect he suggests that the stigmatic surface, i.e., the external part of the pollen-transmitting tissue, is restricted to the notch between the stylar branches. The indusium then consists of the sterilized upper parts of these branches. Hanf's general interpretation of stylar structure has received some confirmation from the investigations of the carpels of the Magnoliales (Bailey and Swamy, 1951). If Hanf's views were sound in this case, one might expect to find vascular tissue in the indusium as in most stylar branches and also, as his own figures indicate, that the whole floor and/or column of the indusium would be stigmatic. As has been stated before, this is not so (Text-fig. 4, C).

The structures within the indusium correspond exactly to a normal style with rather reduced stigmatic branches which are usually separated by a cleft which may, or may not, correspond to the pseudocarpels (Text-figs. 1, 2, 5). Thus this structure can be considered as a continuation of the style proper. The indusium would then be simply an outgrowth of the style. Although the cells of the indusium have thickened walls, this is presumably an adaptation to make the indusium more rigid and, therefore, more efficient in collecting the pollen. In some cases there are echoes of a 4-partite constitution to the indusium, which may be related to the postulated primitive condition of the



Text-fig. 5.—Phylogenetic scheme to show modifications of the pollen presentation structures in the Campanales (||||| stigmatic surface).

ovary (Carolin, 1959). The hairs on the indusium provide further evidence for its stylar nature. Those at the margin may perform the same function as the hairs of the anther apex of Lobelioideae, but the evidence for rejecting the anther origin of this structure has been given above.

Leschenaultia is, in this respect as in others (Carolin, 1959), anomalous. Indeed Bentham (1869) has suggested that the upper lip of the indusium is stigmatic in origin and that the true indusium is represented by the lower lip and the hairs at the base of the upper lip. One would then expect the pollen-transmitting tissue (or in this case the stylar canal) to pass down the centre of the upper lip, which it does not do (Text-fig. 1, A). It is true that in the species which were examined the "stigmatic" surface is limited to the upper lip between the pollen brush and the stiff hairs at the base of the lip, but the position of the stylar canal precludes Bentham's explanation. It is possible that a transference of function has taken place here, the stigmata in *Leschenaultia* being represented by the two large protuberances at the base of, and inside, the indusium (seen particularly well in *L. formosa*, Plate ii). These, apparently, no longer function and certain cells on the external surface of the upper indusial lip have taken over the stigmatic function. Pollen grains are often capable of germinating in any sugary fluid, as shown by those that accidentally fall into the nectary and germinate there. Thus, if conditions are provided elsewhere for pollen germination in such a position that fertilization can take place, the stigmata, in the morphological sense, may be dispensed with. The selective factor operating to produce this transference of function could only be indicated by a greater knowledge of the biological functioning of the flower. The pollen being actually in contact with the stigmata of the same flower, as in most Goodeniaceae, may provide for a greater probability of self-pollination than in *Leschenaultia* where the functional stigmatic surface is not in contact with pollen from the same flower, unless placed there by some external agency. The breeding system of *Leschenaultia* would appear to be one orientated essentially to outbreeding; the other genera may have higher probabilities of self-fertilization.

Stylidiaceae.

In the Stylidiaceae the situation is scarcely comparable at all. Brown's comparison has been dealt with above. In all cases in this family the pollen is presented to visiting insects whilst still contained within the anther lobes (Text-fig. 5). Thus the method of presentation is quite different from that of the previous two families, although the position of the structures involved is the same. Even in *Donatia*, in which the stamens are virtually free from the style, the pollen is not deposited on the style until pollination. In none of these species are there pollen-collecting hairs. Indeed, with regard to these characters, the key ones for the Order, the Compositae stand closer to the Campanulaceae than either of the other two families considered here.

General Conclusions.

The results described here provide further evidence for questioning the naturalness of the Order. Homology, i.e., morphological equivalence, has become the test of phylogenetic relationship and the pollen presentation structures of the three families considered above are not, strictly, homologous. The Stylidiaceae stand quite apart in this respect, and to this considerable difference must be added those previously noted (Carolin, 1960). It seems even more imperative now to make a detailed comparison between Campanulaceae—Stylidiaceae—Saxifragaceae.

Even the Goodeniaceae appear to be much less closely related to the Campanulaceae than most authors have previously thought. The Lobelioideae mechanism is directly derivable from that found in *Campanula* (see above); that of the Goodeniaceae is not.

The indusium has been shown to be not homologous with the stylar hairs of Campanulaceae (see above). It has also been noted that hairs, similar in structure to those of the latter family, are found on the indusia of *Brunonia* and the *Goodenia* group of genera. In the latter these hairs are often concentrated on the lips and function as a pollen-brush (Hamilton, 1894, 1895). Although these hairs show little difference from normal epidermal hairs, they are seldom found on the styles of members of other Orders, and even then they do not usually function as a pollen-brush (but excepting Asterales). Thus the pollen-presentation function, in this case, is carried out by an entirely new structure, an outgrowth from the style. The pollen-collecting hairs perform an ancillary function, i.e., that of brushing pollen *into* the indusium and providing stiff structures with which the visiting insects agitate the indusium, thus releasing the pollen. In *Dampiera* these hairs appear to have disappeared completely for reasons which are not apparent.

The indusium of *Leschenaultia* is probably derived from the condition found in *Goodenia*, but, physiologically at least, is very different. To this considerable difference must be added the anomalous vasculation of the flower (Carolin, 1959) and the formation of mature, segregating pollen tetrads (Martin and Peacock, 1958), a condition unknown elsewhere in the family.

It is difficult to analyse the characters which have influenced systematists in grouping Goodeniaceae with Campanulaceae. As Rendle (1938) has pointed out, the main factor has been pollen presentation, but the general resemblance of the flower to that of the Lobelioideae must also have played a large part; in this case resemblance must be largely a result of convergence. Lindley's hypothesis has been dealt with above. There are members of both Lobelioideae and Goodeniaceae without the slit in the corolla-tube; in those Lobelioideae with bilocular ovaries the vasculation is consistent with a bicarpellary structure, whereas in the Goodeniaceae it is not (Carolin, unpub., 1959); the connation of the anthers in the two families has also arisen separately if the monophyletic origin of the Goodeniaceae is accepted. This general floral resemblance, then, is not a direct result of common ancestory. In addition Colozza (1908) notes that there are anatomical differences between the two families. Rosen's results with regard to embryology are inconclusive (Rosen, 1946).

There seems little else to go on at present, but for these parallel changes and the single, tenuous, structural, homologous link of the pollen-collecting hairs and the functional link of pollen presentation. More data are very necessary, particularly from the point of view of anatomy and biochemistry, but at present the following conclusions of taxonomic importance may be drawn: (i) that the Order, as designed by Hutchinson, is probably unnatural (particularly is this true of the inclusion of the Stylidiaceae); (ii) that the Asterales are probably more closely related to the Campanulaceae than are the Goodeniaceae.

In considering the general functioning of these structures the Stylidiaceae represent the primitive condition. In the vast majority of flowering plants pollen is presented to insects whilst still contained in anther lobes. The actual advantage in transferring this function to the naked style, as has occurred in the Campanulaceae, is not at all clear. Presumably it is that pollen is deposited upon the insect in such a position that the stigmatic lobes in an older flower will be in the exact position to receive it. The turning point of the mechanisms in all three families is the sequential presentation of first mature pollen and then mature stigma in the same position of the same flower but at different times. Indeed, this sequential presentation is of considerably wider occurrence than the Campanales, although in most families it is brought about by movements, growth or otherwise, of the stamens and style (e.g., Labiatae, Scrophulariaceae, Solanaceae, etc., see Knuth, 1909). What is fairly clear, however, is, once the "naked" method of pollen preservation was fixed, there appears to have been certain advantages in reverting to a "closed" method. The probability of a complete reversion in evolution is very low indeed, and in any case there were probably selective factors operating to maintain the presentation function upon the style. The consequence has been that new functional units have developed upon the style, or directly associated with the style, in which pollen is contained. Different evolutionary lines have developed different morphological units to perform the same function of pollen protection, the general tendency being that these structures release pollen only when deposition upon an insect is more or less assured. Thus there is the corolla-style pseudo-indusium of

Phyteuma, the anther-style pseudo-indusium of Lobelioideae, and the stylar indusium of Goodeniaceae. All of these structures may be correlated, to a greater or lesser degree, with the pollen collecting hairs of *Campanula*; the Stylidiaceae occupy no position in this scheme, their structures showing more resemblance to those of other Orders.

The trend, then, has been first sequential presentation and subsequent pollen protection. This protection may operate against unwanted pollinators, but detailed observations on insect visitors and breeding systems in some of the species concerned are needed before this can be considered as anything more than a suggestion. It is interesting to note, however, that the Campanulaceae, with their naked presentation, are considerably commoner in drier than in damp areas and it may be under such conditions that they first developed. The development of pollen-protective devices may have been correlated with an extension into damp temperate regions—a protection against rain or other factors in the physical environment. This might even mean a temperate origin for the Goodeniaceae; a re-entry into dry tropical conditions would not necessarily mean a reversion to "naked" presentation.

I am indebted to Professor N. S. Bayliss, Professor C. L. Wilson and Mr. W. J. Peacock for supplying some of the specimens used in this investigation. The collection of the rest of the material was made possible by a grant from the University of Sydney Research Fund.

VOUCHER SPECIMENS EXAMINED.

Velleia paradoxa R.Br., Armidale, N.S.W., R. Carolin, 11.1956. SYD. *V. lyrata* R.Br., Mt. White, N.S.W., W. J. Peacock, 15.11.1958. SYD. *V. macrocalyx* R.Br., Bowen's Creek, Bilpin, N.S.W., R. Carolin. 20.11.1958. SYD. *Goodenia paniculata* Sm., La Perouse, Sydney, N.S.W., W. J. Peacock, Feb. 1958. SYD. *G. bellidifolia* Sm., Kanangra Tops, N.S.W., R. Carolin, no. 462. 5.4.1958. Syd. *G. ovata* Sm., Kuring-gai Chase, N.S.W., W. J. Peacock, 10.1958. SYD. *G. decurrens* R.Br., Blackheath, N.S.W., R. Carolin, 10.1956. SYD. *Selliera radicans* Cav., Concord, N.S.W., R. Carolin, Sept. 1956. SYD. *Scaevola ramosissima* (Sm.) Krause, Bowen's Creek, Bilpin, N.S.W., R. Carolin, 20.11.1958. SYD. *S. albida* (Sm.) Druce, Concord, N.S.W., R. Carolin, Sept. 1956. SYD. *Verreauxia reinwardtii* (De Vr.) Benth., Lime Lake, Wagin, W.A., N. T. Burbidge, no. 4956, 28.12.1955. CANB. *Leschenaultia formosa* R.Br., University Garden. *L. biloba* Lindl., C. L. Wilson, W.A. No voucher. *L. linarioides* DC., C. L. Wilson, W.A. No voucher. *Dampiera stricta* R.Br., Kuring-gai Chase, N.S.W., W. J. Peacock, Oct. 1958. SYD. *D. purpurea* R.Br., Church Point, Sydney, N.S.W., W. J. Peacock, Oct. 1958. SYD. *D. linearis* R.Br., C. L. Wilson, W.A. No voucher. *Brunonia australis* R.Br., Bell, N.S.W., R. Carolin, no. 607, 20.11.1958. SYD. *Campanula rotundifolia* L., West Lebanon-Plainfield, N. Hants, U.S.A., C. L. Wilson, 17.7.1958. SYD. *Wahlenbergia trichogyna* Stearne, Kanangra-Jenolan, N.S.W., R. Carolin, no. 462, 6.4.1958. SYD. *Specularia speculum* L., Botanischer Garten, Köln. SYD. *Phyteuma orbiculare* L., Botanischer Garten, Köln. SYD. *Lobelia alata* Labill., Marley Beach, National Park, N.S.W., R. Carolin, Oct. 1956. SYD. *L. gracilis* R.Br., Berowra, N.S.W., R. Carolin, 11.1958. SYD. *Laurentia petraea* F. Muell., Floods Creek, Fowlers Gap, N.S.W., R. Carolin, no. 331., Aug. 1957. *L. fluviatilis* (R.Br.) Wimm., Geehi River, R. Carolin (died before preservation, no voucher). *L. syphilitica* L., Private Garden. SYD. *Stylidium graminifolium* Swartz, Oatley, W. J. Peacock, Jan. 1958. SYD. *Donatia nova-zealandiae* (Hook. f.) Berg., collected by Prof. Bayliss. No voucher.

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EXPLANATION OF PLATE II.

1. *Scaevola calendulacea.*—l.s. of young indusium, stigmatic cleft just appearing. 2. *Dampiera linearis.*—l.s. of mature indusium showing young, stigmatic cleft. 3. *Leschenaultia formosa.*—l.s. of mature indusium; the cubical, papillose cells with prominent nuclei situated on the upper lip represent the functional stigmatic surface. 4. *Wahlenbergia trichogyna.*—t.s. of young style showing position of pollen-collecting hairs.

ON TWO SPECIES OF *EPILACHNA* (COLEOPTERA : COCCINELLIDAE) FROM AUSTRALIA.

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(*Communicated by Dr. D. F. Waterhouse.*)

(Six Text-figures.)

[Read 27th July, 1960.]

Synopsis.

Genitalia studies by Dieke (1947) have indicated that phytophagous coccinellid beetles, generally regarded in Australia as belonging to a single species, *Epilachna 28-punctata*, may in fact be referred to three separate species, namely, *Epilachna 28-punctata* (Fabricius), *Epilachna sparsa* (Herbst) subsp. *26-punctata* (Boisduval), and *Epilachna philippinensis* subsp. *australica* (Dieke). Biological studies on the first two species have confirmed their separate identity, and the characteristic differences of the immature stages have been described. Although the two species mated readily, eggs obtained from such cross matings were infertile. Although the larvae of *E. sparsa* fed on cucumber, this species was otherwise generally associated with the Solanaceae, while *E. 28-punctata* was associated with the Cucurbitaceae.

INTRODUCTION.

The genus *Epilachna* is of considerable economic importance, but many doubts still exist concerning the taxonomy and biology of the species found in Australia and the Pacific area (Dieke, 1947). Formerly it was considered that certain spotted beetles of this genus, the larvae and adults of which attack Cucurbitaceae and Solanaceae in Australia, belonged to a single species, *Epilachna 28-punctata* (Fabricius), which showed some variation in external morphology and utilized a wide range of host plants (Temperley, 1928). The studies of Dieke (Dieke, 1947), however, based on an examination of the male and female genitalia, indicated that at least three separate species were likely to be involved, namely, *Epilachna 28-punctata* (Fabricius), *Epilachna sparsa* (Herbst) subsp. *26-punctata* (Boisduval) and *Epilachna philippinensis* subsp. *australica* Dieke. The present paper is concerned with the first two of these species. There is some doubt regarding the correct nomenclature for these species as the type specimens have not been preserved and the original descriptions are too generalized to identify the species with certainty (Dieke, 1947). In this paper, Dieke's nomenclature has been followed as his studies of the genitalia allow the species to be recognized with reasonable certainty. This nomenclature runs contrary to that used by certain other workers. Thus the *E. 28-punctata* of Temperley (1928) is the *E. sparsa* subsp. *26-punctata* of this paper, and the *E. 28-punctata* of this paper is not the *E. vigintioctopunctata* of Kapur's paper on the larval stages of *Epilachna* (Kapur, 1951). The fourth instar larva described here under *E. sparsa* subsp. *26-punctata* agrees closely with that described by Kapur under *E. vigintioctopunctata*, and it is probable that they are the same species. Perhaps the minor differences noted are associated with the Australian subspecies.

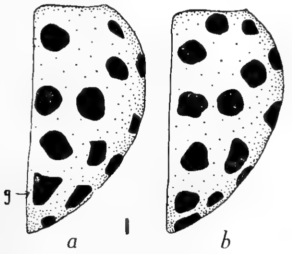
The details of structure and biology presented here were obtained from insects collected in the Brisbane area and maintained in laboratory cultures at Samford, and may not necessarily apply throughout the entire range of the species. Preserved specimens from these cultures have been lodged in the collection of the Division of Entomology, C.S.I.R.O., Canberra.

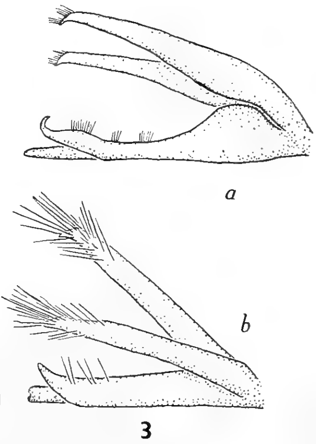
Details of the known distribution of the two species have been given by Dieke. *E. 28-punctata* occurs from Ceylon through New Guinea and Australia to the South Pacific Islands. The various subspecies of *E. sparsa* have been recorded in Asia from

India to North China and Japan, Indonesia, Australia, and the South Pacific Islands. The subspecies *E. sparsa* subsp. *26-punctata* is found in the eastern part of this range from Australia and New Guinea to the South Pacific Islands.

The Adult Beetles.

The adult beetles have been described by Dieke from preserved specimens. A darkening that occurs rapidly after death probably explains Dieke's description of the ground colour as being red. In living specimens it is a dull yellow-orange. The development of the elytral spots of Samford specimens was reasonably constant within the species, the chief difference being the absence of the anterior spot at the base of the elytron in *E. sparsa* subsp. *26-punctata.* This spot was present in all the *E. 28-punctata* examined from Brisbane, but according to Dieke it is sometimes absent in specimens of this species taken in northern Australia. In *E. sparsa* subsp. *26-punctata* there is a tendency for the elytral spot 'g' (Fig. 1) to become enlarged and fuse with its fellow on the other elytron.





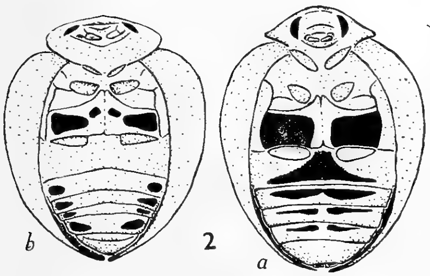


Fig. 1.—Elytral pattern of (*a*) *Epilachna sparsa* subsp. *26-punctata*; (*b*) *Epilachna 28-punctata.*

Fig. 2.—Ventral pattern of (*a*) *Epilachna sparsa* subsp. *26-punctata*; (*b*) *Epilachna 28-punctata.*

Fig. 3.—Male genitalia of (*a*) *Epilachna sparsa* subsp. *26-punctata*; (*b*) *Epilachna 28-punctata.*

Although both species showed considerable variation in the extent of the black markings on the underside, the examples given in Figure 2 are representative of the Samford cultures. In *E. 28-punctata* variation often involved a reduction of the number of black spots on the abdominal sternites and in extreme cases they were absent. In *E. sparsa* subsp. *26-punctata* any ventral abdominal markings consisted of a dark suffusion of the median areas of the sternites involved. Both species showed considerable variation in the development of the black patches on the metasternum.

Diagrams of the male genitalia are given in Figure 3.

Early Stages.

The *eggs* of the two species may be readily distinguished by their colour and arrangement within the egg mass. Those of *E. 28-punctata* are deep yellow and arranged loosely and irregularly in a single-layered egg mass; those of *E. sparsa* subsp. *26-punctata* are cream coloured and packed tightly together in an egg mass that is frequently two-layered. Adult beetles, particularly of *E. 28-punctata*, eat their eggs readily, and successful cultures were obtained at Samford only by keeping small numbers of adults together, and by removing egg masses as soon as they were observed. When maintained at 85°F. the eggs hatched on the fourth day.

The newly hatched *larvae* of *E. 28-punctata* are golden in colour, while those of *E. sparsa* subsp. *26-punctata* are grey. This difference in coloration soon disappears when the larvae commence feeding, both species then being yellow. In later instars the larvae are bright yellow immediately after a moult, but become progressively darker during the instar. There are four larval instars, occupying a total of 17–18 days at 85°F.

The *pupae* of the two species may be readily separated by their colour, that of *E. sparsa* subsp. *26-punctata* being of a dirty white colour, suffused and clouded with grey, while that of *E. 28-punctata* is a pale yollow, flecked with brown and white markings. At 85°F. the pupal stage lasted for approximately six days.

Descriptions of Fourth Instar Larvae.

The terminology of Kapur (Kapur, 1951) has been used in the descriptions of the fourth instar larvae that follow.

A. E. sparsa subsp. 26-punctata.

Body. Elongate, oval, nearly three times as long as its maximum width.

Head. Subrounded, ochraceous, except for the pale yellow epicranial suture and the dark ocelli. The disposition of the ocelli and the larger setae is shown in Figure 4. Some variation occurs in the position of the setae in different specimens. The antenna is three-segmented (Fig. 5) with the third segment small but distinctly visible; second segment rather more than twice as long as its maximum width, carrying two or three lateral setae; third segment small, carrying sensillae. The mandible has five major teeth, the two apical teeth and the basal tooth being conspicuously denticulate (Fig. 5).

Thorax. Prothorax about twice as wide as long; pronotum oval, bordered posteriorly by a dark line, and carrying about 14 dark setae on the disc behind the prothoracic scoli; dorsal scolus as long as pronotum, with about 15 branches of which those at the base are shorter, paler, and more crowded than the others, each branch carrying a terminal spine and generally 2–5 fine lateral setae; subdorsal scolus slender, approximately as long as stem of dorsal scolus, with no branches, but carrying a slender apical seta about half the length of the scolus, and 2–3 fine lateral setae; dorsolateral scolus somewhat larger than the dorsal scolus, with about 25 branches generally similar in type and disposition to those of dorsal scolus. *Mesothorax* with dorsal and subdorsal scoli of same side arising from a common oval sclerotized area; dorsal scolus rather longer than that of prothorax and carrying about 19 branches of which those towards the base are shorter, paler, and more crowded than the others; subdorsal scolus longer than dorsal scolus and bearing about 22 branches; dorsolateral scolus similar to subdorsal scolus. *Metathorax* with scoli essentially similar to those of *mesothorax*.

Ventrally the *prothorax* has a single struma with 6–7 setae, *mesothorax* and *metathorax* with a pair of strumae, each with 6–7 setae.

Abdomen. On each of the first seven abdominal segments the two dorsal scoli arise from a single darkened, oval, sclerotized transverse elevation which has an unpigmented pit at each end; dorsal scoli carrying 12–14 branches of which about 6 are short and arise from the basal region. Subdorsal scoli somewhat longer than dorsal scoli and each rising from a separate sclerotized area which bears an unpigmented pit in its median border; branches approximately equal in number to those of dorsal scoli, but with a smaller proportion of the shorter basal type. Dorsolateral scoli with 12–14 branches on anterior segments of abdomen, but progressively reduced in size from the 4th to the 7th segment so that on latter is present only as a stunted scolus carrying 3–4 branches and several long setae. Scoli on 8th abdominal segment much reduced in size and with short branches or tubercles bearing long slender terminal setae, about 10–12 such setae on the dorsal scolus, and 13–15 on the subdorsal scolus (Fig. 6). Dorsolateral scolus represented by a struma carrying 5–6 setae. Tergite of 9th abdominal segment semicircular, sclerotized, pale, and carrying about 12 long slender setae.

