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MOVEMENT AND MORTALITY OF BLACK DUCK, MOUNTAIN DUCK AND GREY TEAL BANDED IN SOUTH AUSTRALIA, 1953-1963

BY F. I. NORMAN

Summary

Movements shown by recoveries of Black Duck, Mountain Duck and Grey Teal banded at Yalkuri, Waltowa, Joanna, Merretti and Buckland's Park are discussed. It is shown that Grey Teal disperse widely in most directions. Black Duck and Mountain Duck populations appear to contain a proportion which move long distances but the majority of ducks of these two species are recovered near the banding site. Shooting provided most recoveries in each species and mortality and survival parameters have been calculated from return of bands from shot birds. Black Duck show a greater mortality, and consequently a lower expectancy of life, than Grey Teal but Mountain Duck are apparently subject to a lower shooting pressure, since the life expectancy is greatest in this species. Since ducks banded in South Australia do move into other states, it is obvious that conservation of waterfowl and their habitat is of continental concern.

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Introduction

Many Australian waterfowl are nomadic and in some species varying numbers of local populations may undertake random dispersal movements at various times (Frith, 1967). Such nomadism is apparently a response to variations in rainfall, which in turn affect water levels and food availability. Selection for a rigid migratory system, as prevails in many European and North American waterfowl, could lead to reduction in population levels in times of drought. In several Australian species of ducks there may be a regular movement involving a proportion of a population which otherwise disperses widely; other members may remain in a locality for many years (Frith, 1952, 1967).

Results of banding operations conducted on some duck species in South Australia have been reported (Frith, 1959, 1962, 1963, 1967). Data given below presents additional information obtained during banding operations conducted by, or for, the Victorian Fisheries and Wildlife Department and the South Australian Department of Fisheries and Fauna during the period 1953 to 1963. Attention has been paid only to results obtained by banding Black Duck (*Anas superciliosa* Gmelin), Mountain Duck (*Tadorna tadornoides* (Jardine and Selby)) and Grey Teal (*Anas gibberifrons* Müller), although small numbers of other waterfowl species were also banded.

Methods

Irregular trapping for waterfowl was conducted at five sites in South Australia between 1953 and 1963. Birds were caught in wheat-baited traps of the type described by McNally and Falconer (1953) at Merretti Lake (near Renmark), at Yalkuri and Waltowa (on Lakes Alexandrina and Albert), at Buckland's Park (near Adelaide) and at Joanna (south of Naracoorte). More systematic trapping was conducted in 1961 and 1962 at Waltowa, Yalkuri and Merretti when the majority of birds were caught. Once caught, birds were banded but were generally released without details of sex and age being taken.

Data discussed below relate to recoveries (deaths) of these banded birds made to the end of 1969 and involves only those whose bands were returned. It should be noted that some bands were returned with incomplete information and such lack of detail accounts for the variations in totals given in the tables below.

Mortality rates and other survival parameters have been derived by methods discussed by Balham and Miers (1959), Bellrose and Chase (1950) and Reid (1966). In these calculations note has only been taken of birds known and reported to have been shot, since this sample is taken to represent the population in general. Variation in return of bands as a result of changes in shooting pressure is minimised by consideration of data encompassing several seasons. For the calculation of life expectancy, weighted mortality rates have been used to allow for variation in the strength of cohorts available for recovery (Farner, 1955).

During trapping sessions at Yalkuri in March 1961, samples of ducks trapped were

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fluoroscopically examined using a portable X-ray unit developed from models described by Elder (1955) and Bellrose (1959). The presence and number of shot pellets in these birds were noted.

Results

i) BANDING TOTALS

Table 1 presents totals of Black Duck, Mountain Duck and Grey Teal banded and released at the various sites. Whilst other species were also caught, at each site Black Duck, Mountain Duck and Grey Teal predominated.

TABLE 1

Banding of Black Duck, Mountain Duck and Grey Teal in South Australia, 1953-1963.

Banding site	Black Duck	Mountain Duck	Grey Teal
Joanna	384	71	524
Yalkuri	1462	160	961
Merretti	149	130	273
Waltowa	1	690	104
Buckland's Park	45	nil	53
Total	2041	1051	1915

ii) RECOVERIES

Table 2 shows the numbers of Black Duck, Mountain Duck and Grey Teal reported as dead (recovered) up to the end of 1969, and the table also notes the method of recovery where known. In the three species under discussion, shooting provided the majority of recoveries.

Undoubtedly a proportion of recoveries reported merely as "found dead", or without further information being submitted, were also shot.

iii) DISPERSAL

Figure 1 shows the location of recoveries of Black Duck banded at Joanna, Yalkuri and Merretti. The small number of recoveries made of birds banded at Buckland's Park and Waltowa have been omitted. Generally dispersal from the more northern banding sites was towards the coastal regions or along the Murray valley but a large proportion of birds were found close to their banding sites. The majority of birds banded at Joanna was recovered locally; those which dispersed tended to travel eastwards into Victoria. Of six recoveries of Black Duck banded at Yalkuri during summer, five were shot in Lake Alexandrina, and of 67 recoveries of birds banded in summer and recovered in the first winter post-banding, 53 (79·1%) were in the Lake Alexandrina region. No birds banded at Joanna in summer were recovered at Lake Alexandrina up to the first winter following banding but later a few reached the area. Three birds banded at Joanna were eventually recovered in Tasmania and one in Queensland. Birds banded at Merretti (mostly in the November-December period) moved little but those banded at Yalkuri in the mid-March and early June period were recovered widely.

The locations of recovered Mountain Ducks are shown in Figure 2 and in this figure recoveries have been considered as two groups—those made of birds banded in the summer and recovered in their first summer and winter (direct recoveries, shown in insert map), and all recoveries made of any bird banded at any time (main map). Irregular trapping in the summer period of this and other species has restricted the number of direct recoveries involved. The direct recoveries shown in Figure 2 indicate the limited dispersal of birds during

TABLE 2

Recovery methods of Black Duck, Mountain Duck and Grey Teal banded in South Australia.

Recovery method	Black Duck		Mountain Duck		Grey Teal	
	No.	% of total	No.	% of total	No.	% of total
Shot	429	85·8	160	83·0	237	87·1
No information	60	12·0	28	14·4	19	7·0
Freshly dead	5	1·0	2	1·0	6	2·2
Trapped and killed	2	0·4	2	1·0	5	1·8
Hand-killed	2	0·4	nil	nil	4	1·5
Snared and killed	nil	nil	1	0·5	1	0·4
Netted and killed	2	0·4	nil	nil	nil	nil
Total banded	2041		1051		1915	
Total recovered	500	24·5	194	18·5	272	14·2

the first six months following summer banding. Of the recoveries of 25 birds banded at Waltowa during the summer, 17 (68%) were recovered in Lake Alexandrina up to the first winter post-banding, and of 44 recoveries of birds banded at Waltowa made in the first summer 34 (77·3%) were made in that area. Later movement occurs mainly along the Murray, and through the Coorong into western Victoria, particularly the Lake Corangamite region and beyond.

TABLE 3

Distances travelled by Black Duck, Mountain Duck and Grey Teal banded in South Australia.

Distance in kilometers	Black Duck		Mountain Duck		Grey Teal	
	No.	% of total	No.	% of total	No.	% of total
0	6	1·3	1	0·6	4	1·5
1—100	314	67·5	94	57·3	98	37·7
101—200	46	9·9	10	6·1	33	12·7
201—300	48	10·3	26	15·9	35	13·5
301—400	21	4·5	13	8·0	37	14·2
401—500	13	2·8	15	9·1	27	10·4
501—1000	15	3·2	5	3·0	20	7·7
1000+	2	0·4	nil	nil	6	2·3
Total	465		164		260	

Movements undertaken by Grey Teal away from their banding site are shown in Figure 3. Comparison with the previous figures shows the more widespread dispersal undertaken by this species. Although there is a slight tendency for coastal movement, or at least coastal recoveries, no directional dispersal is noticeable for recoveries from any banding site. Long movements have occurred with two birds banded at Joanna being recovered in Queensland and one being shot at Tarblin, Western Australia, 36 months after banding.

Table 3 indicates the distance of recoveries of the three species from the banding sites: 78% of Black Duck, 64% of Mountain Duck and 53% of Grey Teal were recovered within 200 km (75 miles) of their banding sites.

iv) Mortality

The Black Duck apparently suffers a greater shooting pressure than the other species, with 21% of bands being returned from shot birds. Comparable figures for the Mountain Duck and Grey Teal are 15% and 12%. Table 4 presents mortality and survivorship data calculated from recoveries of shot birds for which dates of recovery are known. For all species mortality in the first year post-banding was high, with more than 55% of Black Duck, 54% of Grey Teal and almost 44% of Mountain Duck recoveries being made within the year. Average mortality in the four years after banding is highest in Black Duck (53·9%), with Grey Teal (48·4%) and Mountain Duck (43·6%), having a greater survival rate. It is notable that Mountain Duck have a greater proportion (10·0%) surviving past the first four years post-banding. Average expectancy of life based on the shot sample is least in Black Duck with an expectancy of 1·36 years after banding as compared with 1·56 years for Grey Teal and 1·79 years for Mountain Duck.

v) X-ray examination

Table 5 presents the results of limited fluroscopic examination of a series of Black Duck and Grey Teal made at Yalkuri in 1961. In this series more adult males of both species carried more shot than females, which in turn had a higher shot content than juvenile males. Overall, 11·0% of Black Duck carried shot as compared with 4·8% of Grey Teal. Of all birds carrying shot, 21·2% carried more than one pellet.

Discussion

Black Duck in South Australia are found on the deeper, permanent waters having ranker vegetation (Condon, 1962; Frith, 1967; Terrill and Rex, 1950). Recoveries have shown that most birds do not disperse in any one direction and most do not move widely at all (Fig. 1). There is however a proportion which disperse, generally to the east and south but some birds banded in the south move along the Murray and coastal regions north of Adelaide. Birds

TABLE 4

Mortality and survival parameters based on recoveries of shot Black Duck, Mountain Duck, and Grey Teal banded in South Australia, 1953-1963, and recovered to the end of 1969.

	Recoveries in years post-banding						
	0—1	1—2	2—3	3—4	4—5	5—6	6+
BLACK DUCK							
Total banded and available for recovery	2041	2041	2041	2041	2041	2041	1996
Total recovered	231	94	42	33	11	5	2
Percentage recovered	11·31	4·61	2·06	1·62	0·54	0·25	0·10
Mortality series	55·26	22·49	10·05	7·89	2·63	1·19	0·48
Cumulative recovery (%)	55·26	77·75	87·80	95·69	98·32	99·51	99·99
Survival series	44·74	22·25	12·20	4·31	1·68	0·48	0·01
Mortality rate	55·26	50·27	45·17	64·71	(average, in 0—4 year classes, = 53·85%)		
MOUNTAIN DUCK							
Total banded and available for recovery	1051	1051	1051	1051	1051	1051	1051
Total recovered	66	33	25	11	6	5	4
Percentage recovered	6·28	3·14	2·38	1·05	0·57	0·48	0·38
Mortality series	43·98	21·98	16·67	7·35	3·99	3·36	2·66
Cumulative recovery (%)	43·98	65·96	82·63	89·98	93·97	97·33	99·99
Survival series	56·02	34·04	17·37	10·02	6·03	2·67	0·01
Mortality rate	43·98	39·25	48·97	42·35	(average, 0—4 year classes = 43·64%)		
GREY TEAL							
Total banded and available for recovery	1915	1915	1915	1915	1915	1915	1862
Total recovered	128	42	32	18	7	5	4
Percentage recovered	6·68	2·19	1·67	0·94	0·37	0·26	0·22
Mortality series	54·18	17·76	13·54	7·62	3·00	2·11	1·79
Cumulative recovery (%)	54·18	71·94	85·48	93·10	96·10	98·21	100·00
Survival series	45·82	28·06	14·52	6·90	3·90	1·79	nil
Mortality rate	54·18	38·76	48·26	52·51	(average, 0—4 year classes. = 48·43%)		

banded in late autumn at Yalkuri showed the widest dispersal, in contrast to those banded at Merretti which moved little. Recovery data (Table 3, Fig. 1) agree with Frith's (1963, 1967) conclusion that only a proportion of any population are involved in dispersal, with members of various populations moving in any direction. However recoveries from these more southern banding sites have not shown a tendency for a regular northern movement in winter and a southerly summer movement as is apparent in birds banded in inland south-east Australia (Frith, 1963).

Condon (1962) considered that Mountain Duck inhabited the open grassy flats, swamps, lakes and rivers of South Australia. Frith (1967) found that, though the species preferred muddy shorelines of brackish waters, there was a dependence on fresh water and large congregations moved to Lakes Albert and Alexandrina to moult. Figure 2 clearly shows the importance of these freshwater lakes to this species (as also is the case with the Black Duck). Recoveries there presumably refer to birds shot prior to or in the moulting period, since almost all dispersal up to the first winter post-banding is limited to Lakes Albert and Alexandrina, with much smaller numbers going to the Coorong. Some proportion of birds later disperse widely with an obvious concentration in the Lake Corangamite region of Victoria. It is possible that this too might be a moulting region.

Grey Teal are found widely in South Australia, on rivers, lakes, swamps and coastal estuaries or bays (Condon, 1962; Terrill and Rex, 1950). Though the Murray-Darling basin is the most important breeding area, coastal regions of south-east Australia provide the majority of refuge areas (Frith, 1962). The extensive and erratic movements of the species have already been discussed (Frith, 1962, 1963) and recoveries shown in Figure 3 confirm the more random movements undertaken by the Grey Teal. It has not been possible with the present data to examine the movements in this (and the other) species in relation to climatic variation.