The ventral strumae of 1st abdominal segment lying close together and each carrying about 6 setae; those of the 2nd segment more widely separated, elongate, oval, and with 5–7 setae of variable length; those of 3rd-5th segments clearly defined with 5–7 setae, these mostly long; those of 6th-8th segments smaller, with 3–4 setae, these mostly long. Subventral strumae absent on 1st segment; on 2nd segment small with 2–3 setae; on 3rd-7th segments rather similar to ventral strumae, but with longer setae and a more rounded shape; on 8th segment with 3 long setae. Ventrolateral strumae absent on 1st

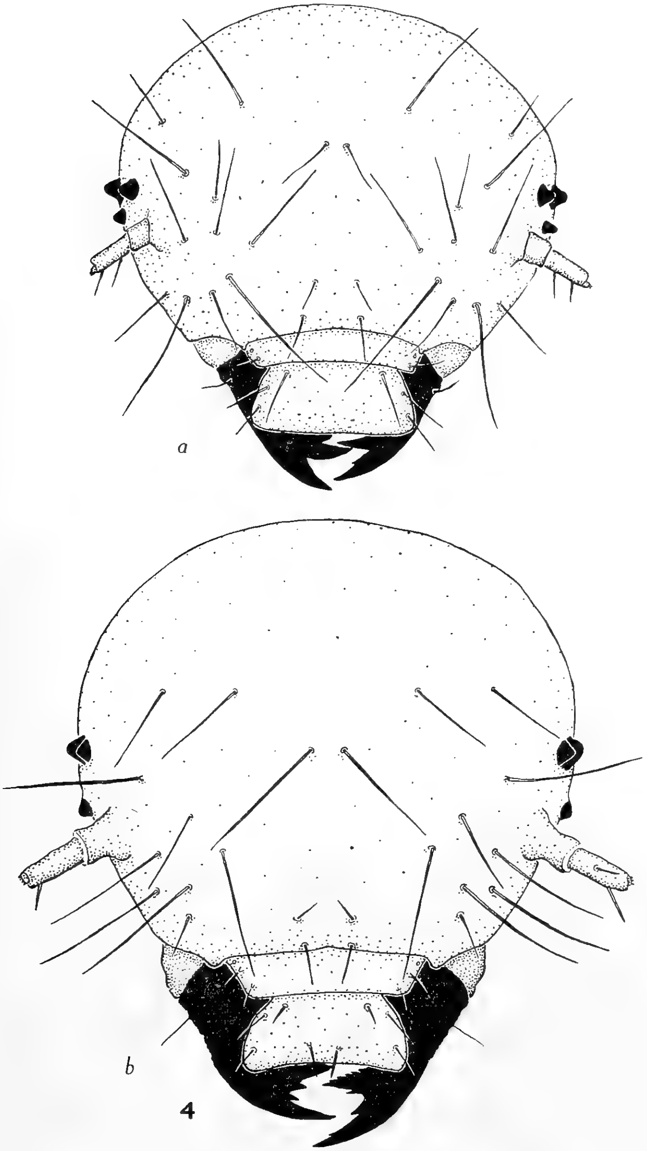


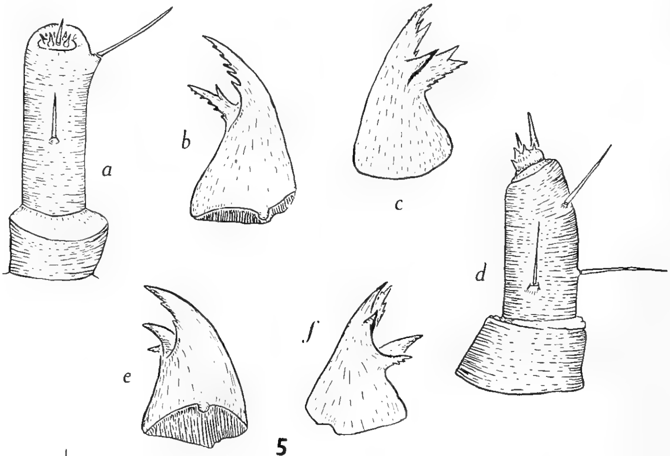
Fig. 4.—Head of 4th instar larva: (*a*) *Epilachna sparsa* subsp. *26-punctata*; (*b*) *Epilachna 28-punctata.*

abdominal segment; on 2nd segment well developed with 3–4 setae; on 3rd-7th segments larger with 5–7 setae; on 8th segment reduced with 3 long setae. Sternite of 9th segment with transverse row of 9–10 long setae.

B. E. 28-PUNCTATA.

Body. Elongate, oval, about three times as long as maximum width.

Head. Somewhat longer than in *E. sparsa* subsp. *26-punctata* and with longer setae, ochraceous (Fig. 4). Antenna 3-segmented, with 2nd segment nearly three times as long as its maximum width, and bearing 2–3 lateral setae; 3rd segment small disc-shaped (Fig. 5). Mandible with two major teeth and two minor teeth, strongly denticulate (Fig. 5).



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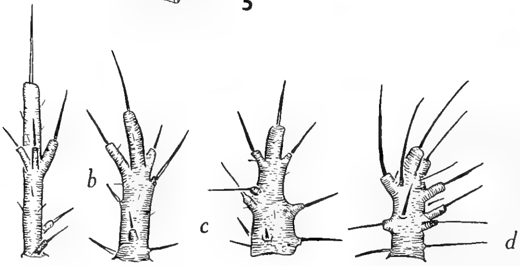

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Fig. 5.—*Epilachna 28-punctata* (4th instar larva): (*a*) antenna; (*b, c*) mandible. *Epilachna sparsa* subsp. *26-punctata* (4th instar larva): (*d*) antenna; (*e, f*) mandible.

Fig. 6.—Scoli of 8th abdominal segment of 4th instar larvae. *Epilachna 28-punctata*: (*a*) dorsal scolus; (*b*) subdorsal scolus. *Epilachna sparsa* subsp. *26-punctata*: (*c*) dorsal scolus; (*d*) subdorsal scolus.

Thorax. Prothorax about twice as wide as long; pronotum oval, bordered posteriorly by a dark line and carrying 16–20 small setae on the disc behind the scoli; dorsal scolus somewhat longer than prothoracic tergum, with about 12 branches, with fewer short basal branches than in *E. sparsa* subsp. *26-punctata* and each branch having a terminal spine and 2–5 lateral setae; subdorsal scolus slender, shorter than stem of dorsal scolus, and bearing a terminal seta, somewhat less than half the length of the scolus, and several fine lateral setae; dorsolateral scolus somewhat larger than dorsal scolus and with 16–20 branches similar to those of latter. *Mesothorax* with dorsal and subdorsal scoli of same side arising close together from a common oval sclerotized area. Dorsal scolus approximately equal in length to that of prothorax and carrying 10–12 branches of which the basal 2–3 are short; subdorsal scolus rather longer than dorsal scolus and with about 15 branches; dorsolateral scolus similar to subdorsal scolus. *Metathorax* with scoli essentially similar to those of *mesothorax*.

Ventrally the *prothorax* has a single struma with 4–6 setae; *mesothorax* and *metathorax* each with a pair of strumae bearing 4–6 setae.

Abdomen. The scoli arise from sclerotized areas similar to those found in *E. sparsa* subsp. *26-punctata.* Dorsal scoli of first seven abdominal segments with 6–7 branches of moderate length and ending in setae, the basal short branches found in *E. sparsa* subsp. *26-punctata* being absent. Subdorsal scoli slightly longer than dorsal scoli, with 10–12 branches of which 2–3 belong to the shorter basal type. Dorsolateral scoli with 11–13 branches on anterior segments of abdomen, but progressively reduced in size from 4th to 7th segment so that on the latter it consists only of a single tubercle bearing a longer terminal seta and several shorter lateral setae. Scoli on 8th segment much reduced (Fig. 6), dorsal scolus with 4–6 branches, subdorsal with 6–8 branches, and dorsolateral represented by a single struma carrying 6–8 setae.

TABLE 1.

Acceptability of Various Plants to Larvae and Adults of E. 28-punctata *and* E. sparsa *subsp.* 26-punctata.

Foodplant.	*E. 28-punctata.*		*E. sparsa* subsp. *26-punctata.*	
	Larvae	Adult Beetle.	Larvae.	Adult Beetle.
Solanum nigrum	—	—	× × ×	× × ×
S. torvum	—	—	×	× ×
S. sodomaeum	—	—	× ×	× ×
S. auriculatum	—	—	×	×
S. seaforthianum	—	—	× × ×	× × ×
S. lycopersicum (Tomato)	—	—	× ×	× ×
S. tuberosum (Potato)	—	—	× × ×	× × ×
Physalis minima	—	—	× × ×	× × ×
P. peruviana	—	—	×	×
Datura arborea	—	—	× × ×	× × ×
D. stramonium	—	—	× × ×	× × ×
Petunia	—	—	×	×
Brunfelsia	—	—	× × ×	× × ×
Cucurbita pepo (Pumpkin)	× × ×	× × ×	—	—
Cucumis melo (Melon)	× × ×	× × ×	—	—
C. sativus (Cucumber)	× × ×	× × ×	× ×	—
Sechium edule (Choko)	×	× × ×	×	—
Gossypium (Cotton)	×	—	—	—
Phaseolus vulgaris (French Beans)	—	—	×	—
Vicia faba (Broad Beans)	× ×	—	—	—

× × ×, eaten readily; × ×, eaten readily by some individuals but refused by others; ×, eaten in small quantities by a few individuals but refused by remainder; —, not eaten.

Starvation conditions were only applied to the larva, the adults being left on the food-plants for only four days.

Ventral strumae of 1st abdominal segment rather closer together than those of succeeding segments, and carrying 3–4 setae; strumae on 2nd, 3rd-5th, and 6th-7th segments carrying 4–6, 5–7 and 3–4 setae respectively. Subventral strumae absent on 1st segment, well developed with 5–6 setae on 2nd, large with 7–10 setae on 3rd-6th segment, smaller with 4–5 setae on 7th segment. Ventrolateral strumae absent on 1st, with 4–5 setae on 2nd, and 6–8 setae on 3rd-7th segment. The ventral and subventral strumae of each side of the 8th sternite are fused together and each compound struma thus formed has about 4 long setae. The 9th abdominal sternite carries a row of 7–9 setae.

When identifying living larvae of the two species the most readily seen characters are the differences in the structure of the dorsal scoli of the anterior abdominal segments, and the dorsal and subdorsal scoli of the 8th abdominal segment.

FOODPLANTS.

The foodplant relationships of these two species are being investigated in some detail and the results will be published later. For the present, however, it seems desirable to publish the general feeding habits of the species since they are of economic significance. From the results summarized in Table 1 it will be seen that *E. 28-punctata* feeds mainly on the Cucurbitaceae and *E. sparsa* subsp. *26-punctata* mainly on the Solanaceae. The only significant overlap in the host plant ranges of the two insects so far discovered is cucumber, which is eaten by some larvae of *E. sparsa* subsp. *26-punctata* but not by the adults. The status of *E. philippinensis* among the pest species of *Epilachna* in Australia is not known.

TABLE 2.

Results of Attempted Cross Fertilization of E. 28-punctata *and* E. sparsa *subsp.* 26-punctata.

Adult Beetles.	No. of Pairs in Separate Cages.	No. of Pairs in which Copulation Observed.	Batches of Eggs.	Batches Hatched.
♀ *sparsa* × ♂ *sparsa*	6	4	26	26
♀ *sparsa* × ♂ *28-punctata* . .	6	2	11	nil
♀ *28-punctata* × ♂ *sparsa* . .	8	5	29	nil
♀ *28-punctata* × ♂ *28-punctata* . .	6	6	23	23

INTERSPECIFIC MATING.

The separate identity of the two species was confirmed by the failure of attempts at cross fertilization.

The females of both species lay eggs irrespective of whether mating has occurred, and the males appear to mate readily with females of the other species. Virgin females were kept in individual cages, some with males of their own species and some with males of the other species. The results of the experiments are summarized in Table 2 and leave no doubt about the true specific status of the two species concerned.

Acknowledgements.

Grateful thanks are due to Mr. R. D. Pope of the Commonwealth Institute of Entomology, London, who identified the two species of *Epilachna* from specimens sent from Australia, and to Dr. D. F. Waterhouse, Chief, Division of Entomology, C.S.I.R.O., for his helpful comments on the original manuscript.

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ANTARCTIC PHYTOPLANKTON STUDIES.

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(Plates iii-v.)

[Read 31st August, 1960.]

Synopsis.

This paper considers 126 species of diatoms which have been recorded in material collected by M.V. *Magga Dan* under charter to the Antarctic Division of the Department of External Affairs. The finding of frustules with the two valves characteristic of two genera, *Coscinodiscus* and *Asteromphalus*, is recorded.

Introduction.

The material described in this paper was collected during December, 1958, to February, 1959, from the vessels *Thala Dan* and *Magga Dan* under charter to the Antarctic Division of the Department of External Affairs, on the relief trip from Australia to the Antarctic. Grateful acknowledgement is made to the Department for allowing the collections of phytoplankton to be made. The details of the positions of stations are available in C.S.I.R.O. Aust. (1960).

The taxonomy of Antarctic diatoms is confused. The illustrations of Karsten (1905–7) are idealized rather than accurate, and later authors have tended to refer to these rather than to reproduce more accurate illustrations. Heiden and Kolbe (1928) have failed to observe the identity of certain species and have caused confusion by uniting certain other species. For example, they united *Biddulphia anthropomorpha* with *B. obtusa*, failed to unite *B. obtusa* with *B. aurita* (a more obvious relationship), and continued to distinguish *B. roperiana*, which is *B. aurita* var. *obtusa*. Because certain authors have not supplied illustrations it is difficult to tell whether much of the lumping and splitting of species is justified. In this paper a middle course has been taken, and illustrations are given of those species which have not been adequately covered in Wood (1960), Crosby and Wood (1958, 1959), and Wood, Crosby and Cassie (1959).

The finding in this collection of frustules with valves characteristic of two genera (*Coscinodiscus* and *Asteromphalus*, Pl. v, figs 67–9) makes the validity of many species doubtful; for instance, it may well be that genera such as *Schimperiella* with different valves may be mutations or crosses between two genera.

DIATOMS.

Sub-Order DISCINEAE.

Family COSCINODISCACEAE.

Genus Melosira Agh. 1824.

1. Melosira sol (Ehr.) Kütz. (Pl. v, fig. 62).

Kütz., 1849, 31; Hend., 1937, 234; *Gallionella sol* Ehr., 1844, 202.

Cells large, discoid, in chains; valves flat or weakly concave, with radial grooves of varying length extending from margin, central area clear; margin with a single row of pores, girdle narrow; valve mantle finely striate. Diam. 50–100μ.

This species is extremely variable and has been described from the Antarctic and other places under a number of names. The following are probable synonyms: *M. godfroyi* Perag., 1921, 86, 5, 1; *M. hungarica* Pant. Ungarn.; *M. interjecta* Jan in vH., 1909, 33; *M. sol* ff. *typica*, *omma* (*M. omma* A.S.), *terminalis* Karst., vv. *hungarica* and *marginalis* Perag., 1921; *M. subhyalina* vH., 1909, 33, 7, 97; *M. vanheurckii* Perag., 1921, 90; *M. de wildmanni* vH., 1909, 33, 7, 98; *M. omma* Heiden and Kolbe, 1928, 467; *M. antarctica* vH., 1909, 32, 7, 93; *M. deblockii* vH., 1909, 32, 7, 93; *M. alphabetica* Mann, 1937; Mann also described variants of this species under several of the above names.

2. MELOSIRA SPHAERICA Karst. (Pl. iii, fig. 1).

Karst., 1905, 70, 1, 2; Hend., 1937, 234.

Cells in short, irregular chains; frustules weakly siliceous, without definite structure; valves rounded. Diam. 40–60μ. *Distribution*: Magga Dan 35, 36, 37. Wilkes Land.

3. MELOSIRA POLARIS Grun. (Pl. iii, fig. 2, *a-c*).

Grun., 1884, 95, E33; Hend., 1937, 234.

Cells in pairs, chains or solitary; frustules doughnut-shaped in girdle view; valves depressed in centre, rounded margins, margin striate, central portion punctate. Diam. 25–35μ. *Distribution*: Magga Dan 27, 28, 29, 30, 31, 34, 35, 37, 41, 42, 47, 51, 52, 54, 56, 58, 76.

Genus HYALODISCUS Ehr. 1845.

4. HYALODISCUS KERGUELENSIS Karst. (Pl. iii, fig. 3).

Karst, 1905, 74, 2, 6–7; Hend., 1937, 235.

Cells usually solitary or in pairs; valves deeply convex, centre with fine, somewhat indistinct granules which may be radial, outer area with radiate finely moniliform striae; marginal flange strongly striate; girdle with numerous annular segments. Diam. 100–120μ. *Distribution*: Thala Dan 8. Magga Dan 28, 35, 41, 45, 46, 60.

Genus THALASSIOSIRA Cl. 1873.

5. THALASSIOSIRA ANTARCTICA Comber (Pl. iii, fig. 4).

Comber, 1896, 491, 11; Hend., 1937, 237.

Cells drum-shaped, in chains or mucilaginous colonies; valves circular, slightly convex, rounded margins, punctate; puncta in radiating, frequently bifurcating rows, central granules larger, margins of valves with small spinulae. Diameter of valve 20–60μ. *Distribution*: Wilkes Land.

6. THALASSIOSIRA CONDENSATA Cl. 1900 (Pl. iii, fig. 5).

Crosby and Wood, 1958, 493, 35, 8.

Distribution: Wilkes Land.

7. THALASSIOSIRA DECIPIENS (Grun.) Jörg. 1905.

Crosby and Wood, 1958, 493, 35, 13.

Distribution: Wilkes Land.

8. THALASSIOSIRA ROTULA Meun. 1910.

Crosby and Wood, 1958, 492, 35, 6.

Distribution: Wilkes Land.

9. THALASSIOSIRA SUBTILIS (Ost.) Gran 1900.

Crosby and Wood, 1958, 493, 35, 11.

Distribution: Magga Dan 37; Wilkes Land.

Genus COSCINOSIRA Gran 1900.

Cells drum-shaped, in loose chains, cells connected by several threads, usually long; valves circular, flat, or slightly convex, areolate; marginal spinulae and spines may be present; chromatophores numerous.

10. COSCINOSIRA ANTARCTICA Mangin (Pl. iii, fig. 6).

Mangin, 1915, 55, 39.

Cells in chains connected by several threads from the inner half of valve; frustules drum-shaped, margins rounded with a series of short and long spinules. Diam. 45μ. *Distribution*: Magga Dan 36, 73.

Genus Coscinodiscus Ehr. 1838.

11. Coscinodiscus centralis Ehr. 1839.

Crosby and Wood, 1958, 495, 31, 7.

Distribution: Magga Dan 23, 24, 36, 37, 77; Wilkes Land.

12. Coscinodiscus comptus Castr. (Pl. iii, fig. 7).

Castr., 1886, 157, 13, 9.

Cells discoid, solitary, valves with a central hyaline area from which radial rows of puncta extend to the margin; between these rows are shorter rows of puncta extending a short distance in from the margin. *Distribution*: Magga Dan 27, 28, 37.

13. Coscinodiscus curvatulus Grun. 1876.

Crosby and Wood, 1958, 496, 31, 14.

Distribution: Magga Dan 15, 17, 20, 23, 26, 35, 74, 87, 88.

14. Coscinodiscus excentricus Ehr. 1840.

Crosby and Wood, 1958, 496, 31, 10.

Distribution: Magga Dan 21, 22, 23, 26, 27, 28, 29, 30, 31, 33, 35, 37, 48, 54, 86.

15. Coscinodiscus gemmatulus Castr. (Pl. iii, fig. 8).

Castr., 1886, 161, 17, 9.

Cells small, discoid, solitary; valves with striate, and punctate margin, large radially disposed puncta and a hyaline central area. *Distribution*: Magga Dan 27.

16. Coscinodiscus granulosus Grun. 1880.

Crosby and Wood, 1958, 496, 31, 13.

Distribution: Magga Dan 21, 23, 29, 30, 41, 51, 60, 74.

17. Coscinodiscus griseus Grev. (Pl. iii, fig. 9).

Grev., 1863, 230, 9, 7; A.S.A., 1885, 58, 13, 14.

Cells small, discoid, solitary; valves flat, with punctate margin and large radiating rows of granules; central area hyaline with scattered granules. *Distribution*: Magga Dan.

18. Coscinodiscus incurvus Karst. (Pl. iii, fig. 10).

Karst., 1905, 85, 7, 8; Hend., 1937, 252.

Cells discoid, solitary; valves flat, with hyaline central area and puncta uniform in size, fasciculate. Diam. 80μ. *Distribution*: Magga Dan.

19. Coscinodiscus intermittens Karst. (Pl. iii, fig. 11).

Karst., 1906, 156, 26, 14; Hend., 1937, 247.

Cells solitary, discoid; valves slightly convex, punctate, puncta coarse with a few in a cluster at centre, rest radiating, some rows reaching centre, others not, margin with small puncta and small spinulae. Diam. 90μ. *Distribution*: Magga Dan 73.

20. Coscinodiscus janischii A.S. 1878.

Wood, Crosby and Cassie, 1959, 16, 1, 16.

Distribution: Magga Dan 32.

21. Coscinodiscus kryophilus Grun. (Pl. iii, fig. 12).

Grun., 1884, 81, 3, 21; Karst., 1905, 85, 7, 4; Hend., 1937, 253.

Frustules discoid, solitary; valves covered with fine puncta in fasciculate rows and secondary oblique rows within each fascicule, no central hyaline area, puncta uniform; spinulae at margin. Diam. 40–60μ. *Distribution*: Magga Dan 27, 56.

22. Coscinodiscus lentiginosus Jan. in A.S. (Pl. iii, fig. 3).

Jan. in A.S. Atl., 1878, 58, 11; Karst., 1906, 155, 26, 11; Hend., 1937, 248.

Cells discoid, small, solitary; valves flat, surface with granules, irregular in centre but radial, and becoming closely packed towards valve margin; narrow hyaline space just inside valve margin which is strong, narrow and radially striate. Diam. 40–100μ. *Distribution*: Magga Dan 27.

23. Coscinodiscus lineatus Ehr. 1838.

Crosby and Wood, 1958, 497, 31, 15.

Distribution: Magga Dan 9, 20, 27, 28, 29, 30, 33, 75, 88.

24. Coscinodiscus marginatus Ehr. 1841.

Crosby and Wood, 1958, 495, 31, 9.

Distribution: Wilkes Land.

25. Coscinodiscus nitidus Greg. 1857.

Wood, Crosby and Cassie, 1959, 5, 1, 11.

Distribution: Magga Dan 16, 26, 27, 29, 31, 33, 52, 53, 54, 56, 57, 74, 78, 88.

26. Coscinodiscus radiatus Ehr. 1840.

Crosby and Wood, 1958, 496, 31, 12.

Distribution: Magga Dan 21, 29, 31, 35, 48, 74.

27. Coscinodiscus rothii (Ehr.) Grun. 1878.

Wood, Crosby and Cassie, 1959, 6, 1, 15.

Distribution: Magga Dan 31.

28. Coscinodiscus stellaris Roper (Pl. iii, fig. 14).

Roper, 1858, 6, 21, 3, 31; A.S., 1892, 164, 4; Hend., 1937, 242. *Coscinosira stellaris* Heiden and Kolbe, 1928, 469.

Cells solitary discoid; valves flat with fine hexagonal areolation; areolae uniform except near margin where they decrease; three to six thickened protuberances or ridges near centre forming a stellate pattern. Diam. 80–95μ. *Distribution*: Magga Dan 62; Wilkes Land.