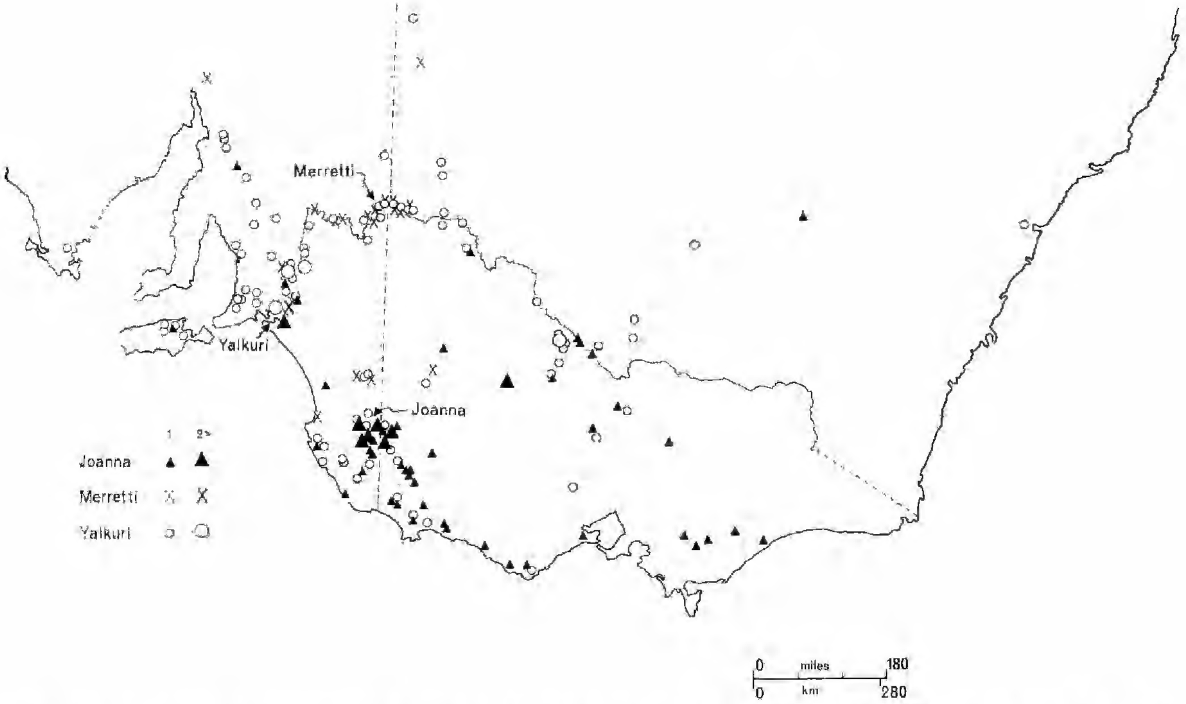

Fig. 1. Location of recoveries of Black Duck banded at Joanna, Merretti and Yalkuri between 1953 and 1963.

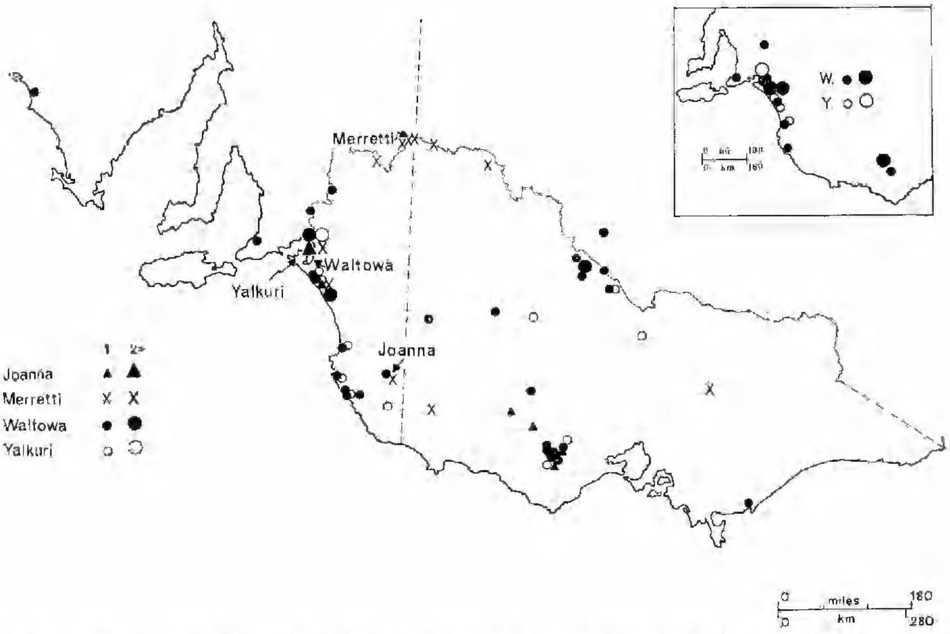

Fig. 2. Location of recoveries of Mountain Duck banded at Joanna, Merretti, Waltowa and Yalkuri between 1953 and 1963. Insert shows recoveries of birds banded in summer and recovered up to the first winter post-banding.

TABLE 5

Fluoroscopic examination of Black Duck and Grey Teal caught at Yalkuri, South Australia, in March 1961.

	Number examined			No. of pellets				
	without shot	with shot	percent with shot	1	2	3	4	5
BLACK DUCK								
Juvenile male	63	5	7·4	4	—	—	1	—
Adult male	86	14	14·0	13	—	1	—	—
All females	113	11	8·8	6	2	1	—	2
Unsexed/unaged	37	3	7·5	3	—	—	—	—
All ducks	299	33	11·0	26	2	2	1	2
GREY TEAL								
Juvenile male	83	3	3·6	3	—	—	—	—
Adult male	25	3	10·7	2	1	—	—	—
All females	122	7	5·4	5	2	—	—	—
All ducks	230	13	4·8	10	3	—	—	—

In contrast to results obtained by Frith (1963), Black Duck banded in southern South Australia suffered a higher mortality than Grey Teal and had consequently a lower life expectancy. Parameters recalculated from Frith's data according to Reid's (1966) methods show that Black Duck banded mainly in inland New South Wales had a mean mortality of 50% during the first four years of life and Grey Teal 52·4%. Comparable figures in this study are 53·9 and 48·4%. It seems probable that Black Duck banded at Joanna, Yalkuri, Merretti and Waltowa (i.e. 97·8% of the total banded) moved less than those reported by Frith (1963) and thus were more prone to local shooting. Indeed the large proportion of Black Ducks carrying shot (Table 5) suggests that they are much more liable to be shot at than Grey Teal though they are of course a larger bird. Mountain Duck, though not considered a good game species (Frith, 1967), are clearly subject to

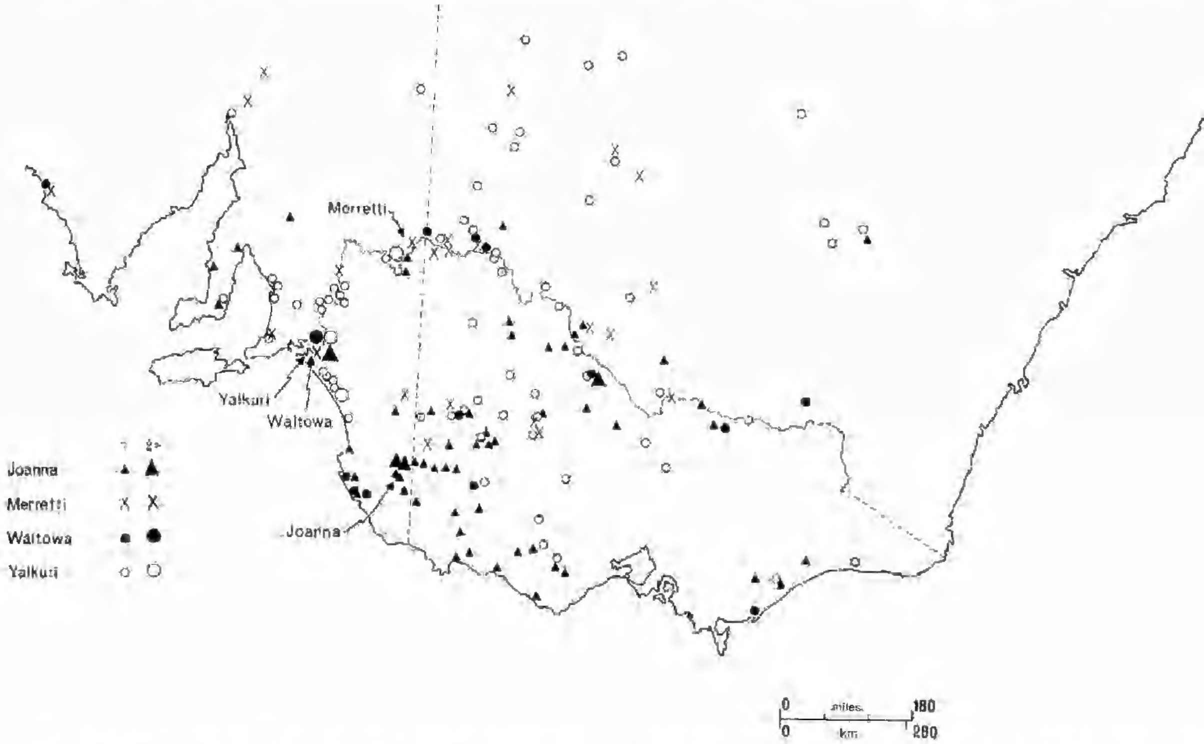

Fig. 3. Location of recoveries of Grey Teal banded at Joanna, Merretti, Waltowa and Yalkuri between 1953 and 1963.

considerable shooting pressure particularly in the Lakes Albert and Alexandrina region, the Coorong and western Victoria, However the lower mortality rate and greater expectancy of life post-banding suggests that this species is less attractive, and perhaps less available to shooters than Grey Teal or Black Duck. Nevertheless Tables 2 and 4 show that Mountain Duck have a higher overall band recovery than Grey Teal, a rate dependent mainly on shooting.

This study has shown the difference in mortality and movement of three species of waterfowl common in South Australia. Recoveries of banded birds have indicated that Grey Teal, which is essentially an inland breeding species, disperse more widely than Black Duck and Mountain Duck. The two latter species, though having some individuals which move long distances, have a higher local recovery rate than the Teal. Black Duck are most sedentary and are thus apparently more prone to local shooting pressures. Though the majority of recoveries of all species were returned from within the state, it is clear that other states, particularly Victoria, receive birds originating in South Australia. It is apparent that conservation of waterfowl and waterfowl habitat in one state will affect, at some stage, waterfowl inhabiting other states.

Acknowledgements

Mr. M. C. Downes, while Superintendent of Game Management, in the Victorian Fisheries and Wildlife Department, was responsible for much of the organisation and collection of data used in this report. Personnel of the South Australian Department of Fisheries and Fauna assisted in 1961 and conducted later trapping sessions. Mr. J. B. Hood was responsible for the majority of banding prior to 1961.

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THE GENUS PLOCAMIUM (RHODOPHYTA) IN SOUTHERN AUSTRALIA

BY *H.B.S. WOMERSLEY*

Summary

Eight species of *Plocamium* are recognised on southern Australian coasts, viz. *P. angustum* (J. Ag.) Hooker & Harvey, *P. cartilagineum* (L.) Dixon, *P. costatum* (C. Ag.) Hooker & Harvey, *P. dilatatum* J. Agardh, *P. leptophyllum* Kuetzing, *P. mertensii* (Grev.) Harvey, *P. patagiatum* J. Agardh and *P. preissianum* Sender. Characters used in differentiating the species include thallus dimensions, the number and form of the ramuli in the alternating series, and the position, morphology and dimensions of the cystocarps and tetrasporangial stichidia; spermatangial position is used in some species.

Apart from the cosmopolitan *P. cartilagineum,* the other species are essentially southern Australian and detailed study is needed of specimens, from other countries, which have been referred to these Australian species.

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Introduction

One of the commonest and most distinctive genera of red algae on southern Australian coasts (from south-west Western Australia to eastern Victoria and including Tasmania) is *Plocamium* Lamouroux. In general the species are subtidal, though some occur in deep or shaded pools on rock platforms. Frequently they are important elements in communities of red algae in the mid or lower sub-littoral zones (e.g. see Shepherd & Womersley 1970) and some species may be codominant.

There has been considerable confusion in records and herbarium determinations of Australian species of *Plocamium*, and records of Australian species from other countries have usually been based on inadequate knowledge of the species in Australia.

This study is based on extensive collections in the Adelaide University Herbarium and the author's field knowledge and collections over many years. All the southern Australian species recognised here occur in the State of South Australia, and all are also found around West Island, a small island (less than ½ km across) near Victor Harbor, South Australia (Shepherd & Womersley 1970). Collections in the State and University Herbaria in Perth, Melbourne and Sydney, and also in the British Museum (N.H.), London, have been studied and annotated, and all type specimens have been studied.

The Morphology and Characteristics of Plocamium

Plocamium is a distinctive genus, justly regarded as a "natural" one. It is readily recognised even when sterile by the flat fronds, branched in one plane, and with the edges of the branch axes bearing alternating series of 2, 3 or more (to 5 or 6) ramuli, the lower of which is normally unbranched and at least the uppermost is branched.

Numerous axes arise from a basal system of entangled, terete, prostrate branches, some of which produce recurved attachment branchlets. Some species occur on rock while others (e.g. *P. leptophyllum*) are normally epiphytic on other algae, including other species of *Plocamium*.

The erect axes are sympodially developed (Fig. 1), and the growth of the axis is continued by the upper of the ramuli in each series. If the species has **n** ramuli in each series, then the upper ramulus develops a further series of (**n—1**) ramuli on its adaxial margin, i.e. facing the previous axis apex, and the latter becomes the lowest of the new series of **n** ramuli. This development proceeds indefinitely giving the regular pattern of branching and in some species (e.g. *P. leptophyllum*) a distinctly flexuose axis. The lowest ramulus in a series (i.e. the previous apex of the axis) normally remains unbranched (except often in *P. mertensii*) and its morphology (entire or serrate margin and form) is distinctive for some species. The upper ramulus normally develops into a lateral branch with the same sympodial branching as the axis, though often it may remain dormant (especially in *P. patagiatum*); the second ramulus (in species with series of 3 or more) may also develop to some extent.

In most species, ramuli occur only in the alternating series. *P. leptophyllum*, however, is characterised by small adventitious ramuli,

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usually simple but occasionally branched, which arise on the branch margin opposite each series of ramuli; sometimes they also arise between the original ramuli of a series. This results in an almost continuous fringe of ramuli on both sides of the branches.