29. Coscinodiscus subtilis Ehr. (Pl. iii, fig. 15).

Ehr., 1841, 412, 3, 18; A.S., 1885, 57, 11, 13; Karst., 1905, 86, 7, 11, 11*a*,

Cells discoid, solitary; valves flat or convex with fine hexagonal areolae in fasciculae; margin with numerous spinulae. *Distribution*: Magga Dan.

Genus Ethmodiscus Castr. 1886.

30. Ethmodiscus subtilis Karst. (Plate iii, fig. 16).

Karst., 1905, 87, 8, 3; Hend., 1937, 255.

Cells drum-shaped; valves weakly convex, sometimes centrally concave; finely punctate, puncta radial, slightly curved towards margin; no central area or rosette. Diam. 45μ. *Distribution*: Magga Dan.

Genus Schimperiella Karst. 1905.

Cells solitary, discoid; but two valves different, one with a striate margin; pseudonodule absent.

31. Schimperiella antarctica Karst. (Pl. iii, fig. 17).

Karst., 1905, 88, 8, 6; Hend., 1937, 256.

Cells discoid, solitary; valves dissimilar, upper with wide flat radially striate margin, interior with puncta in straight or curved irregular striae; lower valve without striate margin and with radial puncta. Diam. 35–50μ. *Distribution*: Magga Dan 24, 27, 28, 30, 31, 33, 43, 45, 48, 51, 52, 53, 54, 56, 68, 71, 72, 74, 75, 76, 78.

32. Schimperiella valdiviae Karst. (Pl. iii, fig. 18, *a*, *b*).

Karst., 1905, 88, 8, 7; Hend., 1937, 256.

Cells discoid, solitary; valves dissimilar, upper convex with wide, flat radially striate margin and convex middle with radial striae and small central hyaline area, puncta increasing in size and denser as they approach margin; lower valve with striate margin, fine areolation and no hyaline central area. Diam. 30–50μ. *Distribution*: Magga Dan 15, 23, 27, 28, 30, 31, 33, 41, 46, 52, 70, 78.

Genus Charcotia M. Perag. 1921.

33. Charcotia bifrons (Castr.) Perag. M. 1921.

Crosby and Wood, 1958, 498, 32, 17.
Distribution: Magga Dan 27, 29, 37.

Family ACTINODISCACEAE.

Genus Actinocyclus Ehr. 1837 em. Ratt. 1890.

34. Actinocyclus bifrons Karst. (Pl. iii, fig. 19, *a*, *b*).

Karst., 1905, 92, 9, 8; Hend., 1937, 260.

Cells solitary, discoid; valves dissimilar, upper slightly convex with narrow radially striate margin; puncta irregular in centre, fasciculate, radiate towards margin; pseudoocellus marginal; lower valve more convex with broad striate margin and inner part with moniliform striae, fasciculate in outer, irregular in central part. Diam. 70–80μ. *Distribution*: Magga Dan 35, 36, 37, 40, 42.

35. Actinocyclus intermittens Karst. (Pl. iii, fig. 20).

Karst., 1905, 92, 9, 5; Hend., 1937, 261.

Cells discoid, solitary; valves convex with slightly flat centre; puncta irregular in centre, radial towards margin which is narrow, hyaline with small pseudoocellus. *Distribution*: Magga Dan 27, 37.

36. Actinocyclus janus Karst. (Pl. iii, fig. 21).

Karst., 1905, 92, 9, 7; Hend., 1937, 262.

Cells solitary, discoid; valves dissimilar, upper convex with flat centre, surface punctate, puncta in irregularly concentric and radial lines, sparser near centre; hyaline area may be present; pseudoocellus small; lower valve convex with depressed centre, broad striate margin and punctate inner portion, irregular, sparser in centre. Diam. 60μ. *Distribution*: Magga Dan 27.

37. Actinocyclus umbonatus Castr. (Pl. iii, fig. 22, *a*, *b*).

Castr., 1886, 145, 4, 4; Karst., 1905, 91, 9, 1.

Cells solitary, discoid; valves convex with broad flat margin which is radially striate and may have hyaline rim; inner part of valve with moniliform striae in radiate or tangential rows; puncta uniform in size, hyaline central area may be present. Diam. 60–100μ. *Distribution*: Magga Dan 42.

38. Actinocyclus sp. a. (Pl. v, fig. 65).

Cells solitary, discoid; valves convex, flattened near centre; puncta radial-fasciculate with stellate, hyaline central area which may contain a few puncta; marginal pseudonodule present. Diam. 50–60μ. *Distribution*: Magga Dan; Antarctic water.

39. Actinocyclus sp. b. (Pl. v, fig. 66).

Cells small, solitary; valves slightly convex; surface covered with small, uniform areolae, arranged radially and secondarily in excentric circles; dotted irregularly over the valve surface are small thickenings which obscure the areolae; pseudonodule marginal. Diam. 40–50μ. *Distribution*: Magga Dan; Antarctic water.

Genus Asteromphalus Ehr. 1844.

40. Asteromphalus beaumontii Ehr. (Pl. iii, fig. 23).

Ehr., 1844, 200, 5; *A. ralfsianus* A.S.A., 1875, 38, 6, 7.

Cells small, discoid, to slightly oval solitary; valves circular, with large hyaline central area and broad rays separating cuneate sectors with very large puncta and joined to centre by undulate lines; this species differs from *A. parvulus* and *A. hookeri* by the cuneate sectors and the very large puncta. Diam. 45μ. *Distribution*: Magga Dan 11.

41. ASTEROMPHALUS FLABELLATUS (Breb.) Grev. 1859.

Wood, Crosby and Cassie, 1959, 24, 2, 24.

Distribution: Magga Dan 45.

42. ASTEROMPHALUS HOOKERI Ehr. 1844 (Pl. iii, fig. 24).

Crosby and Wood, 1958, 502, 32, 27.

Distribution: Magga Dan 9, 11, 16, 20, 21, 23, 26, 27, 28, 29, 30, 33, 35, 39, 41, 42, 43, 45, 46, 48, 51, 52, 53, 56, 57, 63, 64, 66, 70, 71, 72, 73, 74, 75, 76, 80, 86.

43. ASTEROMPHALUS ANTARCTICUS Castr. (Pl. iii, fig. 25, *a*, *b*).

Castr., 1886, 136, 16, 11; Karst., 1905, 90, 8, 14; Hend., 1937, 270.

Cells discoid in valve view, octagonal in girdle view, solitary; valves with large central hyaline area, and 4 to 6 hyaline rays, one much narrower than the others; peripheral sectors with large puncta; branched or zigzag lines radiating from centre to peripheral sectors, meeting these sectors on their indented inner margin. Diam. 30–40μ. *Distribution*: Magga Dan 27, 31, 42, 43, 46, 47, 52, 53, 54, 56, 57, 60, 72, 74, 88.

44. ASTEROMPHALUS ROPERIANUS Ralfs (Pl. iv, fig. 26).

Ralfs in Pritch., 1861; Karst., 1905, 90, 8, 8*a*.

Cells solitary, discoid, valves with central area less than half diameter and seven hyaline rays reaching margin, one much narrower than the others; sectors punctate with a row of much larger puncta adjacent to hyaline portions, joined to centre of valve by irregular lines. Diam. 70μ. *Distribution*: Magga Dan 43, 78.

Family BIDDULPHIACEAE.

Genus CERATAULINA Perag. 1892.

45. CERATAULINA PELAGICA (Cl.) Hend. 1937.

Crosby and Wood, 1958, 502, 36, 18.

Distribution: Magga Dan 26, 37; Lewis I.

Genus BIDDULPHIA Gray 1821.

46. BIDDULPHIA ANTHROPOMORPHA van Heurck (Pl. iv, fig. 27).

van H., 1909, 39, 10, 136–7; Hend., 1937, 277, 13, 5; *B. polymorpha* Mangin, 1915.

Cells in chains with processes often longer than cell, but variable in same chain; valves oval to elliptic-lanceolate, punctate, and with a variable number of spines of varying length, two much stouter than the rest; in girdle view frustule has a narrow to wide simple girdle, centre of valve is domed, and two long somewhat sinuate processes with clavate ends arise on each side of central portion. Length 80–120μ. *Distribution*: Wilkes Land.

47. BIDDULPHIA AURITA (Lyngb.) Breb. 1838.

Crosby and Wood, 1958, 504, 33, 33.

Distribution: Wilkes Land.

48. BIDDULPHIA WEISSFLOGII Jan. in van H. (Pl. iv, fig. 28).

van H., 1880, 85, 100, 1, 2; *B. stricta*, Karst., 1905, 122, 71, 2, 3; Mangin, 1915, 22, 1; Hend., 1937, 278, 10, 4, 5.

Cells in short chains or solitary, almost rectangular in girdle view, elliptical in valve view; valves with very short, rounded processes at margins, and four slightly curved spines near slightly convex or flat central area; girdle may be slightly inflated; surface of cell finely punctate. Length 100–120μ. *Distribution*: Magga Dan 28. Also recorded from Eden, N.S.W., in June, 1959. The latter record is interesting since Hendey (1937) considers that *B. striata* is unlikely to cross the Antarctic convergence.

GENUS TRICERATIUM Ehr. 1839.

49. TRICERATIUM ARCTICUM Brightw. 1853 (Pl. v, fig. 57).

Wood, Crosby, and Cassie, 1959, 12, 2, 30.
Distribution: Wilkes Land.

50. TRICERATIUM FAVUS Ehr. 1839.

Crosby and Wood, 1958, 505, 33, 35.
Distribution: Wilkes Land.

Genus EUCAMPIA Ehr. 1839.

51. EUCAMPIA BALAUSTIUM Castr. 1886 (Pl. v, fig. 58).

Eucampia antarctica Mangin, 1910; *Hemiaulus ambiguous* Jan. Heiden and Kolbe, 1928, 545.
Distribution: Magga Dan 27, 29, 35, 41, 48, 62, 74; Wilkes Land.

52. EUCAMPIA ZOODIACUS Ehr. 1839.

Crosby and Wood, 1958, 511, 36, 28.
Distribution: Magga Dan 36, 37.

Family CHAETOCERACEAE.

Genus CHAETOCEROS Ehr. 1844.

53. CHAETOCEROS AFFINE Lauder 1864.

Crosby and Wood, 1958, 513, 36, 54.
Distribution: Magga Dan 71.

54. CHAETOCEROS ATLANTICUM Cl. 1873.

Crosby and Wood, 1958, 513, 36, 35, *a-c*.
Distribution: Magga Dan 23, 26, 28, 42.

f. AUDAX Gran 1904.

Distribution: Magga Dan 21, 39, 41, 45, 54, 71, 73.

var. NEAPOLITANA (Schr.) Hust. 1930.

Distribution: Magga Dan 37.

55. CHAETOCEROS BOREALE Bail. 1855 (Pl. iv, fig. 29).

Crosby and Wood, 1958, 514.
Distribution: Magga Dan 20, 23, 24, 27, 28, 29, 30, 33, 51, 74.

56. CHAETOCEROS BULBOSUM (Ehr.) Heiden and Kolbe (Pl. iv, fig. 33).

Heiden and Kolbe, 1928, 526, 9, 171; *C. radiculum*, Castr., 1886, 79. Karst., 1905, 117, 15, 3; *Dicladia bulbosa* Ehr., 1844, 35A, 21, 10.

Cells solitary or in pairs; frustules somewhat octagonal; centre of valve slightly raised; setae bulbous at base, tapering sharply and often striate, striae originating in frustule itself; in the chains, the global setae are terminal. Diam. 40–50μ. *Distribution*: Magga Dan 27, 29, 35; Wilkes Land.

57. CHAETOCEROS CASTRACANEI Karst. 1905 (Pl. iv, fig. 30).

Crosby and Wood, 1958, 514, 37, 38.
Distribution: Magga Dan 73.

58. CHAETOCEROS CONCAVICORNE Mangin 1917.

Crosby and Wood, 1958, 514, 37, 40.
Distribution: Magga Dan 23, 24, 42, 43, 45, 48, 54, 60, 74, 84, 88, 91, 92.

59. CHAETOCEROS CONVOLUTUM Castr. 1886.

Crosby and Wood, 1958, 515, 34, 47.
Distribution: Magga Dan 32, 36.

60. Chaetoceros criophilum Castr. 1886.

Crosby and Wood, 1958, 515, 34, 48.

Distribution: Thala Dan 8; Magga Dan 21, 23, 26, 27, 28, 30, 34, 35, 36, 37, 40, 44, 45, 47, 48, 49, 50, 52, 53, 54, 56, 57, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 74, 86, 91, 92.

61. Chaetoceros debile Cl. 1894.

Crosby and Wood, 1958, 515, 37, 43.

Distribution: Magga Dan 21, 35, 92; Wilkes Land.

62. Chaetoceros denticulatum Lauder 1864.

Crosby and Wood, 1958, 516, 37, 45.

Distribution: Magga Dan 23, 29.

63. Chaetoceros diadema (Ehr.) Gran 1897.

Crosby and Wood, 1958, 516, 37, 46.

Distribution: Magga Dan 23, 26, 27, 29, 34, 35, 42, 51, 56, 74, 84.

64. Chaetoceros dichaeta Ehr. 1844 (Pl. v, fig. 59).

Crosby and Wood, 1958, 516, 37, 47.

Distribution: Magga Dan 20, 21, 23, 24, 26, 27, 28, 29, 30, 34, 35, 36, 37, 39, 41, 42, 43, 44, 45, 48, 49, 51, 52, 54, 56, 70, 71, 74.

65. Chaetoceros difficile Cl. 1900.

Crosby and Wood, 1958, 516, 37, 48.

Distribution: Magga Dan 36, 49, 56, 74; Wilkes Land.

66. Chaetoceros filiferum Karst. (Pl. iv, fig. 31).

Karst., 1907, 392, 44, 15.

Cells in short chains, 4–12 in a chain, rectangular in girdle view, with rounded corners; valves almost circular, surface flat or slightly convex; setae arising from corners of cells, and crossing those of neighbouring cell at some distance from margin, short; aperture long and narrow, lanceolate. Diam. 20μ. *Distribution*: Magga Dan.

67. Chaetoceros gaussii Heiden and Kolbe (Pl. iv, fig. 43).

Heiden and Kolbe, 1928, 534, 12, 181.

Cells solitary, cylindrical; valves shallow, concave, with two long marginal hollow processes; girdle with scale-like plates. Length 100–120μ. *Distribution*: Magga Dan 28, 32.

68. Chaetoceros laciniosum Schütt 1895.

Crosby and Wood, 1958, 517, 37, 50.

Distribution: Magga Dan 32, 56.

69. Chaetoceros lorenzianum Grun. 1863.

Crosby and Wood, 1958, 517, 38, 52.

Distribution: Wilkes Land.

70. Chaetoceros peruvianum Brightw. 1856 (Pl. iv, fig. 32).

Crosby and Wood, 1958, 518.

Distribution: Magga Dan 23, 52, 56, 91.

71. Chaetoceros schimperianum Karst. 1905.

Crosby and Wood, 1958, 518, 34, 50.

Distribution: Magga Dan 21, 23, 29, 31, 34, 56, 74, 78.

72. Chaetoceros sociale Lauder, 1864.

Crosby and Wood, 1958, 518, 38, 57.

Distribution: Magga Dan 36; Wilkes Land.

73. Chaetoceros vanheurckii Gran 1897.

Crosby and Wood, 1958, 519, 38, 59.

74. CHAETOCEROS VISTULAE Apstein 1909.

Wood, Crosby and Cassie, 1959, 39, 3, 39.

Distribution: Magga Dan 32, 88.

75. CHAETOCEROS SEYCHELLARUM Karst. (Pl. iv, fig. 34).

Karst., 1907, 387, 43, 4.

Cells in chains, drum-shaped; valve surface domed with a characteristic rectangular depression in the centre occupying about one-third valve surface; setae emerging within valve margin, and extending at right angles to chain axis; apertures narrow, with central rectangular portion due to depressions in opposing valves; chromatophores numerous, extending into setae. Diam. 30μ. *Distribution*: Magga Dan.

Sub-Order SOLENIINEAE.

Family RHIZOSOLENIACEAE.

Genus RHIZOSOLENIA (Ehr.) em. Brightw. 1858.

76. RHIZOSOLENIA ALATA Brightw. 1858.

Crosby and Wood, 1958, 520, 38, 62.

This species appears in various forms including the type form, and formae *indica* and *inermis*. The last does not appear north of the sub-Antarctic convergence, and its distribution will be considered separately.

f. TYPICA.

Distribution: Thala Dan 8, 9, 10; Magga Dan 2, 4, 5, 10, 11, 14, 16, 18, 20, 23, 24, 27, 28, 29, 31, 33, 36, 37, 41, 44, 45, 47, 48, 54, 57, 60, 62, 64, 69, 71, 72, 73, 76, 77, 80, 81, 82, 83, 84, 85, 86, 87, 88, 90, 91.

f. INERMIS.

Distribution: Magga Dan 21, 23, 26, 28, 30, 33, 34, 35, 36, 37, 39, 41, 42, 43, 44, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 60, 62, 63, 65, 66, 67, 68, 69, 71, 72, 74, 75, 85, 87, 92.

77. RHIZOSOLENIA ANTARCTICA Karst. (Pl. iv, fig. 35, *a*, *b*).

Karst., 1905, 95, 11, 1.

Cells cylindrical in straight chains or solitary; valves domed, low, with slightly excentric spine, emerging almost parallel to transverse axis, bent towards apical axis; intercalary bands annular. Length 60–110μ. *Distribution*: Magga Dan 23, 28.

78. RHIZOSOLENIA BIDENS Karst. (Pl. iv, fig. 36).

Karst., 1905, 98, 9, 13; Hend., 1937, 312.

Cells cylindrical, solitary; valves conical with large bifurcated spine, points diverging; intercalary bands scale-like, resembling those of *R. styliformis*. Length 50–85μ. *Distribution*: Magga Dan 30, 36, 45, 75, 76.

79. RHIZOSOLENIA CHUNII Karst. 1905 (Pl. iv, fig. 37).

Crosby and Wood, 1958, 521, 38, 67.

Distribution: Magga Dan 20, 21, 22, 23, 24, 29, 33, 37, 45, 54, 76, 78; Lewis I.; also recorded from Eden, N.S.W., in 1959.

80. RHIZOSOLENIA CRASSA Schimper ex Karst. (Pl. iv, fig. 38).

Karst., 1905, 99, 11, 6; Hend., 1937, 314.

Cells large, usually in chains, cylindrical but may be laterally flattened; valves oblique, abruptly conical, with a long excentric spine which is swollen and hollow at base, tapering to a fine point; girdle with scale-like intercalary bands. Length 300–400μ. *Distribution*: Magga Dan 31, 48; Wilkes Land.

81. RHIZOSOLENIA CURVATA Zach. 1905.

Crosby and Wood, 1958, 521, 38, 69.

Distribution: Magga Dan 16, 21, 80, 85, 86, 88; Lewis I.

82. Rhizosolenia cylindrus Cl. 1897.

Crosby and Wood, 1958, 522, 38, 70.

Distribution: Magga Dan 21, 28.

83. Rhizosolenia hebetata (Bail.) em. Gran 1904.
f. semispina (Hensen) Gran 1904.

Distribution: Magga Dan 3, 6, 10, 14, 18, 21, 27, 30, 33, 35, 37, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 60, 62, 63, 64, 65, 66, 67, 69, 70, 71, 74, 82.

f. hiemalis Gran 1904.

Distribution: Thala Dan 9; Magga Dan 5, 9, 12, 14, 18, 21, 27, 29, 35, 41, 47, 48, 52, 56, 57, 64, 75, 85, 88, 90.

84. Rhizosolenia imbricata Brightw. 1858.

Crosby and Wood, 1958, 522, 39, 74.

Distribution: Magga Dan 28, 48, 80, 82, 84, 85, 88.

85. Rhizosolenia rhombus Karst. (Pl. iv, fig. 39).

Karst., 1905, 97, 10, 6, *a-c*; Hend., 1937, 317.

Frustules large, usually solitary; valves bluntly conical, oblique, with short, stout, winged spine; impression of opposing spine strongly indented into valve; girdle with scale-like intercalary markings, finely punctate. Length 400–500μ. *Distribution*: Magga Dan 84, 85.

86. Rhizosolenia rostrata (Heiden and Kolbe) (Pl. iv, fig. 41).

R. alata v. *inermis* f. *rostrata* Heiden and Kolbe, 1928, 522, 9, 167.

Frustules solitary; valves tapering; spine hollow, spatulate with rounded end; intercalary bands scale-like. Length 150–250μ. *Distribution*: Magga Dan 9, 15, 16, 17, 27, 28, 30, 31, 54, 57, 70, 86, 88.

87. Rhizosolenia simplex Karst. (Pl. iv, fig. 40).

Karst., 1905, 95, 10, 1.

Cells small, cylindrical, usually solitary; frustules straight; valves acutely conical with slender tapering spine; girdle zone with very lightly outlined scale-like intercalary bands. Length 200–300μ. *Distribution*: Magga Dan 43, 51, 91.

88. Rhizosolenia styliformis Brightw. 1858.

Crosby and Wood, 1958, 523, 34, 2.

Distribution: Thala Dan 15, 17; Magga Dan 2, 3, 10, 16, 17, 21, 28, 22, 36, 41, 44, 45, 47, 48, 54, 56, 58, 60, 64, 69, 76, 80, 81, 82, 84, 85, 86, 88, 92.

89. Rhizosolenia truncata Karst. (Pl. iv, fig. 42).

Karst., 1905, 97, 10, 3a; Hend., 1937, 320.

Frustules small, cylindrical, solitary or in short chains; valves rounded, with oblique process and a projection into which opposing process fits; terminal cell of chain has straight process; intercalary markings faint. Length 100–140μ. *Distribution*: Magga Dan 37.

Family LEPTOCYLINDRACEAE.

Genus Leptocylindrus Cl. 1889.

90. Leptocylindrus danicus Cl. 1889.

Crosby and Wood, 1958, 524, 39, 80.

Distribution: Magga Dan 9.

Genus Dactyliosolen Castr. 1886.

91. Dactyliosolen antarcticus Castr. 1886.

Crosby and Wood, 1958, 524, 39, 82.

Distribution: Magga Dan 20, 21, 22, 23, 26, 27, 28, 29, 33, 41, 42, 51, 52, 54, 74, 75, 77, 78, 84, 88, 90.

92. DACTYLIOSOLEN MEDITERRANEUS Perag. 1892.

Crosby and Wood, 1958, 524, 39, 81.

Distribution: Magga Dan 9, 16, 17, 23, 74, 75, 76, 78, 80, 81, 82, 88, 91, 92.

Family CORETHRONACEAE.

Genus CORETHRON Castr. 1886.

93. CORETHRON CRIOPHILUM Castr. 1886.

Crosby and Wood, 1958, 525, 39, 83.

The great variation in this species and the intergrades between forms described by Hendey (1937) were encountered in the Magga Dan material. This differs from the tropical strain which is uniform in appearance, but apparently identical with some of the Antarctic forms. *Distribution*: Thala Dan 8, 9, 10, 15, 16; Magga Dan 4, 6, 8, 13, 16, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 80, 81, 86, 87, 88, 90, 91.

Sub-Order ARAPHIDINEAE.

Family FRAGILARIACEAE.

Genus FRAGILARIA Lyngb. 1819.