In most species the lowest ramulus (the previous apex) remains relatively straight and short. In *P. leptophyllum*, however, many though not all of these ramuli (and the branch end) develop into strongly recurved, hooked ramuli which are most effective in attachment to other algae and help to distinguish this species. Similar hooked branches occur in *P. hamatum* J. Agardh (1876, p. 338) from eastern Australia (Queensland, N.S.W., Lord Howe Is., Norfolk Is.) but in the other southern Australian species hooked ramuli are normally only found irregularly on the prostrate system.

Cystocarpic plants are common, but male plants are much less frequently collected.

Carpogonial branches occur either on the adaxial (occasionally abaxial) margin of the upper ramuli or adjacent branch margin (rarely on the lowest ramulus), or on small, reduced branchlets which arise in the axil of the branch and upper ramulus and which apparently correspond to a small, proliferous branch. In the former case (e.g. *P. angustum*, *P. cartilagineum*) the cystocarp is sessile on the margin of the ramulus, but in the latter case (e.g. *P. mertensii*) the cystocarp appears pedicellate with the small branchlet constituting its pedicel. In some cases the cystocarp bearing branchlet is recognisable as such but in other cases it is reduced to a terete pedicel. Several pedicellate cystocarps may occur in each axil but usually one or two develop further than the others. Cystocarps are usually globular or hemispherical and smooth surfaced, but in *P. preissianum* the pericarp becomes distinctly verrucose. Cystocarps have not been seen in *P. leptophyllum*.

Spermatangial plants have been found in all species except *P. leptophyllum*. The spermatangia are cut off from mother cells produced by the outer cortical cells, in one of two ways. In *P. angustum*, *P. costatum*, *P. dilatatum*, *P. preissianum* and *P. cartilagineum* the spermatangia cover the surface of the branches and ramuli near the branch apices, while in the other species they cover the surface of small, axillary branch tufts.

Tetrasporangial plants are common in most species and the zonately divided tetrasporangia occur in elongate or clavate stichidia borne in the axil of the branch and upper ramulus. In some species they occur also in the axil of the second ramulus. In most species the stichidia form a distinct, compact cluster, but in others (e.g. *P. cartilagineum*) they extend in a series along the margins of the branch and to a lesser extent along the ramulus. When the stichidia are clustered, they arise from a slightly swollen tissue. In some species (e.g. *P. mertensii*, *P. preissianum*) individual stichidia are unbranched, consisting of a narrower, sterile, basal pedicel and swollen upper part bearing the tetrasporangia. In some cases (e.g. *P. costatum*, *P. cartilagineum*) the stichidia become branched in their upper parts.

Fertile specimens of *Plocamium*, especially if all reproductive phases are present, are readily determined, and in many cases sterile specimens are sufficiently distinctive to be determined. In a few cases apparent intergrades occur but these are usually based on infertile specimens. It appears that comparatively little hybridisation occurs between the Australian species of *Plocamium* even though they often occur intermixed.

In most of the southern Australian species, cystocarpic and tetrasporangial plants occur throughout the year. In *P. leptophyllum*, however, sexual plants are unknown and tetrasporangial plants have been found only in August and September. Cystocarpic specimens of *P. patagiatum* are known from May to August and tetrasporangial ones from April to October. Spermatangial plants in most species are rare.

Key to Species of Plocamium in Southern Australia

1. Ramuli mostly in alternate pairs .. 2
1. Ramuli mostly in alternate series of 3-4 (or more) 6
    2. Axes mostly under 2 mm broad; cystocarps sessile, spermatangia covering young ramuli 3
    2. Axes mostly over 2 mm broad; cystocarps appearing pedicellate and axillary, spermatangia on terete, axillary branch clusters (or on reduced, axillary branchlets in *P. dilatatum*) 4
3. Axes slender, mostly less than 1 mm broad; lower ramulus slender and usually entire; stichidia single or in basally branched clusters .... **1.** ***P. angustum***
3. Axes mostly over 1 mm broad; lower ramulus serrate; stichidia in clusters, branched in their upper part **2.** ***P. costatum***

4. Upper ramulus often remaining dormant and digitate, 2-2½ mm broad and usually 3-5 mm long; lower ramulus simple and usually entire: axes mostly 3-4 mm broad.
3. *P. patagiatum*

4. Upper ramulus commonly developing into a lateral branch, not digitate if undeveloped; lower ramulus usually serrate, simple or divided; axes mostly 2-3 (-5) mm broad ... 5

5. Thallus relatively delicate, often large (to 50 cm high); lower ramulus entire or serrate, in many plants becoming multifid; stichidia mostly 75-100μm diam. ... **4.** *P. mertensii*

5. Thallus robust, to 25 cm high; lower ramulus serrate and undivided: stichidia robust and clavate, about 250μm diam.
5. *P. dilatatum*

6. Ramuli mostly in series of 3; thallus robust, axes 1½-2 (-3) mm broad and becoming thickened below; stichidia normally in axillary clusters, basally branched only; cystocarps sessile and verrucose **6.** *P. preissianum*

6. Ramuli in series of 3-4 or more, rarely with some in pairs; thallus slender, axes less than 1½ mm broad; stichidia axillary but on margins of ramulus and axis, becoming branched in their upper parts; cystocarps sessile but smooth 7

7. Ramuli in alternating series of 3-4, with occasional pairs; axes mostly 1-1½ mm broad, tapering above; adventitious ramuli, and hooked branch ends or hooked lower ramuli, absent.
7. *P. cartilagineum*

7. Ramuli in alternating series of (3-)4-5 with short adventitious ramuli developing from the axis opposite each series and often between the members of a series; axis about ½ mm broad, often flexuous; ends of branches or lowest ramuli commonly recurved to a hook.
8. *P. leptophyllum*

1. Plocamium angustum (J. Agardh) Hooker & Harvey 1847: 404. J. Agardh 1852: 402; 1876: 343. De Toni 1900: 596. De Toni & Forti 1923: 32. Ewart 1907: 91. Harvey 1847: 122; 1859b: 318; 1863, synop.: 39. Kuetzing 1849: 885. Lucas 1909: 34: 1929a: 19; 1929b: 50. Lucas & Perrin 1947: 211, fig. 76a (excl. b). Mazza 1908: 228 (No. 215). Reinhold 1897: 52; 1899: 45. Sonder 1853: 682; 1855: 518; 1880: 18. Tate 1882: 19. Tepper 1883: 66. Tisdall 1898: 507. Wilson 1892: 178. Womersley 1966: 147

FIGS. 2-6

Thamnophora angusta J. Agardh 1841: 10. Harvey 1844: 447.

Plocamium angustatum Kuetzing 1866: 17. pl. 48c-e.

Plocamium gracile J. Agardh 1876: 345. De Toni 1900: 598. Lucas 1909: 35: 1929a: 19. Lucas & Perrin 1947: 213, fig. 78. May 1965: 372 Sonder 1880: 19. Tisdall 1893: 507. Womersley 1950: 170.

Plocamium telfairiae sensu Guiler 1952: 90. Levring 1946: 222. May 1965: 372 [not *P. telfairiae* (Harvey) Kuetzing from Mauritius].

Thallus (Fig. 2) to 25 cm high, with numerous, erect, slender, rather linear axes arising from the prostrate base. Axes usually ½-1 mm broad, rarely to 1½ mm, bearing ramuli in alternating pairs, the upper often developing into a lateral branch similar to the axes. Lower ramuli subulate, 1-1½ (-2) mm long, less than ½ mm broad at their base, usually entire but in some plants with several small serrations or spines on the abaxial margin. *Cystocarps* sessile on adaxial base of ramulus or on adjacent axis (Fig. 3), globular, smooth to slightly verrucose, 600-900μm across. *Spermatangia* covering the surface of slender ramuli near the branch apices in male plants (Fig. 4). *Stichidia* in the axils of ramuli, becoming tufted (Fig. 5) and basally branched, the tufts enlarging with age and in some plants stichidia extending along the adaxial margin of the ramuli; sporangium-bearing part of stichidia usually unbranched and swollen (Fig. 6), 60-100μm thick, terete and fairly straight, the stalk remaining slender; tetrasporangia 50-70μm long and 25-30μm broad.

Type locality—"Novae Hollandiae".

Type—Herb. Agardh, LD, 28026

Distribution—From Elliston, Eyre Peninsula, S. Aust. to Tuggerah Lakes, N.S.W. and around Tasmania. Common on coasts of rough to moderate wave action and known from depths from shaded pools near low water level to 50 m.

P. angustum is usually readily recognized by its slender, rather linear axes rarely over 1 mm broad, the tufts of basally branched stichidia, and sessile cystocarps. Some intergrades to *P. costatum* occur however, including

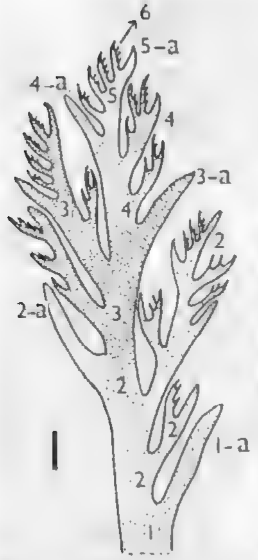

Fig. 1. Thallus development in *Plocamium* (with series of 3 ramuli). 1, 2, 3 etc. indicate branching units; 'a' indicates the previous apices now left as the lowest ramulus in each series.

Figs. 2-6. *P. angustum.* Fig. 2.—Habit. Lady Julia Percy Is., Vic. (*Shepherd*, 3.i.1968; ADU, A32397). Fig. 3.—Branch with cystocarps. Carpenter Rocks (Cape Banks), S. Aust. (*Shepherd*, 4.xi.1968; ADU, A33111). Fig. 4.—Spermatangia covering terminal ramuli of a branch. West Is., S. Aust. (*Shepherd*, 1.i.1969; ADU, A33237). Fig. 5.—Stichidial branch (A33111). Fig. 6.—Stichidia (A33111).

occasional specimens with slightly serrate ramuli.

The type of *P. angustum* is sterile but there is no doubt as to its relationships. *P. angustatum* Kuetzing (holotype in L, 941,240 . . 55) is from Tasmania (J. D. Hooker. 1304 a Gunn specimen). The type bears a few stichidia and is within the range of *P. angustum*. *P. gracile* J. Agardh (holotype in LD, 28075, from Tasmania (*Gunn*)) also bears stichidia, in this case mainly from near the top of spinose ramuli but occasionally in the axils. This form is common in *P. angustum* and it illustrates the range in stichidia position found in this species.

The N.S.W. distribution is based on sterile plants and requires confirmation. The record of Lucas (1931, p. 55) from Rockingham Bay, Qld., is almost certainly incorrect, and that from Lord Howe Island (Lucas 1935, p. 222) needs confirmation. The illustration of Kuetzing (1966, p. 17, pl. 48a-b) is not of *P. angustum* but probably of *P. costatum*.

Levring (1945, p. 16) referred *P. angustum* to *P. telfairiae* (Harvey) Kuetzing (1849, p. 885) from Mauritius. Examination of the type of the latter species (in TCD) shows that they are quite distinct. Whereas *P. angustum* has small cortical cells forming a continuous layer over the surface and the stichidia are usually basally branched only, *P. telfairiae* has a rosette appearance in surface view of the cortical cells; the latter do not form a continuous layer and are also larger than in *P. angustum*. The stichidia of *P. telfairiae* are more elongate and branched in their upper sporangial regions. *P. telfairiae* also has broader and less linear axes and more dense branching than *P. angustum*.

P. angustum has been recorded from New Zealand (e.g. Harvey 1855b, p. 246, Laing 1927, p. 159; 1939, p. 153. Naylor 1954, p. 656), but specimens of Laing's in ADU have cystocarps on slender pedicels and the stichidia are branched. Specimens from New Zealand in MEL show similarity to *P. angustum* but are inadequate for full comparison. New Zealand records must be regarded with doubt and comparisons made of a range of fertile plants.

2. Plocamium costatum (C. Agardh) Hooker & Harvey* 1847: 404. J. Agardh 1852: 403; 1876: 344. De Toni 1900: 597. Ewart 1907: 91. Guiler 1952: 89. Harvey 1847: 122; 1859b: 318; 1863, synop.: 39. Kuetzing 1849: 886; 1866: 18, pl. 52d, e. Lucas 1909: 34; 1929a: 19; 1929b: 50. Lucas & Perrin 1947: 212, fig. 77. May 1965: 372. Mazza 1908: 228 (No. 216). Reinbold 1897: 52; 1899: 45. Sonder 1855: 519; 1880: 19. Tate 1882: 19. Tisdall 1893: 507. Wilson 1892: 178. Womersley 1950: 170; 1966: 147.

FIGS. 7-11

Delesseria plocamium var. *costata* C. Agardh 1823: 181; 1824: 251.

Thamnophora costata (C. Agardh) J. Agardh 1841: 10. Harvey 1844: 447.

Thallus (Fig. 7) erect, fairly slender, to 30 cm high from the prostrate base. Erect axes 1-1½ (-2½) mm broad, often with a lighter coloured central part and thus appearing costate in mid and lower parts of the axes. Ramuli in pairs, strongly and evenly serrate with short blunt teeth on the convex abaxial side, adaxial side straight to slightly concave; ramuli 1-2 (-3) mm long with lower ramulus usually about ½ mm broad at the base. *Cystocarps* sessile, globular, about ½ mm diam., smooth, sometimes slightly verrucose when dry, variously placed in the axil, on the adaxial edge of the ramulus, or more frequently on the abaxial edge of the lower ramulus (Fig. 8). *Spermatangia* covering ends of branches and proliferous branchlets (Fig. 9) in axils of upper ramuli. *Stichidia* in densely branched clusters (Fig. 10) in the axils of ramuli, closely branched several times at wide angles especially in their upper parts (Fig. 11); clusters to about 1½ mm high with branches fairly uniform in width and about 100μm in diam.; in some cases the stichidial clusters extend in a series along the adaxial margin of the lower ramulus and up the axis to the base of the abaxial surface of the upper ramulus. Tetrasporangia densely arranged in apices of stichidial branches, 50-65μm long by 35-45μm broad.

Type locality—Novae Hollandiae (*Desfontaines*).