94. FRAGILARIA GRANULATA Karst. (Pl. iv, fig. 44).

Karst., 1905, 396, 45, 8; Hend., 1937, 230.

Cells in curved chains, often forming horse-shoe; valves linear-lanceolate, slightly inflated, transversely striate; valves slightly rounded in girdle view. Length 40–50μ. *Distribution*: Wilkes Land.

95. FRAGILARIA LINEARIS Castr. (Pl. iv, fig. 45).

Castr., 1886, 56, 19, 9; Heiden and Kolbe, 1928, 550, 6, 128. *Fragilaria curta* van H., 1909, 24, 3, 37.

Cells in flat ribbon-like chains; frustules linear; valves flat, apices rounded, lateral margins straight; surface finely transversely striate; girdle simple. Length 30–50μ. *Distribution*: Magga Dan 9, 30, 35, 36, 39, 49, 51, 52, 53, 54, 56, 58, 60, 62, 68, 69, 66, 72, 75, 86, 26, 41, 43, 48.

96. FRAGILARIA OCEANICA Cl. 1873 (Pl. iv, fig. 46).

Crosby and Wood, 1959, 2, 2, 1.

Distribution: Thala Dan 9; Magga Dan 9, 27, 28, 35, 39, 48, 58, 61, 62, 65, 68, 71, 74, 88.

97. FRAGILARIA STRIATULA Lyngb. 1819 (Pl. iv, fig. 47).

Crosby and Wood, 1959, 2, 1, 1.

Distribution: Magga Dan 8, 17, 21, 23, 24, 26, 30, 33, 35, 37, 74, 75, 76, 78, 80, 81, 82, 88, 91, 92.

98. FRAGILARIA sp. (Pl. iv, fig. 60).

Cells in chains; valves ellipsoid with acute ends, pseudoraphe evident; valves with striae transverse, those towards centre of valve interrupted. Length 40μ. *Distribution*: Wilkes Land.

Genus FRAGILARIOPSIS. Hust. 1913.

99. FRAGILARIOPSIS ANTARCTICA (Castr.) Hust. 1913.

Crosby and Wood, 1959, 3, 2, 3*a*, *b*.

Distribution: Thala Dan 8; Magga Dan 15, 16, 20, 21, 22, 23, 24, 26, 27, 28, 29, 31, 33, 34, 39, 41, 42, 43, 45, 48, 51, 52, 53, 54, 56, 57, 62, 63, 73, 74, 76, 78, 82, 87.

Genus THALASSIOTHRIX Cl. and Grun. 1880.

100. THALASSIOTHRIX ANTARCTICA Karst. 1906.

Crosby and Wood, 1959, 4, 1, 5.

Distribution: Thala Dan 7, 8, 9, 10, 15, 16; Magga Dan 4, 6, 8, 10, 11, 16, 17, 18, 20, 21, 22, 23, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 42, 44, 45, 51, 52, 54, 56, 57, 58, 68, 69, 70, 72, 73, 76, 77, 78, 80, 82, 84, 86, 87, 88, 91.

101. THALASSIOTHRIX LONGISSIMA Cl. and Grun. 1880.

Crosby and Wood, 1959, 3, 1, 4.

Distribution: Thala Dan 4, 8, 9, 10, 15, 17; Magga Dan 1, 2, 3, 4, 5, 6, 10, 12, 14, 16, 18, 21, 27, 31, 33, 34, 35, 36, 41, 45, 46, 48, 49, 54, 56, 61, 62, 63, 64, 66, 68, 69, 71, 76, 80, 87, 88, 90, 91.

Genus LICMOPHORA Agh. 1827.

102. LICMOPHORA FLABELLATA (Carm.) Agh. 1830.

Crosby and Wood, 1959, 9, 2, 24.

Distribution: Wilkes Land.

Genus SYNEDRA Ehr. 1830.

103. SYNEDRA GAILLONII (Bory) Ehr. 1838.

Crosby and Wood, 1959, 6, 2, 14.

Distribution: Magga Dan 15.

104. SYNEDRA REINBOLDII v H. 1909.

S. spathulata Sch. in Karsten, 1905, 124, 17, 11; *S. pelagica* Hend., 1937, 335; Crosby and Wood, 1959, 5, 2, 7.

Distribution: Thala Dan 8, 11, 13, 15, 17; Magga Dan 2, 17, 18, 20, 23, 24, 36, 37, 40, 42, 45, 47, 52, 54, 56, 78.

105. SYNEDRA ULNA (Nitzsch) Ehr.

Crosby and Wood, 1959, 3.

var. AMPHIRHYNCHUS (Ehr.) Grun. (Pl. v, fig. 63).

Grun., 1862, 397; *Synedra amphirhynchus* Ehr., 1841, 3, 1, 25.

Sub-Order MONORAPHIDINEAE.

Family ACHNANTHACEAE.

Genus ACHNANTHES Bory 1822.

106. ACHNANTHES BREVIPES Agh. 1824.

Crosby and Wood, 1959, 13, 3, 37.

Distribution: Wilkes Land.

107. ACHNANTHES TAENIATA Grun. in Cl. and Grun. 1880.

Wood, 1960, 2, 48.

Distribution: Wilkes Land.

Genus COCCONEIS Ehr. 1838, em. Grun. 1868.

108. COCCONEIS IMPERATRIX A.S. (Pl. iv, fig. 48, *a*, *b*).

A.S., 1894, 189, 11–15; Hend., 1937, 342, 10, 8–9.

Cells elliptical, large; valves dissimilar; upper very ornate; raphe fine; hyaline area narrow, central area broad, dilated reaching margin; surface furrowed, furrows with two rows of puncta which also occur in the marginal loculi; lower valve with fusiform pseudoraphe, furrows with double row of puncta but no submarginal hyaline ridge. Length 80–120μ. *Distribution*: Wilkes Land.

Sub-Order BIRAPHIDINEAE.

Family NAVICULACEAE.

Genus NAVICULA Bory 1794.

109. NAVICULA MEMBRANACEA Cl. (Pl. iv, fig. 49).

Cl., 1897, 24, 2, 25–28; Hend., 1937, 345, 11, 4.

Cells in straight chains; frustules in valve view linear with slight median inflation and pointed apices; in valve view rectangular with wide girdle; chromatophores two undulating ribbons. Length 60–70μ. *Distribution*: Magga Dan 30, 56, 60, 71.

Genus TRACHYNEIS Cl. 1894.

110. TRACHYNEIS ASPERA (Ehr.) Cl. 1894.

Crosby and Wood, 1959, 22, 5, 63.

Distribution: Magga Dan 21, 42; Wilkes Land.

Genus Pleurosigma W. Sm. 1853.

111. Pleurosigma decorum W. Sm. (Pl. v, fig. 52).

W. Sm., 1853, 63, 21, 196.

Valves lanceolate, sigmoid, apices acute, one margin slightly angled opposite central nodule; raphe very sigmoid, close to margin from half-way between central nodule and apices; striae fine. Length 80μ. *Distribution*: Magga Dan 28; Wilkes Land.

112. Pleurosigma directum Grun. 1880 (Pl. iv, fig. 51).

Wood, 1960, 4, 100.

Distribution: Thala Dan 9; Magga Dan 9, 21, 24, 27, 30, 33, 34, 56, 69.

Genus Amphiprora Ehr. 1843.

113. Amphiprora alata (Ehr.) Kütz. 1844.

Crosby and Wood, 1959, 31, 7, 91.

Distribution: Wilkes Land.

114. Amphiprora kjellmanii Cl. (Pl. v, figs 53–64).

Cl. and Grun., 1880, 15, 4, 83; Hend., 1937, 349.

Cells large, solitary, twisted about valve axis; valves elliptic-lanceolate, apices rounded, keel prominent, winged; alae sigmoid, striate, striae medium; girdle zone complex, plicate. Length 125μ. *Distribution*: Wilkes Land.

Genus Tropidoneis Cl. 1891.

115. Tropidoneis antarctica (Grun.) Cl. (Pl. iv, fig. 50).

Cl., 1894, 24; Karst., 1905, 128, 18, 7; Hend., 1937, 350.

Cells large, weakly siliceous; valves linear-elliptic; not winged; lateral area narrow, dilated at middle into a narrow stauros; surface finely striate; striae transverse, divergent near apices; girdle view slightly constricted at central nodule, girdle zone simple. Length 100–160μ. *Distribution*: Magga Dan 41, 42, 51, 27, 37, 46, 52, 54, 56, 60, 70, 77.

Family BACILLARIACEAE.

Genus Nitzschia Hassall, 1845, em. Grun. 1880.

116. Nitzschia closterium (Ehr.) W. Sm. 1853.

Crosby and Wood, 1959, 33, 1, 17.

Distribution: Magga Dan 40.

117. Nitzschia compressa (Bail.) Boyer 1926 (Pl. v, fig. 61).

Wood, 1960, 6, 174.

Distribution: Magga Dan.

118. Nitzschia granulata Grun. 1880.

Wood, 1960, 6, 178.

Distribution: Magga Dan.

119. Nitzschia longissima (Breb.) Ralfs 1861.

Crosby and Wood, 1959, 38, 1, 16.

Distribution: Magga Dan 2, 14, 30, 34, 35, 37, 45, 56, 60, 73, 86, 88.

120. Nitzschia martiana (Ag.) Schütt 1896.

Crosby and Wood, 1959, 39, 1, 24.

Distribution: Wilkes Land.

121. Nitzschia pacifica Gupp 1843.

Crosby and Wood, 1959, 39, 1, 23.

Distribution: Magga Dan 9, 15, 21, 23, 26, 27, 28, 29, 30, 31, 33, 35, 36, 37, 42, 41, 46, 47, 45, 62, 74, 84.

122. NITZSCHIA PELAGICA Karst. (Pl. v, fig. 54).

Karst., 1905, 129, 18, 10; Hend., 1937, 352.

Cells large, elliptic-lanceolate, apices acute; raphe central, distinct; girdle zone deep. simple. Length 250μ. *Distribution*: Magga Dan.

123. NITZSCHIA SERIATA Cl. 1883.

Crosby and Wood, 1959, 38, 1, 18.

Distribution: Magga Dan 16, 21, 22, 23, 24, 27, 31, 34, 41, 61, 64, 73, 74, 76, 77, 80, 83, 86, 88.

124. NITZSCHIA TRYBLIONELLA Hantzsch 1859.

Wood, 1960, 6, 185.

Distribution: Magga Dan 27, 34, 42, 43, 45, 48, 51, 56, 60, 62.

Genus CHUNIELLA Karst. 1905.

Frustules with a more or less excentric keel and raphe; keel puncta may be present.

125. CHUNIELLA ANTARCTICA Karst. (Pl. v, fig. 55).

Karst., 1905, 130, 18, 14.

Cells solitary or in pairs, in girdle view lanceolate with blunt ends and a slight median constriction, in valve view lanceolate evenly tapering to pointed ends, raphe strongly excentric, borne on keel; chromatophores small, spherical. Length 180μ. *Distribution*: Magga Dan 23, 24, 27, 28.

126. CHUNIELLA OCEANICA (Karst.) Hend. (Pl. v, fig. 56, *a*, *b*).

Hend., 1937, 353; *Navicula oceanica* Karst., 1905, 126, 18, 4.

Frustules large, usually solitary; valves broadly lanceolate, apices acute; surface apparently hyaline; raphe excentric, slightly depressed in the middle; girdle view truncate-elliptic, ends rounded, girdle simple. Length 200μ. *Distribution*: Magga Dan 16, 20, 21, 23, 24, 27, 28, 29, 31, 33, 41, 42, 51, 52, 56, 61, 68, 75.

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EXPLANATION OF PLATES III-V.

Plate iii

1, *Melosira sphaerica*; 2, *M. polaris*; 3, *Hyalodiscus kerguelensis*; 4, *Thalassiosira antarctica*; 5, *T. condensata*; 6, *Coscinosira antarctica*; 7, *Coscinodiscus comptus*; 8, *C. gemmatulus*; 9, *C. griseus*; 10, *C. incurvus*; 11, *C. intermittens*; 12, *C. kryophilus*; 13, *C. lentiginosus*; 14, *C. stellaris*; 15, *C. subtilis*; 16, *Ethmodiscus subtilis*; 17, *Schimperiella antarctica*; 18, *a, b, S. valdiviae*; 19, *a, b, Actinocyclus bifrons*; 20, *A. intermittens*; 21, *A. janus*; 22, *a, b, A. umbonatus*; 23, *Asteromphalus beaumontii*; 24, *A. hookeri*; 25, *a, b, A. antarcticus.*

Plate iv.

26, *Asteromphalus roperianus*; 27, *Biddulphia anthropomorpha*; 28, *B. weissflogii*; 29, *Chaetoceros borealis*; 30, *C. castracanei*; 31, *C. filiferum*; 32, *C. peruvianum*; 33, *C. bulbosum*; 34, *C. seychellarum*; 35, *a, b, Rhizosolenia antarctica*; 36, *R. bidens*; 37, *R. chunii*; 38, *R. crassa*; 39, *R. rhombus*; 40, *R. simplex*; 41, *R. rostrata*; 42, *R. truncata*; 43, *Chaetoceros gaussii*; 44, *Fragilaria granulata*; 45, *F. linearis*; 46, *F. oceanica*; 47, *F. striatula*; 48, *a, b, Cocconeis imperatrix*; 49, *Navicula membranacea*; 50, *Tropidoneis antarctica*; 51, *Pleurosigma directum.*

Plate v.

52, *Pleurosigma decorum*; 53, *Amphiprora kjellmanii*; 54, *a, b, Nitzschia pelagica*; 55, *Chuniella antarctica*; 56, *a, b, Ch. oceanica*; 57, *Triceratium antarcticum*; 58, *Eucampia balaustium*; 59, *Chaetoceros dichaeta*; 60, *Fragilaria* sp.; 61, *Nitzschia compressa*; 62, *Melosira sol*; 63, *Synedra ulna* v. *amphirhynchus*; 64, *Amphiprora kjellmanii*; 65, *Actinocyclus* sp. a; 66, *Actinocyclus* sp. b; 67-9, *Coscinodiscus asteromphalus.*

TEGEA ATROPICTA STÄL (HEMIPTERA, REDUVIIDAE), AN UNUSUAL PREDATOR OF TERMITES.

By M. Casimir, Entomology Branch, N.S.W. Department of Agriculture.

[Read 27th July, 1960.]

Synopsis.

Observations made in the field and laboratory indicate that *Tegea atropicta* Stäl is an efficient predator of termites in the Sydney region. The unusual feeding behaviour observed in the laboratory is believed to be unique and it is concluded that the "fishing" technique used to entice termites within range is particularly well adapted for predation of certain termite species that cover infested timber with an extensive thin layer of woody carton material. Thus, *T. atropicta* is probably a specific predator of *Nasutitermes exitiosus* Hill and related species. Field records support this conclusion.

T. atropicta is widely distributed over at least the eastern half of Australia.

INTRODUCTION.

The well-insulated environment maintained by many species of termites generally serves to protect them from outside intrusion, and there appear to be few successful predators of termites in Australia, apart from ants, which are non-specific predators and whose attacks are limited to chance penetrations of the termites' gallery systems. However, observations carried out on the Reduviid bug, *Tegea atropicta* Stäl, indicate that this insect is probably a specific predator of certain termite species and that it overcomes in a unique fashion the formidable barriers of cemented earth erected by the termites for their gallery system.

A strikingly coloured red and black insect, *T. atropicta*, was originally described by Stäl (1863) from specimens collected in the Sydney region. Letherry and Severin (1896) also made reference to this insect, but in neither publication were any biological details given.

DISTRIBUTION.

Information made available from collections of the Australian Museum, the museums of Queensland, Victoria and South Australia, and the Department of Agriculture of N.S.W., indicate that the species is widely distributed in at least the eastern half of Australia. Individual locality records are: VICTORIA: Belgrave; NEW SOUTH WALES: Forbes (1899), Tweed Heads (1903), Bogan River (1931), Neilson Park (1932), Wallacia, Penrith, Glenfield, Kurrajong (1942), Tamworth (1951), Sydney (1955), Finley, Sydney (1958), Sydney (1959); QUEENSLAND: Carnarvon Range (1939), Kuranda (1949), Bowen, Mount Garnet (1954); NORTHERN TERRITORY: Port Darwin.

Only a few of the above records were accompanied by additional data and these are: (*a*) Newport (Sydney), 1955—in large numbers in a garage. (*b*) Kurrajong, 1942—on termite mound. (*c*) Kingswood (Sydney), 1958—on fallen timber heavily infested by a *Nasutitermes* species. (*d*) West Pennant Hills (Sydney), 1958—in large numbers in a garage heavily infested by *Nasutitermes exitiosus* Hill. (*e*) Galston (Sydney), 1959—engorged nymphs under bark of dead Eucalypt, in galleries of *N. exitiosus.*

FIELD OBSERVATIONS.

On 4th March, 1958, large numbers of *T. atropicta* were observed by the writer at West Pennant Hills, an outer suburb of Sydney, in a garage heavily infested by the mound-building termite, *N. exitiosus.* The mound colony was located about 100 feet from the garage and the termites had constructed an extensive system of earthen galleries over many of the structural timbers inside. Much of the wood had been badly damaged.

Colonies of nymphal and adult *T. atropicta* were noticed clustering thickly around many of the galleries and individuals were even located inside the termite-infested timber. Wherever the bugs were numerous there appeared to be fewer termites in the associated galleries than in normally active galleries which, in some cases, were almost deserted. Most of the nymphal bugs observed had greatly distended abdomens as if they had been feeding heavily.

LABORATORY OBSERVATIONS.

Several dozen specimens of *T. atropicta* were taken from the garage and maintained as a stock colony for several weeks. At the same time, small colonies of *N. exitiosus* were established. These were collected in the field from active mounds, separated from the earthy material by sieving as described by Gay *et al.* (1955), and finally transferred to eight-inch by one-inch test tubes provided with a moisture gradient by using plaster of paris columns (Pence, 1957) or moistened sand (Ebeling and Pence, 1957). Healthy groups of 10–20 termites were maintained for 2–3 weeks in the moistened sand without food, tunnels being quickly excavated by the termites, often next to the glass wall of the tube where tunnelling activities could be readily observed with the aid of a low power binocular microscope. The tubes containing moistened plaster of paris columns were used with less success, although groups of up to 200 termites were maintained for 4–5 days before accumulation of free moisture appeared to cause a quick decline in termite numbers.

Specimens of *T. atropicta* from the stock colony were introduced into several of the tubes containing termites. Those placed into the plaster of paris tubes showed no interest in the termites and were, in fact, often attacked by the latter and driven to the top of the tube where they remained motionless until removed. Similarly, in the tubes containing moist sand, the termites tended to emerge from their burrows onto the sand surface and attack any bugs introduced. The latter were never observed to retaliate, but rather appeared to become frantic in their attempts to escape.

Normally, termites in these tubes containing sand left the mouths of their tunnels open and thus maintained free access to the sand surface. However, in one tube, the termites constructed a thin shelf of cemented sand particles over the wide mouth of the main burrow and continued tunnelling beneath. Adult and nymphal *T. atropicta* introduced to this tube moved about slowly over the sand surface and eventually congregated near the top of the sealed tunnel. Each bug appeared to test the sand shelf for vibration with the tips of its antennae and, when satisfied that there was some activity beneath, probed the shelf with its rostrum, leaving about one-third of the latter protruding into the tunnel. The intruding rostrum was then invariably attacked by termites guarding the entrance and grasped fiercely in their mandibles. However, they appeared unable to damage this chitinous structure and, after continual small and unsighted adjustments of the rostrum, the predator generally managed to pierce the attacking termite's head capsule in the region of the mouth parts. No sudden movements were made, the pointed rostrum sliding smoothly into the termite, and, although the rostrum itself did not appear to penetrate far, it was assumed that the stylets were introduced deep into the head or body cavity of the termite. The body contents were then sucked out by regular pumping movements of the predator which continued feeding for periods of up to one hour.

Bodies of termites killed in this fashion were quickly removed by other termites to an offshoot tunnel or little used section of the main tunnel, after having had all the appendages chewed off. The corpse was then walled off with a layer of cemented sand particles. This procedure was observed several times and the "colony" of twelve active termite workers was finally reduced to three by the predators. Both nymphal and adult bugs fed in this way, in every case observed the method of attack being similar.

DISCUSSION.

Predation in the family Reduviidae ranges from the straight-forward hunting habit of many species to a wide variety of methods such as camouflage and mimicry to entice prey within range. However, there is no recorded instance paralleling the "fishing" technique adopted by *Tegea atropicta* to entrap termites.

Little is known about the biology of *Tegea* and related species belonging to the small subfamily Tegeinae Villiers 1948. According to Miller (1956) all four generic members of the group are confined to the Indo-Australian region; their habitats are trunks of trees, and, although no information is available regarding their food, from the shape of the rostrum it seems likely that they search for their prey by probing crevices and borings in the bark of trees. However, the laboratory evidence presented above indicates that *T. atropicta* is a predator of termites under some circumstances, and field records also indicate an association with termites under natural conditions.

The unusual feeding behaviour involving deliberate use of the rostrum to provoke attack by the intended prey which is never even sighted by the predator lends support to the conclusion that *T. atropicta* is a specific predator of termites. This specificity may be further restricted to certain termite species such as some of the Nasutitermes group which typically construct an extensive network of thin-walled galleries over the surface of an infested object and would therefore provide conditions approaching those in the laboratory where successful predation was observed. Other common and destructive termite species belonging to the *Coptotermes* genus would be less susceptible to attack because of their preference for attacking timber from the centre and packing gallery spaces with quantities of fine clay in contrast to the Nasutitermes habit which is to gouge the surface of timber to a rough face under cover of a thin layer of woody carton material. Field records also indicate a strong association between *T. atropicta* and *Nasutitermes* species, particularly *N. exitiosus*.

The wide distribution of the species in Australia and the observations of large numbers of engorged nymphs in close proximity to galleries of *N. exitiosus*, in an infested garage at West Pennant Hills and an infested tree at Galston, indicate that, under favourable conditions, this predator may be a significant factor in regulating termite numbers.

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THE LARVAL ECOLOGY OF *AËDES AUSTRALIS* (ERICHSON) (DIPTERA, CULICIDAE) IN THE SYDNEY AREA.

By A. K. O'Gower, School of Biological Sciences, University of New South Wales.

(Plate vi; seven Text-figures.)

[Read 31st August, 1960.]

Synopsis.

The distribution of the larvae of *A. australis* in the Sydney area was found to be correlated with the geological formation of the coastline, for the larvae occurred only in saltwater rock pools formed in sandstone rock platforms.

At Mackenzie Bay a series of six rock pools was studied to try to correlate egg hatching and larval mortality with the environmental factors of flushing, temperature, salinity and evaporation. Temperature did not affect larval mortality as the larvae could withstand a daily range in temperature of at least 27°F., a seasonal range in temperature of at least 54°F., and an hourly change in temperature of at least 9°F. However, salinity affected both egg hatching and larval mortality as first instar lavae were absent from pools in which the salinity of the water had increased beyond the mean value 4·6%, and fourth instar larvae could tolerate a salinity of up to 24% and a daily increase in salinity of 5·2%.

The percentages of occurrences of first and fourth instar larvae in these rock pools were 59 and 68 respectively, while larvae were absent from the pools in 25% of the examinations, 10% being due to flushing by heavy seas, 5% being due to flushing by rain water and 10% being due to drying of the pools. The significance of these findings is then discussed with regard to the ecology of this species.

INTRODUCTION.

The larvae of *Aëdes australis* (Erichson) (= *concolor* Taylor) are found in the Sydney area in sandstone rock pools in which the salinity varies (Mackerras, 1926; Woodhill, 1936). O'Gower (1959) was able to explain the presence of these larvae in such habitats by studying the oviposition behaviour of the female mosquito, but this study did not explain the absence of larvae from freshwater pools. To understand more fully the larval ecology of this species a series of six rock pools was studied at Mackenzie Bay to try to correlate larval mortality and emergence with the environmental factors of salinity, temperature, flushing and evaporation.

METHODS.

The coastline of the Sydney area from the Hawkesbury River to Botany Bay was examined where physically possible for larvae of *A. australis* and all areas examined, together with all positive findings, were plotted on a distribution map.

The influence of the environmental factors of temperature and salinity on larval emergence and larval mortality was then studied in a selected series of six rock pools at Mackenzie Bay. These rock pools were examined at 0700 hours thrice weekly over a period of twelve months for the presence or absence of first instar larva and fourth instar larvae, and at the same time the salinity and the temperature of the water in each pool were measured. Concurrently at monthly intervals hourly changes in the temperature of the waters of these pools were recorded from 0700 hours to 2000 hours.

Temperatures were measured with a thermometer shielded against radiant heat and were read at the centres of the pools with the thermometer bulb one inch below the water surface. However, when the depths of the pools became less than one inch due to evaporation, temperatures were read with the thermometer case resting on the bottoms of the pools.

Water samples for salinity determinations were collected in tightly stoppered bottles and titrated within half an hour against N/10 silver nitrate using potassium dichromate as the indicator. Four determinations of each sample were made and the mean of these used for the salinity value.

The degree of exposure of each of the six pools to sunlight, salt spray and to wave action was noted, while such physical dimensions as area of the water surface, length of intersurface between water and rock surface, depth and volume were measured.

RESULTS.

It can be seen from Figure 1 that the distribution of the larvae of *A. australis* between the Hawkesbury River and Botany Bay is continuous except along the coast line from Palm Beach to Long Reef. This is due to an outcrop of Narrabeen shales in an area which is predominantly Hawkesbury sandstone, for weathering forms rock pools of varying shapes and sizes in rock platforms of sandstone, but not in those of shale. Thus the type of larval habitat occupied by this species is not available in areas where there are outcrops of shale.

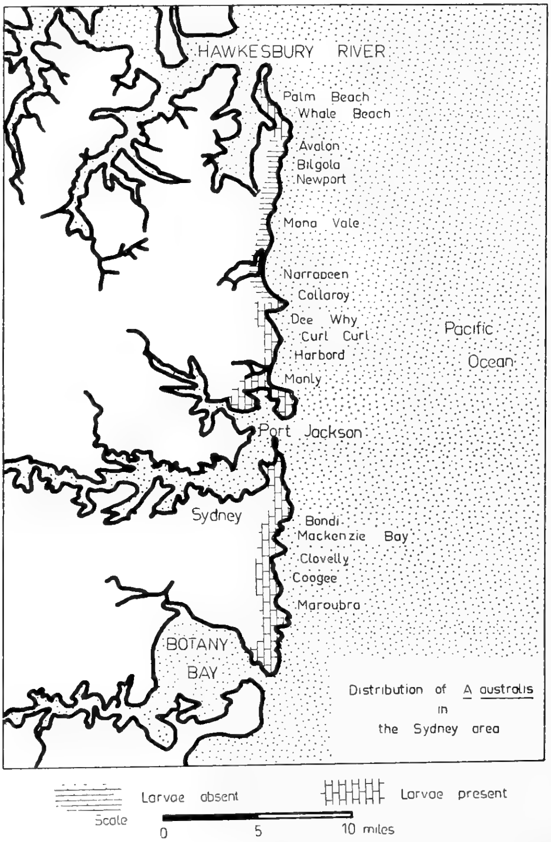


Fig. 1. The larval distribution of *Aëdes australis* (Erichson) in the Sydney area.

Tri-weekly examinations of the rock pools over the twelve-month period showed: (i) first instar larvae were not present in any of the pools in which the salinity had increased beyond the value, mean 4·6%, variance 0·12, and in two instances over this period fourth instar larvae died when the salinity reached an approximate value of 25% (less than 24% in Pool A with a daily increase in salinity of 5·2% and 25·7% in Pool B with a daily increase in salinity of 1·4%); (ii) the percentages of occurrences of first and fourth instar larvae were 59 and 68 respectively; (iii) larvae were absent from these pools in 25% of the examinations, 10% being due to flushing by heavy seas, 5% being due to flushing by rain water and 10% being due to drying of the pools.

The degree of exposure of each of the six rock pools to sunlight, salt spray and to wave action is given below; figures are presented of the hourly changes in temperatures of the pools for a sunny day in each of the months January, April, July and October; the physical dimensions of the pools are shown in Table 1; and the position of each pool in the study area is shown on Plate vi.

Pool A is approximately seven feet above mean high tide, but is placed in such a position relative to the surf that moderate seas at high tide flush the pool with sea water. During the stormy winter months this flushing is sufficiently regular to allow such marine animals as the worm *Galeolaria caespitosa* and the anemone *Oulactis mucosa* to colonize the pool temporarily. At other times the pool receives a considerable amount of salt spray, which, together with a high rate of evaporation of water due to the large surface area of the pool and its shallow depth, can cause a daily increase in salinity of the water of 5·2%. The pool is exposed to sunlight from sunrise to midday over the whole year and the resulting hourly changes in the temperature of the water can be seen in Figure 2.

TABLE 1.

Dimensions of Six Selected Rock Pools.

Pool.	Area. (Square Feet.)	Circumference. (Feet.)	Mean Depth. (Inches.)	Volume. (Cubic Feet.)
A	31·6	27·0	2·0	5·3
B	2·8	8·4	3·8	0·8
C	3·8	8·8	4·4	1·4
D	11·3	21·4	1·7	1·6
E	12·2	25·8	14·4	14·6
F	2·7	8·3	2·7	0·6

Pool B is on the same platform as Pool A, but further from the edge of the surf. Thus only heavy seas at high tide flush the pool with sea water. Although the pool is exposed to considerable amounts of salt spray at other times, the daily increase in salinity due to evaporation was low (1·4%), for the pool is sunlit for only a few hours after sunrise in winter and thus the hourly change in temperature was slight and the daily maximum temperature was low (Figure 3).

Pool C is also on the same platform as the two former pools, but further from the edge of the surf and at a slightly lower level. Thus only heavy seas at high tide can flush it with salt water, but it is exposed to salt spray. Due to its position relative to run-off from domestic effluent the water was frequently polluted with organic matter. The pool is exposed to sunlight from sunrise to midday over the whole year and the effect of this can be seen in the hourly change in the water temperature (Figure 4).

Pool D, although on the same rock platform as the three former pools, is at a considerable distance from the edge of the surf and is therefore only rarely flushed with sea water, but is exposed to a considerable amount of salt spray. This pool is exposed to sunlight from sunrise until the sun sinks below the low cliffs behind it at about 1500 hours, and this exposure, together with the large surface area and the shallow depth of the pool, resulted in high temperatures, large hourly changes in temperature (Figure 5) and a high rate of evaporation. Thus the pool was dry 64 days during the period October to March inclusive, but the salinity did not exceed 4·7% during this period.

Pool E is on a sheltered rock platform above and beyond the edge of the surf. Thus it receives only a fine salt spray mist even in huge seas. The pool is exposed to sunlight for about four hours in the middle of the day in summer. However, due to the small surface area of the pool relative to its volume, hourly changes in the

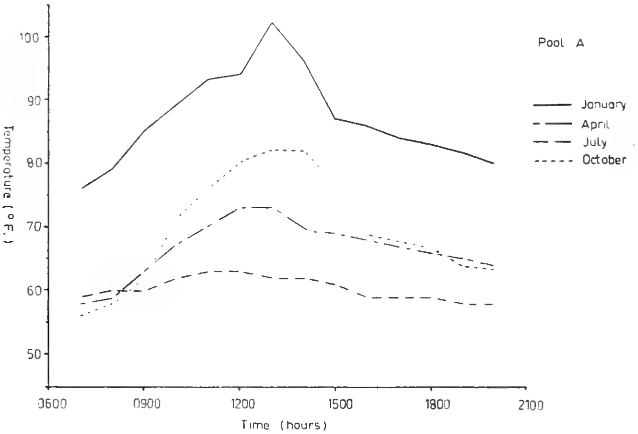
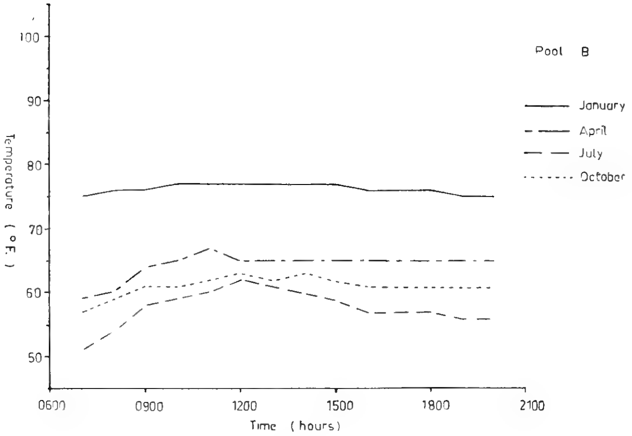


Figure 2.



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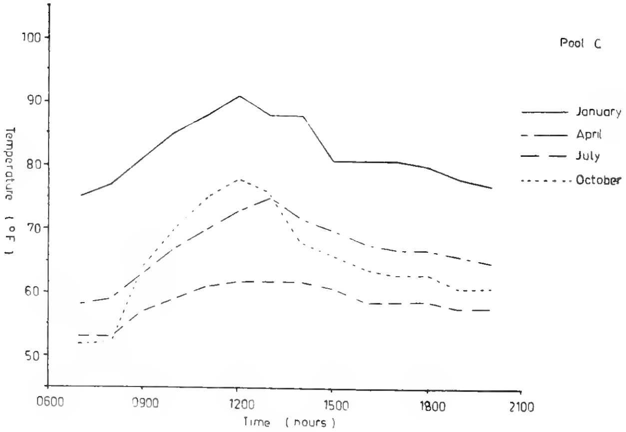

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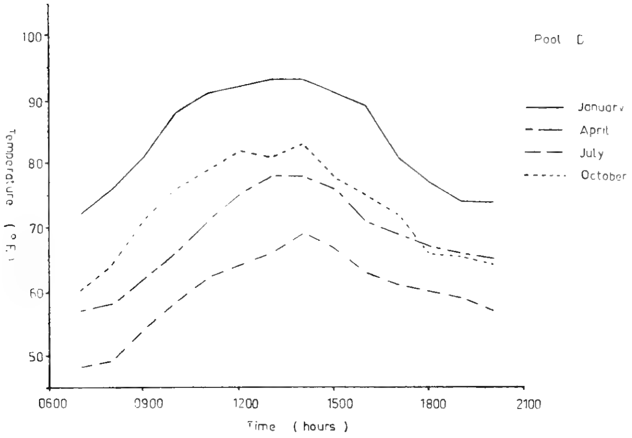

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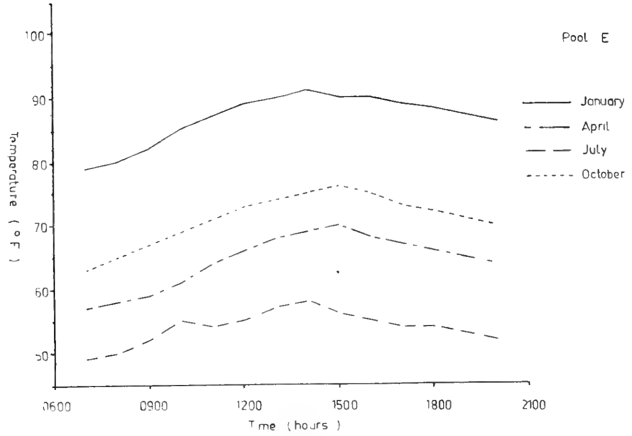

Figure 6.

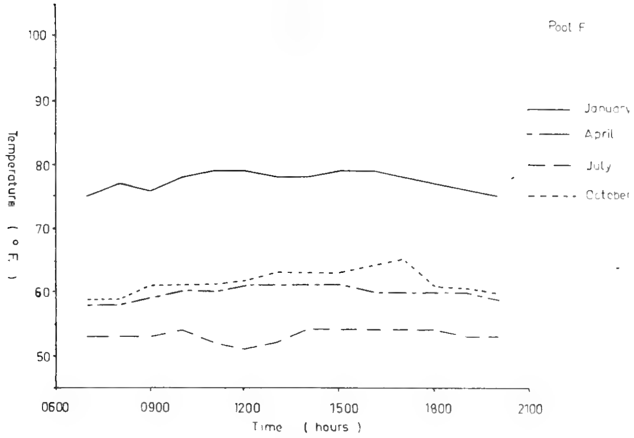

Figure 7.

Figs 2 to 7. Hourly changes in the temperatures of the waters of Pools A to F respectively for the months January, April, July and October.

temperature of the water were small (Figure 6) and never during the period of study did the pool dry out.

Pool F is on a small rock platform above the surf and thus receives only a fine salt spray mist, and, as it is continuously shaded all the year by overhanging rock, the hourly changes in the temperature of the water were slight (Figure 7).

DISCUSSION.

A study of the hourly changes in temperature of each of the six rock pools for the months January, April, July and October (Figures 2, 3, 4, 5, 6 and 7) shows first that there was a correlation between the physical dimensions of the pools and the hourly changes in water temperatures; second that in all pools except B and F the water temperature rose to a maximum at or about midday; and third, that there was a striking seasonal variation in the water temperatures. As no mortalities due to high or low temperatures were recorded in any of the pools, the larvae must be able to tolerate a daily range of temperature of at least 27°F. (Figure 2: from 75°F. to 102°F.), a seasonal range in temperature of at least 54°F. (Figures 5 and 1: from 48°F. to 102°F.), and an hourly change in temperature of at least 9°F. (Figure 1: January, 1400 hours to 1500 hours).

The ability of the larvae of *A. australis* to tolerate these relatively large changes in temperature is of obvious ecological importance to this species, for the salt-water rock pools, in which these larvae occur, lack either emergent or overhanging vegetation which usually shades fresh-water rock pools. Thus water temperature, although it may be a factor which limits the larval distribution of those species breeding in fresh-water rock pools, appears to have little influence in limiting the distribution of *A. australis*, and the larvae appear to be physiologically adapted to such an environment.

Tri-weekly salinity determinations in all six rock pools showed that first instar larvae only occurred in water which had a mean salinity of less than 4·6%. Thus either rain water or sea water can hatch the eggs of *A. australis*. It was also shown that fourth instar larvae can tolerate a daily increase in salinity of 5·2% up to a maximum of approximately 24%, and this maximum agrees closely with the 20% salinity which Woodhill (1936) showed did not affect survival but which did affect pupation. Finally it was noted that over the twelve-month period deaths of larvae due to high salinities occurred only twice. It may therefore be concluded that the larvae of *A. australis* are physiologically adapted to a salt-water rock-pool environment and that salinity, apart from limiting egg hatching, does not affect the larval population.

During the period of study the rock pools were dry in 10% of the examinations and in all cases the larvae died from desiccation and not from the increase in salinity. For example, Pool D, which has a large surface area, a shallow depth and a small volume, was empty of water 28% of the time during the period October to March inclusive, and the maximum salinity recorded during this period was 4·7%. Thus one hazard to the survival of the larvae of *A. australis* is the physical drying out of the rock pools from evaporation.

The unsuccessful colonization of Pool A by *Galeolaria* and *Oulactis* indicates that this pool was regularly flushed with sea water for at least some period during this study; otherwise these invertebrates could not have become established. Thus the constant flushing of the more exposed rock pools by heavy seas in winter, which accounted for 10% of the examinations being negative for larvae, is another hazard to the survival of the larvae of *A. australis*.

The widespread simultaneous hatching of first instar larvae which invariably closely follows the filling of dry rock pools with rain water (O'Gower, 1958) indicates that the egg stage must be resistant to desiccation. Therefore the drying out and the flushing of rock pools by rain water, although accounting for 15% of the examinations being negative for larvae, did not destroy the breeding potential of the pools. But, as flushing by rain water did eliminate breeding in 5% of the examinations, then it must be another hazard to breeding by *A. australis*.

The above, together with the oviposition studies of Woodhill (1941) and O'Gower (1959), in which the presence of larvae of *A. australis* in salt-water rock pools could be explained but not their absence from fresh-water rock pools, indicates that further studies on the physiology of this species should be made to try to determine which factors of the environment limit the ecological distribution of this species to salt-water rock pools. It seems probable, however, that the following adult behaviour patterns tend to limit the dispersal of the adult mosquitoes away from their ecological habitats. These patterns are: the apparent reluctance to "take wing" in a resting site after being disturbed; the apparent lack of an appetitive drive of migration; the apparent limitation of the blood-feeding drive to periods of low wind velocity; the apparent movement of blood-fed mosquitoes back to the salt-water rock-pool habitat during the early morning off-shore breezes; and the resting stance of the adult in which the body is held very close to the resting surface (O'Gower, 1958).

It therefore seems likely that the ecological distribution of the larvae of *A. australis* in salt-water rock pools is due to (i) the oviposition behaviour of the adult mosquito (O'Gower, 1959; Woodhill, 1941), (ii) behaviour patterns of the adult which tend to limit the dispersal of the population away from this habitat (O'Gower, 1958), (iii) physiological adaptations of the larvae to varying salinities and temperatures, (iv) the lethal effects of distilled water on first instar larvae (Woodhill, 1941), (v) undetermined behaviour patterns of the larvae which may place them at a disadvantage in fresh-water rock pools, and (vi) the ability of the eggs to withstand long periods of drought.

Acknowledgements.

Plate vi was kindly made available by the Cumberland County Council and the author gratefully acknowledges this service.

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EXPLANATION OF PLATE VI.

Mackenzie Bay showing the positions of the six rock pools.

THE GENUS *THEOBALDIA* (DIPTERA, CULICIDAE) IN VICTORIA. II.

By N. V. DOBROTWORSKY, Zoology Department, University of Melbourne.*

(Three Text-figures.)

[Read 31st August, 1960.]

Synopsis.

Two new species of *Theobaldia*, *T. drummondi* and *T. sylvanensis* have been found in the Dandenong Ranges breeding in pits concealed by undergrowth and debris. Larvae of both species are typical subterranean inhabitants: they are milky-white in colour and show no response to moving shadows.

The larvae of a third new species, *T. otwayensis*, n. sp., have been found in a pool under a fallen tree; they are brownish and react normally to moving shadows. All three species belong to the subgenus *Culicella*.

All Australian species of the genus *Theobaldia* are uniformly brownish in colour and lack ornamentation. The species are not easily recognized and, since the pleural scales become detached very easily, reliable identification may be impossible unless the specimens are in really perfect condition. On the other hand, the larvae of all known species can be separated easily, and because of this adults bred from larvae are most important in the study of the genus in Australia.

Collecting of larvae in the field entails great difficulties, as apparently most of the species breed in subterranean waters.

Raising the progeny of females collected and fed in nature is laborious since the immature stages require low temperature (optimum 14–15°C.) at which development is very slow; in laboratory conditions it takes up to four or five months. Nevertheless reared specimens with the associated larval and pupal skins should be used for description of new species.

The females of most species of *Theobaldia* are very similar and provide only a few conspicuous morphological traits by which they can be distinguished from one another. Previously it had been found that females of *T. frenchi* Edw. and *T. hilli* Edw. could sometimes not be separated with confidence, and similar difficulties now arise with other species. Some adults of *T. drummondi*, n. sp., can hardly be distinguished from those of *T. victoriensis* Dobr.; the male terminalia which usually enable reliable identification to be made are very similar in *T. sylvanensis*, n. sp., and *T. frenchi* Edw.

Two of the new species described in this paper, *T. drummondi* and *T. sylvanensis*, are closely related to *T. victoriensis*; the third, *T. otwayensis*, appears to be a link between the *victoriensis* group of species and *T. inconspicua* Lee.

Distribution and Ecology: *T. drummondi* and *T. sylvanensis* are known from only one locality which is situated on the eastern slopes of the Dandenong Ranges. They were found on a west-facing hillside with a good cover of forest and undergrowth. The larvae were breeding in pits some 2–3 feet deep, concealed by undergrowth, fallen branches and other debris. The origin of these pits is obscure and possibly they are derived from deserted wombat burrows. The water in them is more or less cloudy and its temperature remains low even during the summer (11°C. in October, 15°C. in February). During the spring the water level may be close to the surface, but during the unusually dry summer of 1959–60, even the deepest pits contained only a few inches of water.

The larvae and pupae of these two species are able to develop normally only at low temperatures. In the laboratory they produced adults successfully at 13°–15°C., but

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temperatures above 20°C. are fatal for larvae and pupae: at 23°C. all larvae died within six days and pupae died without producing any adults.

During the spring the dominant species was *T. victoriensis* (65·2%); less numerous were *T. drummondi* (27·7%), *T. sylvanensis* (7·1%) and odd specimens of *T. frenchi*. Larvae of *T. drummondi* and *T. sylvanensis* are similar to other subterranean Victorian species (*victoriensis*, *frenchi* and *hilli*); they are milky-white in colour, show no response to moving shadows and, if disturbed, generally do not move down to the bottom, but remain close to the surface.

The larvae of *T. otwayensis* have been found in the Cape Horn area of the Otway Ranges, in a pit under an uprooted tree and shaded for most of the day. The water was slightly cloudy, with a temperature of 13–14°C. The larvae of *Aë. queenslandis* Strick. were numerous, but only one larva of IV stage and eleven larvae of II stage of *T. otwayensis* have been collected.

Biting Habits: *T. drummondi* and *T. sylvanensis* are day-biting species which attack man freely near their breeding places. Nothing is known yet about the biting habits of *T. otwayensis*.

THEOBALDIA DRUMMONDI, n. sp. (Fig. 1.)

Types.—The type series was bred from larvae collected 26.10.59 at Sylvan, Victoria. Holotype, allotype and 20 paratypes have their associated larval and pupal skins. The holotype male, allotype female, 5 paratype males and 5 paratype females are in the collections of the National Museum, Melbourne. One paratype male and one paratype female are in each of the following collections: C.S.I.R.O., Division of Entomology, Canberra; School of Public Health and Tropical Medicine, Sydney; University of Queensland, Brisbane; British Museum (Natural History), London; U.S. National Museum, Washington.

Distinctive Characters: Adult. Forked upright scales black in ♀; sometimes an admixture of lighter ones. Proboscis black. Scutum clothed with goldish scales with admixture of some dark-bronze scales. Tarsi with inconspicuous yellowish bands. Last two tarsal segments yellowish. Terminalia: Tergally, coxite has numerous long goldish mesially directed setae; basal lobe of coxite about two-thirds length of coxite. Phallosome simple, widening distally and with several small denticles on top.

Larva. Milky-white. Head seta 6, single. Lateral comb consists of stout, short tooth-like scales. Siphon brown with index 8·1–9·3. Basal siphonal tuft and setae 1–5 of VIIIth segment small tufts.