Type—Herb. Agardh, LD, 28056

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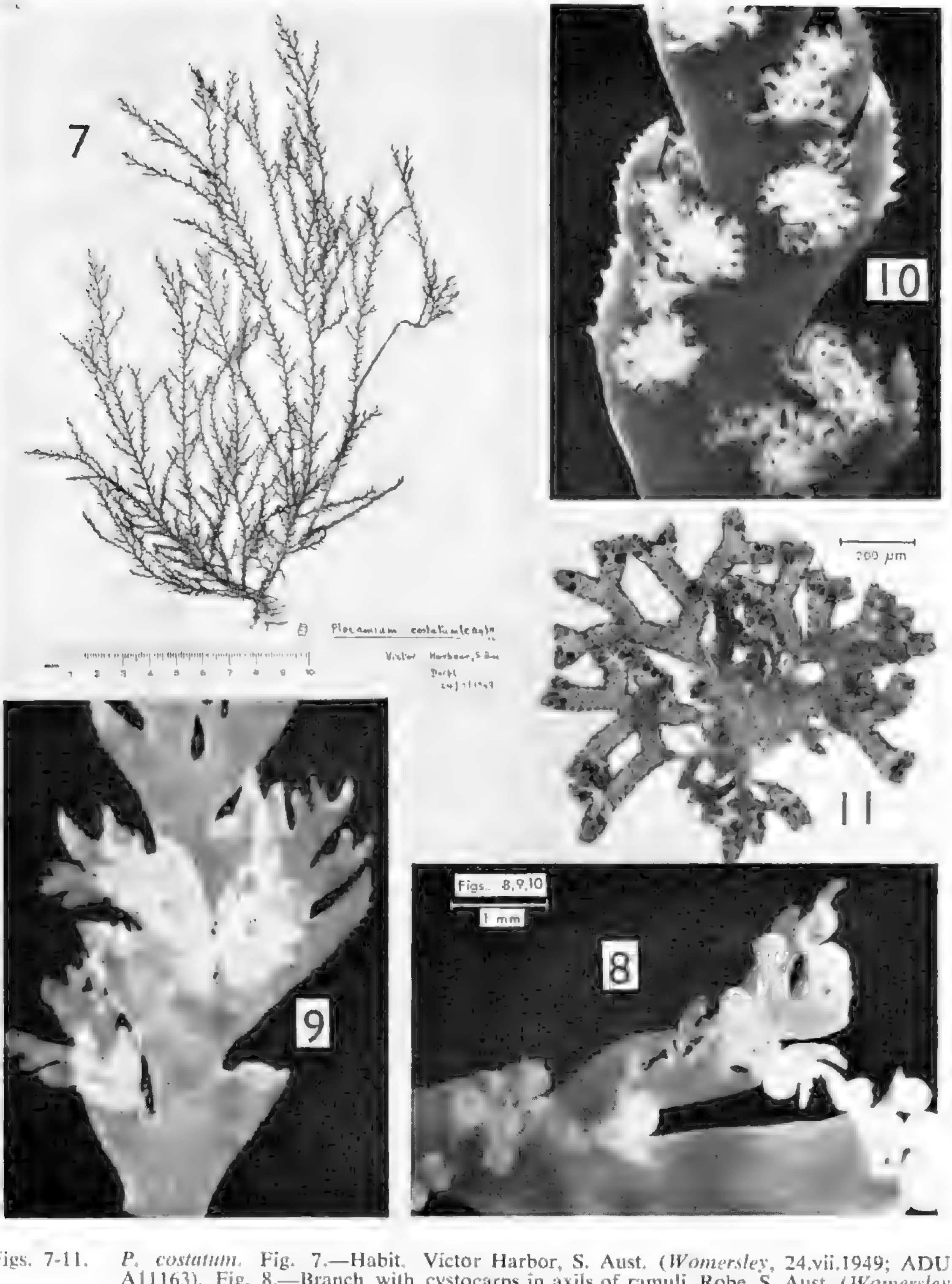
* It is uncertain whether this combination should be credited to Hooker & Harvey or Harvey. Hooker & Harvey (1847) probably was published in Pt. 8 or Pt. 9 (Aug. or Sept.) of Vol. 6 of the London Journal of Botany, which appeared in 12 monthly parts. Harvey (1847) has the preface dated May 24, 1847, but actual date of publication is unknown. The introduction to the Hooker & Harvey paper states "Full descriptions . . . have further appeared in Dr. Harvey's 'Nereis Australia', in the press."



Figs. 7-11. *P. costatum*. Fig. 7.—Habit. Victor Harbor, S. Aust. (*Womersley*, 24.vii.1949; ADU, A11163). Fig. 8.—Branch with cystocarps in axils of ramuli. Robe, S. Aust. (*Womersley*, 15.v.1967; ADU, 31491). Fig. 9.—Branch of a male plant with small axillary branches bearing spermatangia (A31491). Fig. 10.—Stichidial branch (A31491). Fig. 11.—Stichidia (A31491).

Distribution—From Elliston, Eyre Peninsula, S. Aust., to Point Dromedary [16 km (10 miles) south of Narooma], N.S.W. and around Tasmania. Found on coasts of rough to moderate wave action, and known from depths of 3 to 20 m.

P. costatum is distinguished by the clustered stichidia which are branched in their upper parts (often near their apices), and sessile cystocarps. The thallus branches are broader than in *P. angustum* and also have strongly serrate, curved ramuli; in thallus characters *P. costatum* is close to *P. dilatatum* but the massive, unbranched stichidia and pedicellate cystocarps distinguish the latter.

In some specimens of *P. costatum*, the cystocarps in young branches appear pedicellate. This, however, is due to their occurrence on short proliferous branches arising in the axils of older branches and the cystocarps are actually sessile on very slender ramuli; older parts of such plants show typical sessile cystocarps on mature ramuli.

P. costatum has been recorded from New Zealand by Harvey (1855b, p. 246), Laing (1927, p. 159; 1939, p. 154), Chapman (1961, p. 350) and others. These records are based, at least in part, on that of *P. cunninghamii* (Grev.) Harvey which was referred by Hooker & Harvey (1847, p. 404) to *P. costatum*. These New Zealand records need critical revision to establish whether true *P. costatum* occurs there; a closely related taxon is present but it is doubtfully the same as the Australian species.

P. costatum was recorded with doubt from Japan by Yendo (1918, p. 68) and Okamura (1923, p. 189, pl. 198) but later redescribed as *P. serrulatum* by Okamura (1932, p. 101).

3. **Plocamium patagiatum** J. Agardh 1894: 133. De Toni 1900: 601; 1924: 317. Guiler 1952: 90. Lucas 1909: 35. Lucas & Perrin 1947: 215. May 1965: 372. Mazza 1908: 230 (No. 218)

FIGS. 12-16

Thallus (Fig. 12) robust, to 30 cm high. Erect axes 3-4 (-5) mm broad, fairly regularly branched. Ramuli in alternate pairs, the upper ramulus commonly remaining dormant, otherwise developing into a long, straight, lateral bearing regular ramuli with occasional further laterals; the upper ramulus of each pair usually 2-2½ mm broad and 3-5 mm long, digitate with divisions more on the abaxial side; lower ramulus simple, entire, rarely serrate, subulate, acuminate (1-)1½-2½(-3) mm long and ½-1 mm broad at its base. *Cystocarps* 1-2(-3) in axils of upper or lower ramuli (Fig. 13), globular and smooth, ¾-1(-1½) mm diam., with a pedicel ½-1 times as long as the cystocarp and sometimes bearing abortive cystocarps on branches of the pedicel. *Spermatangia* covering the surface of much divided branchlets (Fig. 14) forming dense, globular clusters to ½ mm high in the axils of ramuli. *Stichidia* in dense, globular clusters in the axils of ramuli (Fig. 15); individual stichidia basally branched only (Fig. 16), oblong and swollen where bearing tetrasporangia, on a narrower stalk, 300-400(-500) μm long and (100-)120-150(-170) μm broad. Tetrasporangia in two series, 75-100 μm long and 40-60 μm broad.