Holotype Male.—Vertex clothed with narrow curved creamy scales and forked upright scales, some light and some dark. Proboscis and palps dark-scaled. Palps as long as proboscis with labella. Integument light brown. Scutum clothed with narrow curved light goldish scales, with some admixture of dark bronze scales particularly in front of bare area. Scutal bristles goldish or dark. Scutellum with a few narrow pale scales and 6–7 long dark bristles on each lobe. Anterior pronotum with a few narrow curved pale scales and dark, or light, goldish bristles. Posterior pronotum with some narrow curved pale scales and hairs. Three spiracular bristles. Sternopleura with one strong dark bristle, several weaker pale ones and a few elongate pale scales. Four lower mesepimeral bristles; some narrow pale scales towards middle. Wing length: 4·7 mm. Legs: Femora and tibiae purplish-black above, ochreous pale below. Segments 3 and 4 of fore tarsi with yellow scales at base, segment 5 pale-scaled. Mid and hind tarsi with some yellowish scales at base of segment 3; segments 4 and 5, yellowish-scaled. Fore and mid claws toothed, hind claws simple. Tergites black-scaled; sternites dark-scaled with admixture of paler scales, which increase towards end of abdomen. Terminalia (Fig. 1, *a*, *b*): Coxite more than twice as long as broad with dark scales sternally and laterally. On sternal aspect coxite also bears long, strong setae laterally and apically. Tergally coxite has numerous long goldish, mesially-directed setae. Basal lobe of coxite about two-thirds length of coxite, it bears tuft of long curved setae at tip. Style slightly more than half length of coxite, broad at base, narrowing towards tip.

Terminal appendage small. Paraproct with six teeth. Phallosome simple, widening distally, with several small teeth at top. Lobes of IXth tergite prominent, with 12–14 long, strong setae.

Allotype Female.—This differs from the holotype as follows: Upright forked scales on vertex black. Torus and base of first antennal segment light brown. Palps one-fifth length of proboscis. Dark bronze narrow curved scales dominant on scutum. Mid lobe of scutellum with nine strong, dark bristles. One strong dark lower mesepimeral bristle and three weaker paler ones. Patch of elongate scales larger than in male. Wing length 5·2 mm., R_2 about four times its stem. There is a faint blotch in middle of wing membrane. Small creamy knee spots. Fore and mid tarsi with some pale scales at base of second segment, segments 3, 4 and 5 pale-scaled. Hind tarsi with narrow

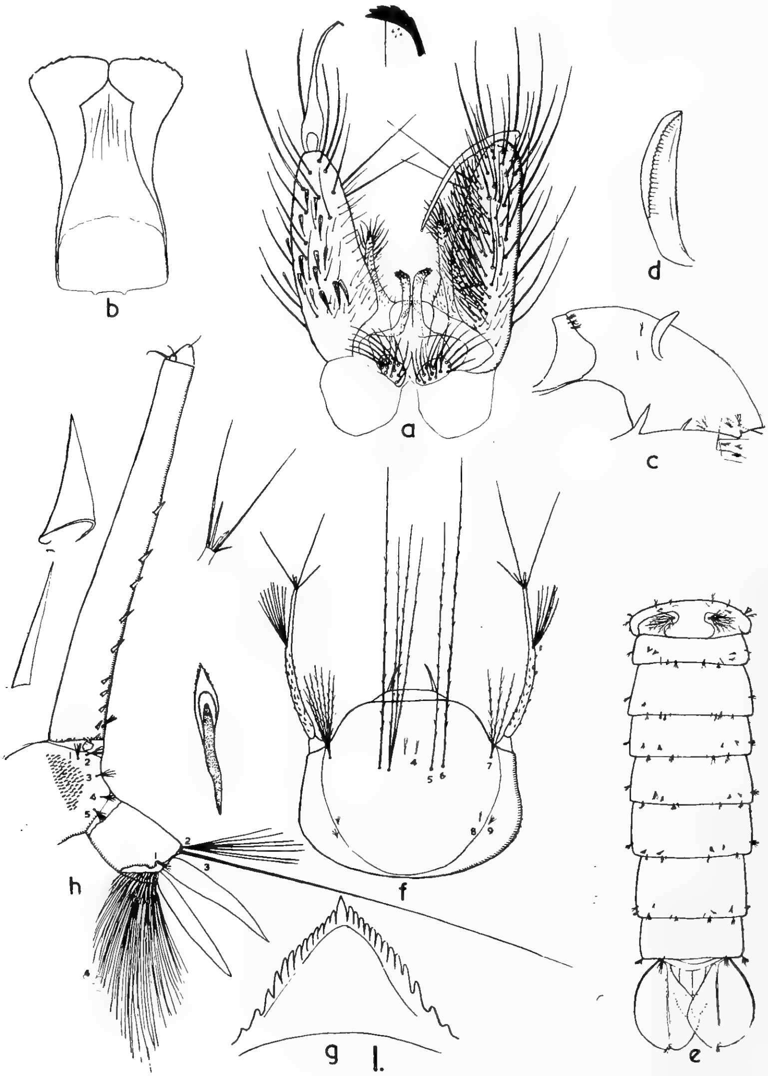


Fig. 1. *Theobaldia drummondi*, n. sp. *a-b*, ♂ terminalia: *a*, left coxite sternal aspect, right tergal aspect; *b*, phallosome; *c*, *d*, *e*, pupa: *c*, cephalothorax and metanotum; *d*, trumpet; *e*. abdomen; *f*, *g*, *h*, larva: *f*, head; *g*, mentum; *h*, terminal segments.

bands of pale scales at base of segments 2 and 3; segments 4 and 5 pale. All claws simple. Sternites creamy with some admixture of dark scales.

Paratype Males.—The series of ten paratype males does not show much variation. There are some variations in length of palps, but they are always equal to, or slightly shorter than, proboscis with labella. Scutellum with 8–9 long bristles on each lobe. 3–5 lower mesepimeral bristles. Wing length: 4·3–4·8 mm. Pale-scaled sternites may have some admixture of ochreous and dark scales.

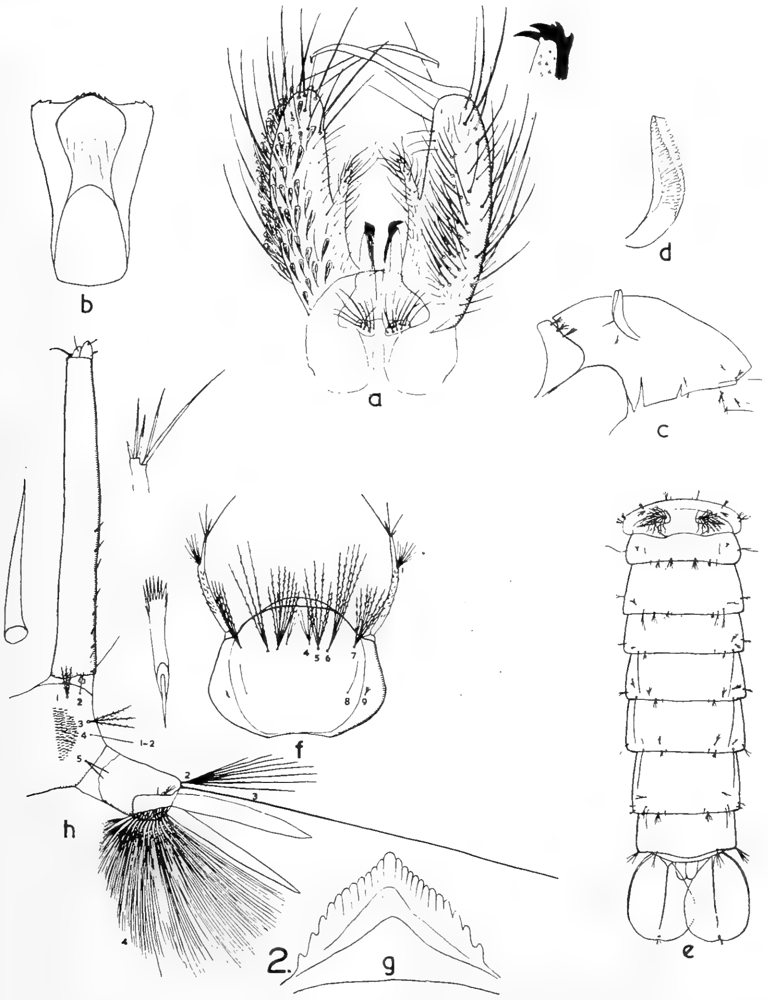


Fig. 2. *Theobaldia sylvanensis,* n. sp. *a-b,* ♂ terminalia: *a,* left coxite sternal aspect, right tergal aspect; *b,* phallosome; *c, d, e,* pupa: *c,* cephalothorax and metanotum; *d,* trumpet; *e,* abdomen; *f, g, h,* larva: *f,* head; *g,* mentum; *h,* terminal segments.

Paratype Females.—The series of ten paratype females likewise does not show significant variations. Proportion of golden and dark bronze scales on scutum varies; in some specimens bronze scales dominate, particularly mesially.

Scutellum with 8–11 long bristles. 4–6 lower mesepimeral bristles. First tarsal segment of hind legs may have pale scales at base. Sternites may be dark-scaled with admixture of pale ochreous scales. Wing length 5·0–5·3 mm.; R$_2$ about 3·3–4·0 times its stem.

Pupa (Fig. 1, *c*, *d*, *e*). All abdominal setae small, tuft-like, no long setae as in other species.

Larva (Fig. 1, *f*, *g*, *h*). Head yellowish; body milky-white; siphon brown, thoracic setae black. Head: seta 4 small, 2-branched; 5, single or 2–3-branched; 6, single; 7, 3–7-branched; 8 and 9, 2–4-branched. Antenna long curved, slightly shorter than length of head; seta 1 with 19–24 branches. Mentum with longer central tooth and 13 lateral teeth on each side. Thorax: Prothoracic setae 1–6 single, except seta 4, which is a minute tuft, and seta 7 which is 2–3-branched. Abdomen: VIIIth segment: Lateral comb triangular patch of more than a hundred stout, tooth-like scales. Setae 1–5 small tufts. Siphon very long, gradually tapering, with index 8·1–9·3, mean 8·6. Basal siphonal seta small tuft. Pecten of 8–11 flattened spines. Anal segment: Saddle complete

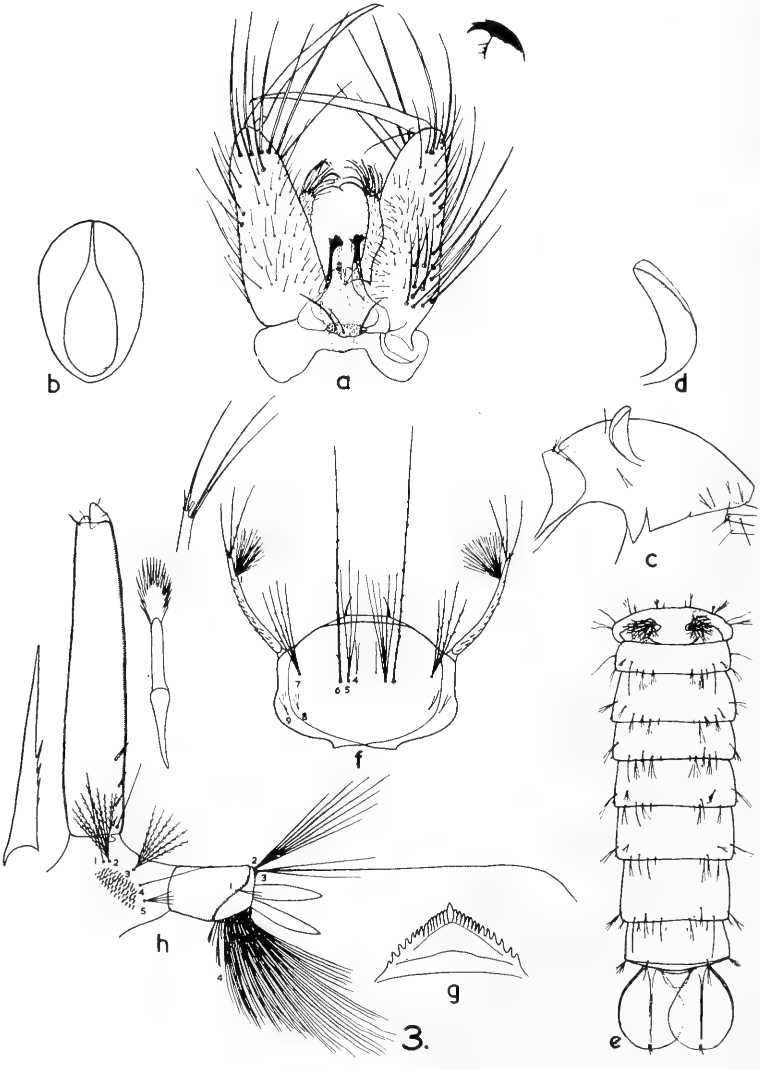


Fig. 3. *Theobaldia otwayensis*, n. sp. *a*-*b*, ♂ terminalia: *a*, left coxite sternal aspect, right tergal aspect; *b*, phallosome; *c*, *d*, *e*, pupa: *c*, cephalothorax and metanotum; *d*, trumpet; *e*, abdomen; *f*, *g*, *h*, larva: *f*, head; *g*, mentum; *h*, terminal segments.

ring. Seta 1, small tuft; 2, 6–7-branched; 3, single; 4 (ventral brush) of 13–14 tufts. Anal papillae long narrow, pointed, almost twice as long as saddle.

This species is named in honour of Dr. F. H. Drummond who discovered the breeding site of this species, generously co-operated, and has shown much interest in mosquito work carried out by the author.

THEOBALDIA SYLVANENSIS, n. sp. (Fig. 2.)

Types.—The type series was bred from larvae collected 26.10.59 at Sylvan, Victoria. Holotype, allotype and two paratype males and six paratype females have their associated larval and pupal skins. The holotype male, allotype female, five paratype males and five paratype females are in the collections of the National Museum, Melbourne. One paratype male and one paratype female are in each of the following collections: C.S.I.R.O., Division of Entomology, Canberra; School of Public Health and Tropical Medicine, Sydney; University of Queensland, Brisbane; British Museum (Natural History), London; U.S. National Museum, Washington.

Distinctive Characters: *Adult.* Forked upright scales almost black. Proboscis black. Palps in male longer than proboscis with labella. Scutum clothed mainly with dark bronze scales. Last 2–3 tarsal segments with pale reflection. Terminalia: Tergally, on inner aspect, coxite has dense dark setae directed mesially. Basal lobe about two-thirds length of coxite. Phallosome only slightly widened distally, with small denticles on top.

Larva milky-white. Head setae 5 and 6 almost equal in length, multibranched and plumose. Siphon index 5·5–7·9; basal seta long, single.

Holotype Male.—Head: Vertex clothed with narrow curved scales; upright forked scales dark, almost black. Palps and proboscis black-scaled. Palps longer than proboscis with labella. Thorax: Integument brown. Anterior pronotum with a few narrow curved scales and pale and dark bristles. Posterior pronotum with narrow curved scales. Scutum mainly with dark-bronze narrow curved scales; scales around bare area paler. Bristles black. Scutellum with narrow curved pale scales. Each lobe of scutellum with six long black bristles. One very small spiracular bristle. Sternopleura with two stronger dark bristles and several weaker pale ones. Mesepimeron with two lower bristles and patch of hairs and narrow and elongate scales towards middle. Knob of haltere pale-scaled. Legs black. Femora pale below. Last segments of tarsi with pale reflections. Claws of fore and mid legs toothed, hind simple. Wing length: 4·0 mm. Abdomen: Tergites black-scaled, sternites yellowish-scaled. Terminalia (Fig. 2, *a*, *b*): Coxite about twice as long as broad with black scales sternally and laterally. Tergally coxite has long strong black setae laterally and distally; on inner aspect they are shorter, but denser and directed mesially.

Basal lobe about two-thirds length of coxite; it bears a tuft of long curved setae. Style narrow, about two-thirds length of coxite; appendage short. Paraproct with five teeth. Phallosome simple, only slightly widened distally, with small denticles at top. Lobes of IXth tergite with 8–10 long setae.

Allotype Female.—This differs from the holotype as follows: Palps one-fifth length of proboscis. Two spiracular bristles. Two strong dark and one weak pale lower mesepimeral bristles. Hind femur pale with dorsal black stripe, widening to knee. Fore tarsi with last three segments pale; mid and hind tarsi with some pale scales on second segment, segments 3–5 completely pale. All claws simple. Wing length 4·1 mm., R_2 about three times its stem.

Paratype Males.—The series of ten paratype males does not show much variation. The upright forked scales may be paler than in holotype. There is some variation in length of the palps, but they are always slightly longer than the proboscis with labella. Usually only one spiracular seta, which in some specimens cannot be located. Each lobe of scutellum with 6–7 long black bristles. 2–4 lower mesepimeral bristles. Venter may be pale-scaled or with admixture of some black scales, particularly basally on each sternite. Wing length 3·7–4·1 mm.

Paratype Females.—The series of ten paratype females likewise does not show much variation. Vertex may have a mixture of dark and pale upright forked scales. Each lobe of scutellum may have from 6 to 8 long bristles. 2–3 lower mesipimeral bristles. Wing length: 3·8–4·3 mm., R_2 about 3·3–3·6 times its stem.

Pupa (Fig. 2, *c*, *d*, *e*). Can be distinguished from the pupa of *T. drummondi* by abdominal seta 5, which is single and long on segments 4–7.

Larva (Fig. 2, *f*, *g*, *h*). Head and siphon yellowish; body milky white; setae black. Head: Seta 4, large, 3–5-branched; 5, 4–7-branched; 6, 3–5-branched; 7, 4–8-branched; 8, single; 9, 2–5-branched. Setae 5, 6 and 7 plumose. Antenna about two-thirds length of head. Seta 1, 5–10-branched. Mentum with 11–12 lateral teeth on each side. Thorax: Prothoracic setae 1–6 single; seta 7, 2-branched, seta 3 may be 2-branched. Abdomen: VIIIth segment: Lateral comb patch of more than a hundred fringed scales. Seta 1, 2–4-branched; 2 and 4, single; 3, 2–4-branched; 5, 2–3-branched. Setae 1 and 4 plumose. Siphon long, slightly tapering, with index 5·5–7·9, mean 6·7. Basal seta long, single. Pecten of 8–11 spines. Anal segment: Saddle complete ring. Seta 1, small tuft; 2, 4–6-branched; 3, single; 4 (ventral brush), of 14 tufts. Anal papillae long, narrow, pointed, about twice as long as saddle.

THEOBALDIA OTWAYENSIS, n. sp. (Fig. 3.)

Types.—The type series was bred from larvae collected 18.12.59 at Cape Horn (Otway, Victoria). All specimens have their associated larval and pupal skins. The holotype male and allotype female are in the collections of the National Museum, Melbourne. One paratype male and one paratype female are in collections of C.S.I.R.O., Division of Entomology, Canberra. One paratype female is in each of the following collections: School of Public Health and Tropical Medicine, Sydney; University of Queensland, Brisbane; British Museum (Natural History), London; U.S. National Museum, Washington.

Distinctive Characters: *Adult.* Upright forked scales creamy. Proboscis black. Male palps shorter than proboscis. Scutum clothed with dark brown scales. Posterior pronotum with hairs and narrow scales. Tarsi dark. Mesepimeron with patch of hairs towards middle. Male terminalia: Basal lobe two-thirds length of coxite. Phallosome oval. Lobes of IXth tergite with 1–2 strong setae. Larva brownish. Head seta 5, 3–5-branched. Siphon index 4·8–5·6; pecten of 3–5 spines; basal seta single.

Holotype Male.—Head: Vertex clothed with narrow, curved and upright forked, creamy scales. Proboscis and palps dark-scaled. Palps slightly shorter than proboscis without labella. Torus yellow. Thorax: Integument light brown. Scutum clothed with dark brown narrow curved scales and black bristles; scales around bare area light goldish. Scutellum with a few narrow light goldish scales and fine long black bristles. Anterior pronotum with dark bristles. Posterior pronotum with some dark bristles. Two small spiracular bristles. Sternopleura with one strong black bristle, a few weak pale ones and a few narrow curved scales. Mesepimeron with one strong and one weaker dark lower bristles, and pale hairs towards middle. Legs dark. Wing length 3·8 mm. Underside of subcostal vein with hairs and 2–3 dark scales. Abdomen: Tergites black-scaled, sternites with brownish scales. Terminalia (Fig. 3, *a*, *b*): Coxite more than twice as long as broad, with long, strong and fine setae. Basal lobe about two-thirds length of coxite; it bears a tuft of rather long, curved, thick setae. Style as long as coxite, almost straight; terminal appendage small. Phallosome simple, oval in shape. Paraproct with three teeth. Lobes of IXth tergite inconspicuous, with 1–2 strong setae.

Allotype Female.—This differs from the holotype as follows: Palps one-eighth length of proboscis. Mid lobe of scutellum with seven long bristles. Posterior pronotum has more hairs and a few narrow curved scales. Mesepimeron with hairs and a few narrow scales towards middle. Wing length 4·3 mm., R_2 about four times its stem. Legs black-scaled, femora lighter ventrally. Scales of sternites lighter than in male.

Paratype Females.—The series of seven paratype females likewise does not show much variation. Mid lobe of scutellum may be with 6–8 long bristles. Up to 5 small, pale spiracular bristles. Mesepimeron may be with one long dark lower bristle. Lower part of sternopleura usually with one long, strong, dark bristle, one weaker and shorter, and several fine ones. Wing length 4·1–4·5 mm.

Pupa. Details shown in figure 3, *c*, *d*, *e*.

Larva (Fig. 3, *f*, *g*, *h*). Brownish head about three-fifths as long as broad. Antenna slightly shorter than length of head. Seta 1 about 2–5-branched. Head: Seta 4, moderately long, single or 2-branched; 5, 3–5-branched; 6, single; 7, 3–4-branched; 8 and 9, 2–3-branched. Mentum small, with larger central and 13–14 lateral teeth. Thorax: Prothoracic setae 1–7 single, but seta 4 may be 2-branched on one side. Abdomen: VIIIth segment: Lateral comb patch of 50–60 fringed scales. Seta 1, plumose, 8–9-branched; 2 and 4, single; 3, plumose, 5–6-branched; 5, 3–4-branched. Siphon slightly tapering; index 4·8–5·6. Pecten of 3–5 spines. Basal seta single. Anal segment: Saddle complete ring. Seta 1, 2-branched, about one-third of length of saddle; 2, 6–8-branched; 3, with 1 long and 2 short branches; 4 (ventral brush) of 15–17 tufts. Anal papillae narrow, pointed, about as long as saddle.

Acknowledgements.

I am indebted to Dr. F. H. Drummond and J. A. Thomson, Melbourne University, who discovered the breeding places of these three new species of *Theobaldia*.

CONTRIBUTIONS TO THE FLORA OF NEW SOUTH WALES: NEW SPECIES AND COMBINATIONS IN *ACACIA* AND *BLECHNUM*.

By Mary D. Tindale, National Herbarium of New South Wales.

(Plate vii.)

[Read 31st August, 1960.]

Synopsis.

Two new species of *Acacia,* both members of the Bipinnatae, are described. Two Australian species of *Blechnum* are raised to specific rank and a new combination is made in the latter genus. Notes are made on two other species of *Blechnum,* also a key is provided to the five species of the *B. procerum* group found in New South Wales.

Introduction.

Due to the impending publication of the new *Flora of New South Wales* and a new handbook to the Flora of the Central Coast and Tablelands of New South Wales, it has been necessary to publish the following new species, new combinations and notes on certain taxa. *Acacia* is a genus of the family Mimosaceae, both of the new species being members of the *A. decurrens* group. On the other hand *Blechnum* is the type genus of the fern family Blechnaceae.

Acacia trachyphloia Tindale, sp. nov.

Frutex vel arbor plerumque 4·5–12 m. alta, cortice truncorum et ramorum grisea, levi, sed in arboribus vetustis asperrima, corrugata. Ramuli vix costati, pilis patentibus, longis, aureis, sericeis dense ornati. Ramuli novelli aurei. Spinae nullae. Folia: petiolus teres, 0·3–1·5 cm. longus, eglandulosus; rhachis teres, 3·5–8 cm. longa, ut ramuli vestita, inter paria pinnarum 4–8 suprema glandulis globosis, villosis praedita. Pinnae 9–22-jugae, 1–2·2 (–3·5) cm. longae, 3–4 mm. latae. Foliola 16–28-juga, anguste oblonga, 1–2·5 mm. longa, 0·3–0·5 mm. lata, subtus et saepe supra pilis aureis vel albis, laxe appressis ornata, margine pubescente, costa subcentrali, apice acuta vel obtusa. Capitula flava, globosa, in racemis vel paniculis, floribus 10–16, pedunculis pilis aureis tomentellis. Bracteolae 0·3–0·5 mm. longae, spathulatae vel peltatae, sursum curvatae, dilatatae, ciliolatae. Calyx 0·3 mm. longus, obconicus, breviter quinquelobatus, costis tubi ciliolatis; lobis obtusis, apicem versus ciliolatis. Corolla 1 mm. longa, tubulosa, quinquelobata, lobis acutis, anguste lanceolatis, costis et apicem versus parce ciliolatis. Staminum filamenta numerosa, circiter 1·5 mm. longa. Antherae biloculares. Ovarium subsessile, glabrum, 0·2 mm. longum, ovale. Stylus glaber, circiter 1·5–2 mm. longus. Legumina stipitata, subcoriacea, glauca, atrocaerulea, parce inter semina constricta, 3–6·5 cm. longa, 5–6 mm. lata. Semina nigra, nitida, oblongo-elliptica, parum compressa, in legumine longitudinaliter disposita, funiculo primum filiformi deinde in arillum pileiformem super seminis apicem incrassato, areolo prominente.

Shrub or tree, mostly 4·5–12 m. high, the bark of the trunk and branches grey, smooth but very rough and corrugated in old trees. *Branchlets* scarcely ridged, densely clothed with spreading, long, golden, silky hairs. *Young tips* golden. *Spines* none. *Leaves*: petiole terete, 0·3–1·5 cm. long, eglandulose; rhachis terete, 3·5–8 cm. long, clothed as in the branchlets, bearing globose, villose glands between the upper 4–8 pairs of pinnae. *Pinnae* 9–22 pairs, 1–2·2 (3·5) cm. long, 3–4 mm. broad. *Pinnules* 16–28 pairs, narrowly oblong, 1–2·5 mm. long, 0·3–0·5 mm. broad, clothed below and often above with golden or white, loosely appressed hairs, the margin pubescent, the costa submedian, the apex acute or obtuse. *Heads* yellow, globose, in racemes or panicles, with 10–16 flowers, the peduncles tomentellose with golden hairs. *Bracteoles* 0·3–0·5 mm. long, spathulate or peltate, towards the apex curved, dilated and ciliolate. *Calyx* 0·3 mm.

long, obconical, shortly 5-lobed, with the costae of the tube ciliolate, the lobes obtuse, ciliolate towards the apex. *Corolla* 1 mm. long, tubular, 5-lobed, the lobes acute, narrowly lanceolate, the midribs and towards the apex scarcely ciliolate. *Filaments* of the stamens numerous, about 1·5 mm. long. *Anthers* bilocular. *Ovary* subsessile, glabrous, 0·2 mm. long, oval. *Style* glabrous, about 1·5–2 mm. long. *Pods* stipitate, subcoriaceous, glaucous, dark blue, scarcely constricted between the seeds, 3–6·5 cm. long, 5–6 mm. broad. *Seeds* black, glossy, oblong-elliptical, scarcely compressed, longitudinal in the pod, the funicle at first filiform, later thickening into a pileiform aril over the apex of the seed, the areole prominent.

Holotype: Charlie's Forest, Braidwood, J. L. Boorman, 9.1915 (NSW.47363), located in the National Herbarium, Sydney, Australia. *Isotypes*: K; US; L.

Range: South Coast and tablelands of New South Wales, Australia, from Termeil southwards to Broulee Beach.

Ecological Distribution: Along creek flats in heavy alluvial soil, but also on mountainsides in dry sclerophyll forests.

Flowering Period: August to October.

The salient features of *Acacia trachyphloia* are the pendulous, golden, villous tips of the branchlets, the narrow, dark blue, glabrous pods and the rough, corrugated bark of the older trees. The pods ripen in December as shown in NSW.47364 and NSW.47359.

This species is probably most closely allied to *A. o'shanesii* F. Muell. et Maiden (syn. *A. arundelliana* F.M. Bail.), but the lower surface of the pinnules is very much paler than the upper in the latter species, also the general vestiture is fawn instead of golden. Both species are characterized by pendulous branchlets and few glands restricted to the bases of the upper pairs of pinnae, interjugary glands being absent.

Representative Specimens Examined: New South Wales: Higgins Creek, 13 miles north of Bateman's Bay, tree 9 metres high, H. Boyd, 22.8.1959 (NSW.47509; K; L; US; A); Clyde Mountain, J. L. Boorman, 12.1915 (NSW.47364); top of Clyde Mountain, 3000 ft. alt., tree 30 ft., D.B.H. 12 inches, frequent as forest understorey, principal associate species *Eucalyptus radiata*, J. S. Beard 903, 22.8.1957 (NSW.42190); Cabbage Tree Creek, 11 miles from Nellingen on the Braidwood Road, small to large trees, spreading habit, tips of the branches pendulous, bark rough and dark at the base of the tree, branches mottled and brown, frequent along the creek flats, also along Curraween Creek, E. F. Constable, 22.10.1957 (NSW.43123); Cockwhy Creek, about 18½ miles south of Milton, J. H. Maiden, 12.1892 (NSW.47359); on the left of the road from Braidwood to Nelligen, 11·6 miles from Braidwood, large tree 25 to 30 ft. high, rough bark, S. P. Sherry 17, 22.10.1957 (NSW.47400); Nellingen, near Bateman's Bay, tree 40 ft. high, D.B.H. 18 inches, J. S. Beard 901, 22.8.1957 (NSW.42195); Mosquito Bay, near Mogo, on hillside, chocolate soil, volcanic, light yellow flowers, G. Sheppard, 8.1924 (NSW.47365); Broulee Beach, 5 miles north-east of Moruya, shrub 10 ft. high, spreading habit, bark greyish, frequent, E. F. Constable, 13.10.1957 (NSW.43088).

Acacia parvipinnula Tindale, sp. nov.

Frutex vel plerumque arbor 2·5–10 m. alta, cortice truncorum et ramorum laevi, argentea vel caeruleo-grisea. Ramuli vix costati, pilis brevibus, aliquanto rigidis, aliquantum patentibus, albis vel griseis vestiti, denique fere glabri, atrobrunnei, saepe glaucissimi. Ramuli novelli albi vel flavi. Folia: petiolus 1–2 cm. longus, lateraliter planus, glandulis 3–6 depresso-oblongis vel depresso-sphericis, puberulis ornatus; rhachis 2·5–5 (–6·5) cm. longa, aliquanto in plano verticulo applanata, ut ramuli vestita, basim omnis pinnae glandula praedita, etiam glandulis 2 vel 3, interjugalibus, depresso-oblongis vel depresso-sphericis, saepe contiguis ornata. Pinnae 4–12-jugae, 1·5–5 cm. longae, 3·5–8 mm. latae, leviter glaucae. Foliola 14–30 (raro plures)-juga, cultrata vel linearia, plerumque 2–3·5 (raro –5·5) mm. longa, 0·5–1 mm. lata, margine et subtus pilis patentibus, appressis, albis parce vestita, supra prope glabra, apice obtusa, dense pubescente, basi oblique rotundata. Capitula pallido-flava, globosa, in racemis vel paniculis, floribus 14–18, pedunculis pilis brevibus, rigide patentibus, flavis vel griseis dense vestitis. Bracteolae circiter 0·4 mm. longae, spathulatae, late petiolatae, apicem versus ciliolatae. Calyx 0·3 mm. longus, obconicus, breviter quinquelobatus, angulatus, costis et marginibus ciliolatis. Corolla 1–1·2 mm. longa, quinquelobata, tubo glabro, lobis acutis, glabris, praeter margines minutissime granulosos vel ciliolatos. Staminum filamenta numerosa, circiter 1·2 mm. longa. Antherae biloculares. Ovarium subsessile, glabrum, oblongum, apicem versus parce dilatatum, 0·5 mm. longum. Stylus glaber, 1·5–2 mm. longus. Legumina stipitata, coriacea, 5–11 cm. longa, 5–9 mm. lata, cultrata vel linearia, caeruleo-brunnea vel caeruleo-nigra, submoniliformia, glabra vel pilis brevibus, albis, appressis sparsissime vestita. Semina nigra, nitida, oblongo-elliptica, parum compressa, in legumine longitudinaliter disposita, funiculo primum filiformi deinde in arillum pileiformem super seminis apicem incrassato, areolo prominente.

Shrub or mostly a small tree 2·5–10 m. high; bark of the trunk and branches smooth, very silvery or blue-grey. *Branchlets* with unobtrusive ridges, minutely clothed with short, rather stiff, somewhat spreading, white or grey hairs on and between the ridges, later almost glabrous, dark brown, often very glaucous. *Young tips* white or yellow. *Leaves*: petiole 1–2 cm. long, flattened laterally, bearing 3–6 depressed-oblong or depressed-spherical, puberulous glands; rhachis 2·5–5 (–6·5) cm. long, somewhat flattened in the vertical plane, clothed as on the branchlets, with a gland at the base of each pair of pinnae as well as 2–3 interjugary, depressed-oblong or depressed-spherical, often contiguous glands. *Pinnae* 4–12 pairs, 1·5–5 cm. long, 3·5–8 mm. broad, slightly glaucous. *Pinnules* 14–30 (rarely more) pairs, cultrate or linear, usually 2–3·5 (rarely up to 5·5) mm. long, 0·5–1 mm. broad, sparsely clothed with spreading, appressed, white hairs on the margin and lower surface, the upper surface sometimes glabrous, the apex obtuse with an apical tuft of hairs, the base obliquely rounded. *Heads* pale yellow, globose, in racemes or panicles, 14–18 flowers in a head, the peduncles densely clothed with short, stiffly spreading, yellow or grey hairs. *Bracteoles* about 0·4 mm. long, spathulate, broadly stalked, ciliolate towards the apex. *Corolla* 1–1·2 mm. long, the tube glabrous, 5-lobed, the lobes acute, glabrous except granulose or ciliolate along the margins. *Calyx* 0·3 mm. long, shortly 5-lobed, angular, ciliolate on the midribs and margins. *Filaments* of the stamens numerous, about 1·2 mm. long. *Anthers* bilocular. *Ovary* subsessile, glabrous, oblong, slightly dilated towards the apex, 0·5 mm. long. *Style* glabrous, 1·5–2 mm. long. *Pods* stalked, coriaceous, 5–11 cm. long, 5–9 mm. broad, cultrate to linear, blue-brown or blue-black, submoniliform, glabrous or very sparsely clothed with short, white, appressed hairs. *Seeds* black, glossy, oblong-elliptical, slightly compressed, longitudinal in the pod, the funicle filiform at first, then thickened into a fleshy pileiform aril over the top of the seed, the areole prominent.

Holotype: Colo Heights, *ca.* 360 m. alt., tree 30 ft. high, smooth grey bark, in a stand on the plateau, growing in dry sclerophyll forest, M. Tindale, 15.11.1958 (NSW.46171), located at the National Herbarium, Royal Botanic Gardens, Sydney. *Isotypes*: K; BM; US; L; MEL.

Range: Coast and tablelands of New South Wales, Australia, from Singleton southwards to Hill Top. This species is common in the Hunter River Valley between Singleton and Cessnock, in the Howe's Valley–Colo Heights district and on the lower slopes of the Blue Mountains.

Ecological Distribution: In dry sclerophyll forest, on shale or sandstone, usually on plateaux but sometimes on the alluvial flats.

Flowering Period: September to early December, sometimes a second flowering between April and July.

Representative Specimens Examined: 5 miles south-east of Cessnock, in fairly moist eucalypt forest, R. Story 6652, 3.9.1959 (NSW.48973); Reedy Creek, south of Howe's Valley, 650 ft. alt., shrub 10-12 ft. high, several-stemmed, flowers pale yellow, occasional on creek bank, L. A. S. Johnson and E. F. Constable, 30.10.1954 (NSW.30173); Colo Heights, approx. 360 m. alt., shale, J. S. Beard 924 and M. Tindale, 27.9.1957 (NSW.42256); ditto, *ca.* 300 m. alt., tree 4·8 m. high, in dry sclerophyll forest, M. Tindale, 28.11.1959 (NSW.48873); Blaxland, Blue Mountains, 768 ft. alt., tree 14 ft. high, dry sclerophyll forest, M. Tindale, 2.1.1960 (NSW.48983); ditto, E. F. Constable, 13.11.1957 (NSW.42380); Bargo Bridge, E. Cheel, 6.8.1928 (NSW.47479).

A. parvipinnula is probably most closely allied to *A. filicifolia* Cheel et Welch, although the latter is characterized by much broader, blue, unconstricted pods and there are usually between 30 and 53 pairs of pinnules, also the flowering time is earlier, i.e., August to September, rarely extending into October. On the Colo River flats where both species are common, *A. filicifolia* has completed flowering before the trees of *A. parvipinnula* are in flower, this being an important factor in preventing hybridization. In the northern part of its range, i.e., near Cessnock, the latter species flowers earlier than at Colo Heights and Blaxland, where the principal flowering time is November.

I have observed no hybrids between *A. parvipinnula* and other species of the *A. mearnsii* group, although I have spent a considerable amount of time looking for them both in the Colo River district and in the Blue Mountains between Blaxland and Yarramundi, where these species are common. At Blaxland both *Acacia decurrens* and *A. baileyana* (which hybridize quite freely) flower in the spring several months before *A. parvipinnula*.

BLECHNUM CAMFIELDII Tindale, sp. nov.

Filix robusta, erecta, usque ad 1·5 m. alta. Caudex ascendens, erectus, usque ad 5 cm. altus, cum rhizomate horizontale continuus, paleis longe acuminatis, tenuibus vel coriaceis, integris vel sparse denticulatis, nitidis, linearibus vel angusto-lanceolatis, castaneis vel rufo-atrobrunneis, brunneis vel atrobrunneis, marginem versus pallidis, usque ad 2·5 cm. longis et usque ad 3 mm. latis, apicem versus fibrillosis et contortis dense vestitus. Stipes erectus, plerumque rufo-brunneus vel niger, plerumque dense tuberculatus. Rhachis rufo-brunnea vel nigra, in filicibus juvenilibus aliquanto straminea vel ochroleuca, in plantis maturis dense tuberculata, paleis fibrillosis, rufo-brunneis, nitidis, integris vel denticulatis, marginem versus pallidis et squamellis appressis castaneis vestita. Frondes usque ad 1·5 m. longae, dimorphae, 8–33-jugae, 1-pinnatae, atrovirides, pinnis inferioribus sensim reductis. Pinnae steriles rigide coriaceae, in filicibus juvenilibus subcoriaceae, usque ad 25 cm. longae, 1·2–3 cm. latae, approximatae, saepe imbricatae, apice acuminatae, acutae vel obtusae, basi auriculatae in filicibus maturis, auriculis prominentibus usque ad 5 cm. longis, usque ad 1·5 cm. latis, margine regulariter et minutissime denticulato-serrulatae, dentibus pungentibus. Costa paleis castaneis, mediam partem versus atrobrunneis, denticulatis, basi fimbriatis dense vestita. Venae prominentes, simplices vel furcatae, paleis minutis, appressis, castaneis vestitae. Pinnae fertiles lineares, 5·5–12 cm. longae, 3–5 cm. latae, subtus ad costam sporangiis omnino obtectae, basi auriculatae vel pinnula brevi sorifera instructae. Indusium membranaceum, brunneum, lineare, integrum vel erosum, 0·5–1 mm. diametro. Sporae bilaterales, ellipticae vel subglobosae, perisporiis aliquantum reticulatis, 52–62μ × 41–49μ, ala angusta, erosa, dissecta, circiter 6μ lata.

Robust, erect fern up to 1·5 m. high. Caudex ascending, erect, up to 5 cm. high, continuous with a horizontal rhizome, densely clothed with scales which are long-acuminate, thin or coriaceous, entire or sparsely denticulate, glossy, linear or narrowly lanceolate, chestnut, red-brown, brown or dark brown, paler towards the margin, up to 2·5 cm. long and up to 3 mm. broad, towards the apex fibrillose and contorted. *Stipes* erect, usually red-brown or black, mostly densely tuberculate. *Rhachis* red-brown or black, in young ferns sometimes stramineous or buff, in mature plants densely tuberculate, clothed with fibrillose, red-brown, pale towards the margin, glossy, entire or denticulate scales and appressed, chestnut squamules. *Fronds* up to 1·5 m. long, dimorphic, 8–33 pairs, 1-pinnate, dark green, the lower pinnae gradually reduced. *Sterile pinnae* rigidly coriaceous, in young ferns subcoriaceous, up to 25 cm. long, closely spaced, often imbricate, the apex acuminate, acute or obtuse, the base auriculate in mature ferns, with prominent auricles up to 5 cm. long and up to 1·5 cm. broad, the margin regularly and minutely denticulate-serrulate, with pungent teeth. *Costa* densely clothed with scales which are chestnut, dark brown towards the centre, denticulate, fimbriate at the base. *Veins* prominent, simple or forked, clothed with minute, appressed, chestnut scales. *Fertile pinnae* linear, 5·5–12 cm. long, 3–5 cm. broad, the whole of the lower surface covered with sporangia, the base auriculate or with a short, soriferous pinnule. *Indusium* membranous, brown, linear, entire or erose, 0·5–1 mm. in diameter. *Spores* bilateral, elliptical or subglobose, with somewhat reticulate perispores, 52–62μ × 41–49μ, the wing narrow, erose, dissected, about 6μ wide.

Holotype: Fraser Island, Wide Bay district, in scanty forest, in swampy grey sandy soil amongst shrubs and sedges (*Gahnia* sp.) and other ferns (*Gleichenia* sp.); common, fertile fronds dark brown, rhachis black, sterile fronds green, C. E. Hubbard 4576, 17.10.1930 (NSW.P8046), located in the National Herbarium of New South Wales, Sydney. *Isotype*: K.

Range: South-eastern Queensland and the coastal regions of New South Wales.

Ecological Distribution: Low-lying, swampy land not far from the sea, sometimes in sheltered swamps where *Livistona australis* (R.Br.) Mart. is the dominant species.

Absolute Synonyms: *Blechnum capense* (L.) Schlecht. var. *scabrum* Domin in *Bibl. Bot.*, 85: 116. 1913. *Holotype*: Australia, Sieber Syn. Fil. exsic. No. 107. Domin did not state in which herbarium this specimen was located, but I have examined isotypes at the Natural History Museum, Paris, and the Riksmuseum, Stockholm. *Blechnum minus* (R.Br.) Ettingsh. in *Denkschr. Ak. Wien*, 23: 63. 1864, ssp. *scabrum* (Domin) Tindale in *Amer. Fern Journ.*, 50, 1: 117. 1960.

This species is named in honour of Mr. J. H. Camfield, a naturalist, who collected this species in great quantity in the Oatley-Kogarah district between 1893 and 1902. Unfortunately this fern seems to be extinct in that area, as the swamps were drained long ago for building sites. As the epithet *scabrum* is already occupied in *Blechnum* by *B. scabrum* Liebm., a new name had to be chosen for the Australian species.

After the publication of my paper in *Amer. Fern Journ.*, 50, 1: 117. 1960, I found a number of mature and juvenile plants of *Blechnum camfieldii* growing at Bay View, N.S.W., in a small swamp where the palm, *Livistona australis* (R.Br.) Mart., is the dominant species. I had been searching for living specimens of this fern for several years. Five specimens (namely NSW. P4600, P4367, P4357, P4609 and P4364) which I had previously believed to be intermediates between *B. minus* and *B. camfieldii*, I would now consider to be rather depauperate, young plants of *B. camfieldii*. The main rhachis is often stramineous or buff-coloured in young specimens of the latter species, also the bases of the pinnae are usually without auricles and the margins of the pinnae are less pungently toothed, although these young plants are more stiffly erect than in *B. minus*. The very distinctive appearance of older plants of *B. camfieldii* (when studied in the field) and the apparent absence of intermediates have led me to alter my decision and raise this subspecies to specific rank.

BLECHNUM AMBIGUUM.

Blechnum ambiguum (Pr.) Kaulf. ex C.Chr. in *Dansk Bot. Arkiv*, 9, 3: 21. 1937.

Basionym: *Parablechnum ambiguum* Presl, *Epim. Bot.*: 109. 1849.

Absolute Synonyms: *Blechnum ambiguum* Kaulf., Sieb. Syn. Fil. exsic. No. 106; Presl, *Tent. Pterid.*: 103. 1836, nomen nudum. *Lomaria ambigua* Fée, *Gen. Fil.*, 5: 68. 1852.

Misapplied Names: *Blechnum laevigatum* auctt. (non Cav., *Desc.*: 263. 1802); R.Br., *Prodr. Fl. N. Holl.*: 152. 1810; Benth., *Fl. Austr.*, 7: 739. 1878; Moore & Betche, *Handb. Fl. N.S.W.*; 510: 1893; C.Chr., *Ind. Fil.*: 155. 1906. *Blechnum capense* (L.) Schlecht. ssp. *laevigatum* Domin in *Bibl. Bot.*, 85: 117. 1913. *Blechnum capense* (L.) Schlecht. var. *laevigatum* Melvaine in PROC. LINN. SOC. N.S.W., 61, 3–4: 119. 1936.

Lectotype: New Holland (Australia), Sieber Syn. Fil. No. 106, 1827 (P), examined.

Range: Coast and tablelands of New South Wales, Australia.

Ecological Distribution: Sandstone cliff-faces especially near waterfalls, in dry or wet sclerophyll forests or in rainforests.

Chromosome Number: n = 56. Published as *B. procerum*? by Manton & Sledge in *Phil. Trans. Roy. Soc. Lond.*, Ser. B, Biol. Sciences No. 654, Vol. 238: 165 (footnote). 1954. *Voucher Specimen*: Upper Falls, National Park, growing under the falls, R. Melville 3757 and M. Tindale, 13.4.1953 (K; NSW).

B. ambiguum is a common, pendulous fern on wet sandstone cliffs especially near waterfalls in the Sydney district, Blue Mountains and Southern Dividing Range of New South Wales. In *Dansk Bot. Arkiv*, 9, 3: 20–21. 1937, Carl Christensen explained how *B. ambiguum* was confused with the South American *B. levigatum* (*laevigatum*) Cav., by which name the Australian species was known for some years. *B. ambiguum* is characterized by a creeping, very flattened rhizome (up to 6 cm. in diam.) which is densely covered with the short, broken bases of the old stipes and with scales which are papery, silky, acuminate or shortly acuminate, light fawn to dark chestnut-brown, sometimes darker towards the centre, slightly glossy or dull, narrowly lanceolate to narrowly ovate. The lamina is pale to medium green, coriaceous, 1-pinnate, semi-dimorphic, the fertile fronds being very similar to the sterile except that they are about one-half to one-third of their width. The spores are characterized by alate perispores which are distinctively marked by dark, convoluted lines. Some specimens which I have collected, e.g., NSW.P8124 and NSW.P8125 from the Hazlebrook district, Blue Mountains, show great variability in spore size which might indicate apogamy. Other specimens of *B. ambiguum*, e.g., Upper Falls, National Park, R. Melville 3757 and M. Tindale, show little variation in the size of the spores.

Other representative specimens of *B. ambiguum* are as follows: Blackheath, in a damp sandstone cave, E. F. Constable, 7.10.1948 (NSW.P5327); Narrabeen, in soil pockets under a waterfall, K. Mair & M. Tindale, 14.5.1949 (NSW.P4829); Head of Linden Creek, Linden, Blue Mountains, on rocky sandstone cliffs under a waterfall, E. F. Constable, 20.1.1954 (NSW.P6718).

BLECHNUM GREGSONII.

Blechnum gregsonii (Watts) Tindale, comb. et stat. nov.

Basionym: *Blechnum capense* (L.) Schlecht. var. *gregsonii* Watts in *Proc. Roy. Soc. N.S.W.*, 49: 125–6. 1915.

Lectotype: Gully, Green Mountain, near Mt. Wilson, Blue Mountains, New South Wales, J. Gregson, 4.1902 (NSW.P4316), located in the National Herbarium, Royal Botanic Gardens, Sydney, Australia.

Distribution: Blue Mountains and Minnamurra Falls, South Coast, N.S.W.

Ecological Distribution: In rainforest gullies or ravines, either pendulous on sandstone cliff-faces, rock-ledges or sometimes epiphytic on trees.

Representative Specimens: NEW SOUTH WALES: Green Mountain, gully, J. L. Boorman, 5.1915 (NSW.P4327 and P4319); Lawson, Blue Mts., W. W. Watts, 4.1903 (NSW.P4323); Hazlebrook, pendulous on a cliff-face in a rainforest gully, growing amongst *Schizaea rupestris*, M. Tindale, 5.3.1960 (NSW.P8120); ditto, fronds very yellow-green, M. Tindale, 22.4.1960 (NSW.P8088); ditto, on a rock ledge under a waterfall, M. Tindale, 22.4.1960 (NSW.P8087); Minnamurra Falls, 3 miles west of Jamberoo, *ca.* 2000 ft. alt., pendulous in the crevices about the mouth of a cave, H. K. Judd, 20.5.1960 (NSW.P8122); ditto, epiphytic and pendulous on the trunk of *Callicoma serratifolia*, Judd, 20.5.1960 (NSW.P8123).

Rhizome robust, creeping, 1·5–2 cm. diam., clothed with scales which are shortly and finely acuminate, dull, thin, papery, pale brown or brown, very broadly ovate to ovate, 5–10 mm. long, 2–4 mm. broad, the margin with a few, long, often glandular-tipped processes; young circinate buds green, fleshy, densely paleaceous. *Stipes* pendulous, pale stramineous, smooth and glossy on the lower surface, often dark brown and asperous in the deep groove on the upper surface, the base of the stipe dark brown and clothed with the same type of scales as on the lower surface. *Fronds* pendulous, 30–75 cm. long including the stipes, uniform or almost so, coriaceous, pale green or yellowish-green. *Main rhachis* pale stramineous and glabrous on the lower surface. *Sterile pinnae* shortly stalked in the lower pairs, the upper subsessile or attached by their broad bases, 4–12 pairs, opposite or subopposite, widely spaced, the terminal segment elongated (often with 1 or 2 broadly rounded, sessile lobes at its base), 6·5–15 cm. long, 1·5–2·2 cm. broad, the lower base rounded or slightly cut away, the upper base truncate or rounded or sometimes slightly auriculate, the margin irregularly but pungently toothed, the apex abruptly acuminate with the marginal teeth coarser and more widely spaced. *Costa* glabrous. *Veins* fairly prominent, glabrous, simple or forked, ending in a hydathode close to the margin. *Fertile pinnae* eublechnoid, 4·5–15 cm. long, 0·6–2·1 cm. broad, the upper and lower base often slightly auriculate. *Sori* linear or sometimes discontinuous, close to the costa. *Indusium* linear or sometimes discontinuous, papery, firm, brown, facing inwards, 0·5–1 mm. diam., entire or erose. *Spores* bilateral, elliptical or subglobose, with a perispore, tuberculate but without dark lines, 52–90μ × 44–86μ, the wing very narrow, 3·75–6μ, developed on one side of each spore.

The spores were uniform in size in all the material of *B. gregsonii* examined. A specimen collected by the author at Hazlebrook, N.S.W., namely, NSW.P8092, is obviously an intermediate between *B. procerum* and *B. gregsonii*, both species growing close by where the two habitats meet.

BLECHNUM PROCERUM.

Blechnum procerum (Forst. f.) Sw. in *Schrad. Journ.*, 2: 75. 1800. 1801.

Basionym: *Osmunda procera* Forst. f., *Prodr.*: 78. 1786.

Two photographs of part of the type collection of *B. procerum* were very kindly forwarded to Sydney by the Director of the herbarium at Göttingen, Germany. Dr. R. E. Holttum and Mr. A. C. Jermy also supplied information about Forster's material of this species at the Herbarium, Kew, and the British Museum of Natural History, respectively. These specimens all have lomarioid fertile pinnae, the scales of the rhachis dark brown with a pale border, the smaller scales of the costae laciniate or substellate and very broadly alate spores. The latter have a reticulate perispore, 52·5–64μ × 26–32μ, with the wing usually 15–18μ wide. This is the fern which has been known as *B. minor* auctt. in most publications on the flora of New Zealand. There is a photograph under this name in Dobbie and Crookes "New Zealand Ferns" (1951), page 285. The only morphological differences which I have been able to find between the Australian and New Zealand material of *B. procerum* are the broader wing of the spores and a tendency of the costal scales to be bicolorous in the specimens collected in New Zealand.

In New South Wales I have found a small percentage of intermediates between *B. procerum* and *B. ambiguum*, where the habitats of these two ferns meet. *B. procerum* is a stiffly erect, terrestrial species usually growing on hillsides or on the banks of creeks, whereas *B. ambiguum* is a pendulous fern found on cliff-faces and in caves.

Key to the New South Wales Species of the Blechnum procerum *Group.*

A. Lower pinnae gradually reduced in size.
  B. Sterile and fertile pinnae of mature plants very prominently auriculate at the base. Scales of the rhizome glossy, with a darker central band. Stipes of mature plants dark red to black, very tuberculate .... *B. camfieldii.*
  B.* Sterile and fertile pinnae not auriculate at the base or the lower pairs very slightly auriculate. Scales of the rhizome dull, mostly concolorous, rarely with a paler border. Stipes stramineous, sometimes mottled with brown, the base dark brown, smooth or slightly tuberculate .... *B. minus.*
A.* Lower pinnae not or almost imperceptibly reduced in size.
  C. Fertile pinnae lomarioid. Plants erect, growing in soil on hillsides or along creek banks. Scales of the rhizome glossy, dark brown, with a pale border. Spores with a reticulate perispore, mostly marked with dark lines, usually 45-75μ × 30-41μ (rarely larger), the wing 4-17μ diam., surrounding each spore .... *B. procerum.*
  C.* Fertile pinnae eublechnoid. Plants pendulous, growing on cliff-faces or rock-ledges or rarely on trees.
    D. Fertile pinnae almost as broad as the sterile pinnae. Rhizome with very fleshy, circinate buds. Scales of the rhizome brown or fawn, dull, almost as broad as long. Spores with a perispore, corrugated, without dark lines, 56-90μ × 44-86μ, with a narrow wing 3·75-6μ diam., on one side of each spore .... *B. gregsonii.*
    D.* Fertile pinnae about ⅓ to ½ of the width of the sterile pinnae. Rhizome with non-fleshy buds. Scales of the rhizome light fawn, brown or ferruginous, sometimes slightly darker towards the centre when old, dull or slightly glossy, silky, narrowly lanceolate to narrowly ovate. Spores with a reticulate perispore, with dark lines, 49-75μ × 44-56μ, the wing 3·75-11μ diam., surrounding the spore .... *B. ambiguum.*

BLECHNUM AGGREGATUM.

Blechnum aggregatum (Col.) Tindale, n. comb.

Basionym: *Lomaria aggregata* Col. in *Trans. N.Z. Inst.*, 20: 223. 1888.

Synonym: *Blechnum lanceolatum* (R.Br.) Sturm, *Enum. Pl. Cr. Chil.*, 25. 1858, non *B. lanceolatum* Raddi, *Opusc. Sci. Bol.*, 3: 294. 1819.

Distribution: New Zealand and south-eastern Australia (New South Wales, Victoria and Tasmania).

Since *B. lanceolatum* (R.Br.) Sturm is a later homonym, a new combination is necessitated for this species. At the Kew Herbarium I have examined a possible isotype of *Lomaria aggregata* Col. labelled "communicated by Colenso, May 1890", without any specific locality. It resembles young plants of the species formerly known as *B. lanceolatum* and collected in eastern Australia. The type of *L. aggregata* was collected near Danneverke, County of Waipawa, New Zealand, by W. Colenso in 1887, whereas the type of *Stegania lanceolata* R.Br. was obtained by Brown in Van Diemen's Land (Tasmania).

Acknowledgements.

I wish to acknowledge with many thanks the facilities afforded by the Directors and Keepers of the following institutions: The Herbarium, Kew; the British Museum of Natural History, South Kensington; the Natural History Museum, Paris; the Riksmuseum, Stockholm; the National Herbarium, Pretoria; the University Herbarium, Göttingen; the National Herbaria at Sydney and Melbourne and the Botanic Museum and Herbarium, Brisbane. Dr. J. W. Vickery and Mr. L. A. S. Johnson very kindly read through and checked my Latin diagnoses. My thanks are also due to Dr. J. S. Beard and Mr. S. Sherry of Pietermaritzburg, South Africa, for good material of my new species of *Acacia*, as well as to Mr. E. F. Constable and Mr. H. Judd who made special collections on my behalf. The author is also indebted to Prof. R. E. Holttum, Mr. A. C. Jermy, Dr. R. Melville and Mr. J. H. Willis for information about type specimens and also to Miss B. G. Briggs for her help in various ways.

EXPLANATION OF PLATE VII.

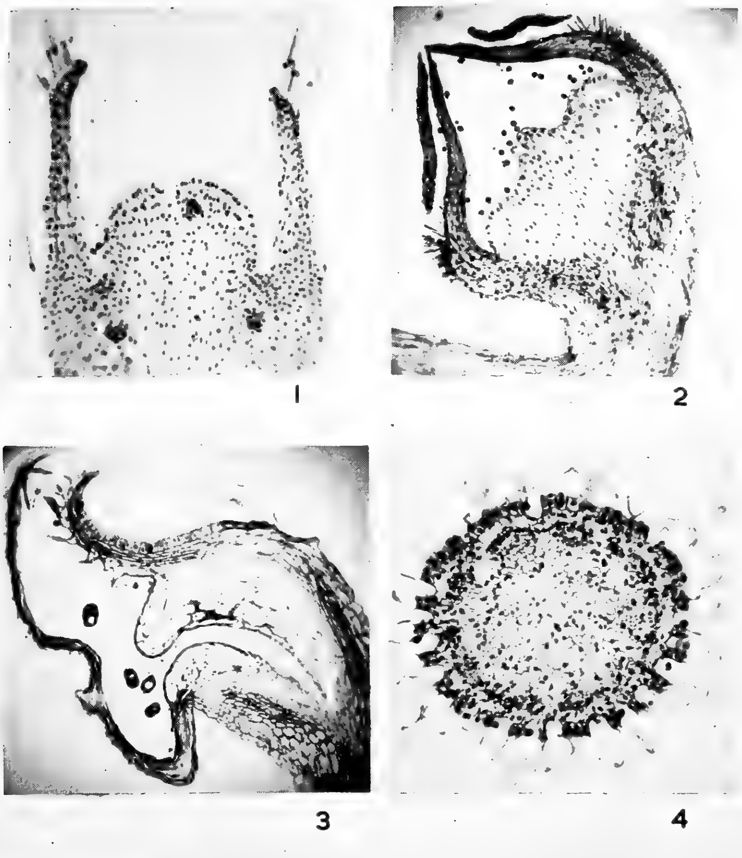
Photograph of the type specimen of *Osmunda procera* Forst. f., "In Nova Zeelandia, leg. Forster", in the herbarium of the University of Göttingen, Germany.

Photo by courtesy of the Director, The Herbarium, University of Göttingen.

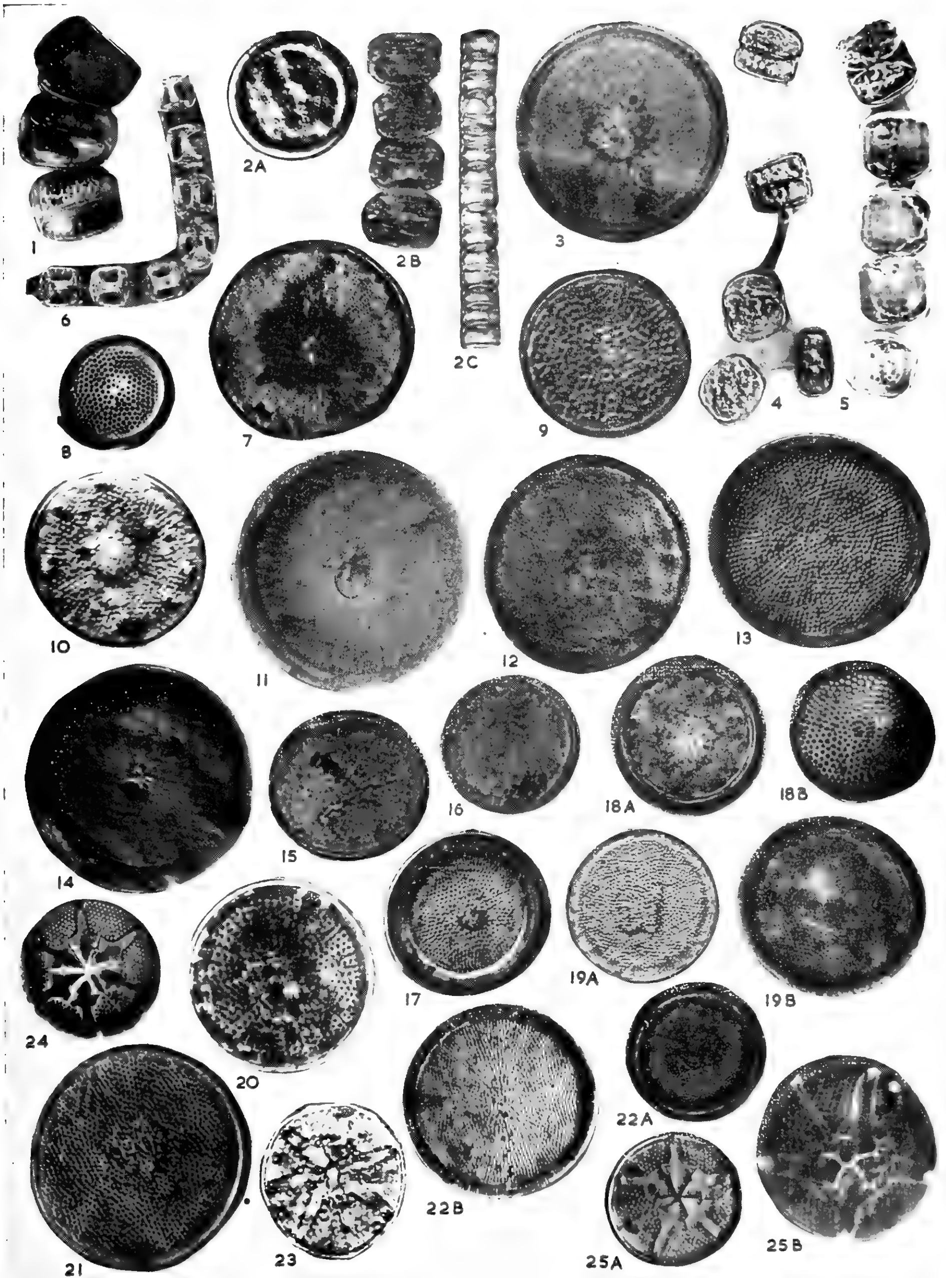
CORRIGENDA

(1) Some Species of *Culex* (*Lophoceraomyia*) from New Guinea and Adjacent Islands, with Descriptions of Four New Species and Notes on the Male of *Culex fraudatrix* Theobald (Diptera, Culicidae), by Donald H. Colless. These PROCEEDINGS, 1959, lxxxiv: 382-390.—In this paper the type series of *Culex* (*Lophoceraomyia*) *fraudatrix* Theo. was incorrectly described. It consists in fact of a male (labelled "holotype") and a female (labelled "allotype") from the Hungarian National Museum, and a further male and female, presumed paratypes, belonging to the British Museum (Nat. Hist.). The author has been informed by Dr. Alan Stone that there has never been any formal designation of a holotype. He therefore selects as hololectotype the male specimen from the Hungarian National Museum, labelled "Friedrich-Wilh. Hafen, N. Guinea, Biró, 1900".

(2) *Ranunculus lappaceus* and Allied Species of the Australian Mainland. I. Taxonomy, by Barbara G. Briggs. These PROCEEDINGS, 1959, lxxxiv: 295-324.—The numbers were transposed in the explanation of Plate xv, placed on the plate and on page 324. This should read: 2. Lectotype of *R. muelleri* var. *muelleri*. 1. Specimens excluded from lectotype.



1. *Scaevola calendulacea* (l.s. young indusium). 2. *Dampiera linearis* (l.s. mature indusium). 3. *Leschenaultia formosa* (l.s. mature indusium). 4. *Wahlenbergia trichogyna* (t.s. young style).



Antarctic Diatoms.

Antarctic Diatoms.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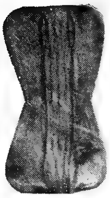
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54A


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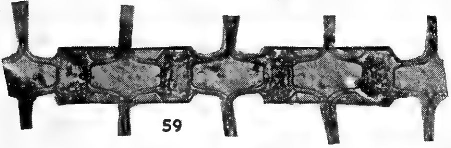
56A


56B


58


61


54B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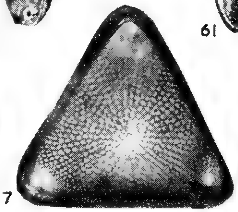
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62A


62B


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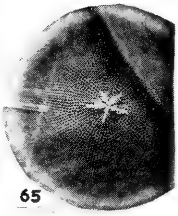
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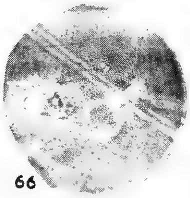
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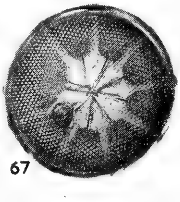
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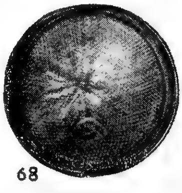
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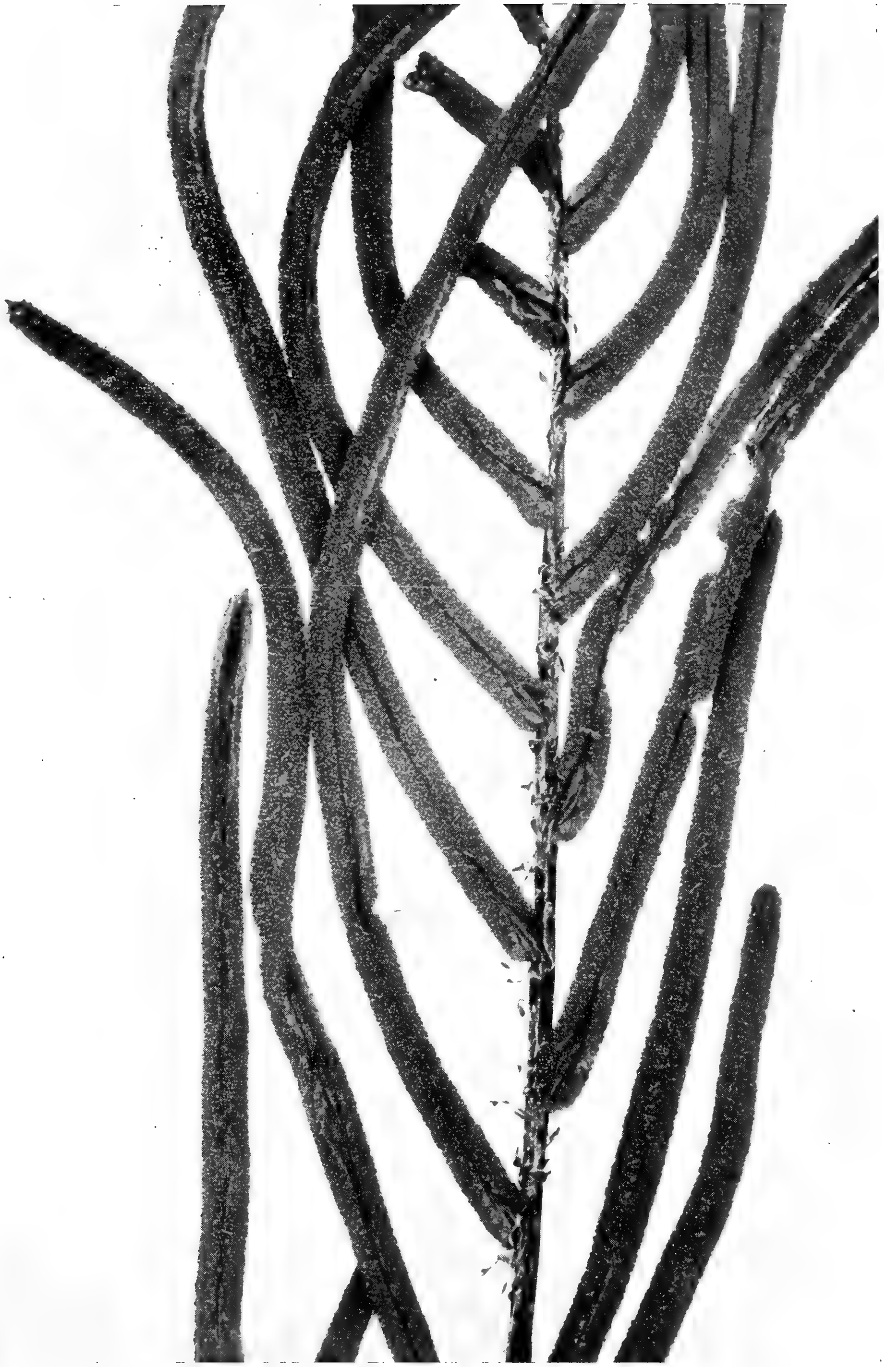
Antarctic Diatoms.

Mackenzie Bay, showing positions of six rock pools.



Type specimen of *Osmunda procera* Forst. f.