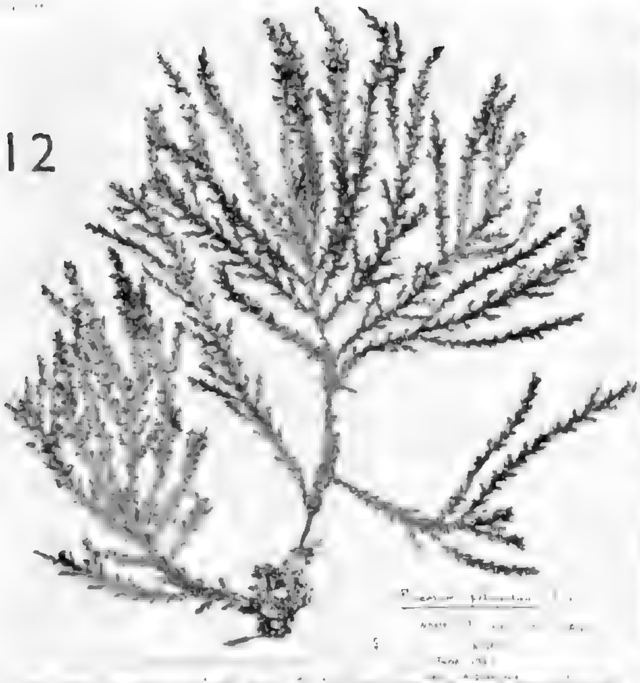
Type locality—Encounter Bay, S. Aust. (*Hussey*).

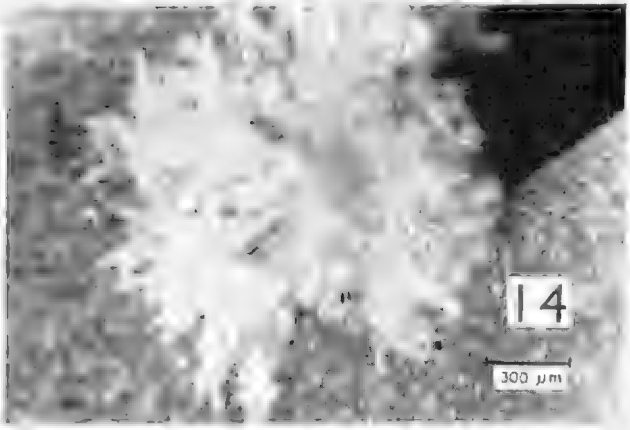
Type—Herb. Agardh, LD, 28174.

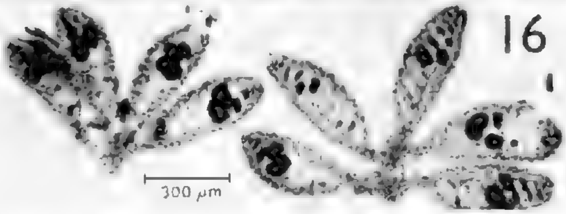
Distribution—From Encounter Bay, S. Aust. to Warrnambool (and Gabo Is.), Vic. and around Tasmania. Found on coasts of strong wave action and known from depths of 10 to 26 m. A sterile specimen, apparently of this species, is known from Elliston, Eyre Peninsula, S. Aust.

P. patagiatum was not distinguished from *P. mertensii* until 1894, and until then had probably been included under the latter. However, its distribution is restricted compared to that of *P. mertensii* which occurs all along southern Australia, and it differs clearly in the form and size of the stichidia (which are shorter, stouter and more clavate than in *P. mertensii*) and usually in the habit and form of the upper and lower ramuli. In contrast to *P. mertensii*, the upper ramulus of *P. patagiatum* is broadly digitate and often remains dormant and the lower ramulus remains undivided. A few sterile specimens appear to be intermediate in form between these two species but tetrasporangial specimens are readily distinguished.

4. **Plocamium mertensii** (Greville) Harvey 1847, 122; 1855a: 553. J. Agardh 1852: 401; 1876: 346. De Toni 1900: 599. Guiler 1952: 90. Lucas 1909: 35; 1929a: 19; 1929b: 50. Lucas & Perrin 1947: 215, fig. 80. May 1965: 372. Mazza 1921: 1545 (No. 767). Reinbold 1897: 52. Sonder 1853: 682; 1880: 19. Tate 1882: 19. Tepper 1883: 66. Tisdall 1893: 507. Wilson 1892: 178. Womersley 1950: 170; 1966: 147.





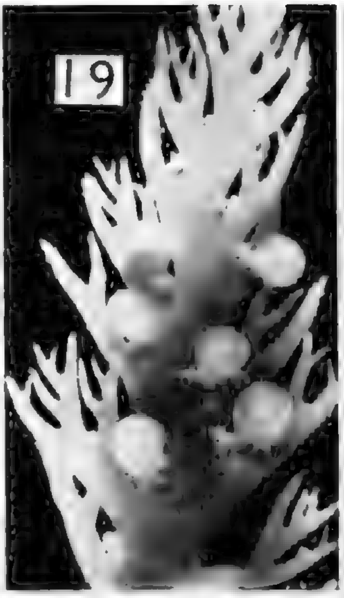


Figs. 12-16. *P. patagiatum.* Fig. 12.—Habit. West Is., S. Aust. (*Shepherd*, June 1966; ADU, A30568). Fig. 13.—Branch with cystocarps in axils of ramuli. West Is., S. Aust. (*Shepherd*, June 1966; ADU, A30568). Fig. 14.—Cluster of spermatangial branches in axil of ramulus. Port Elliot, S. Aust. (*Womersley*, 23.v.1953; ADU, A18720). Fig. 15.—Stichidial branch (A30568). Fig. 16.—Stichidia (A30568).

Figs. 17-23. *(opposite page)* *P. mertensii.* Fig. 17.—Habit. West Is., S. Aust. (*Shepherd*, 13.vi.1970; ADU, A35914). Fig. 18.—Habit of the form with much-branched lower ramuli. Tipara reef, S. Aust. (*Shepherd*, 24.vi. 1970; ADU, A35943). Fig. 19.—Branch with cystocarps in axils of ramuli (A35914). Fig. 20.—Branch with axillary clusters of spermatangial filaments. Daly Head, Yorke Pen., S. Aust. (*Woelkerling*, 22.iv.1969; ADU, A34138). Fig. 21.—Spermatangial branches from a cluster (A34138). Fig. 22.—Stichidial branch (A39514). Fig. 23.—Stichidia (A39514).

17

19



18

20

Figs 19 20, 22

1 mm

22

23

300 µm

21

FIGS 17-23

Thamnophora mertensii Greville 1830: xlix. Sonder 1846: 193.

Thamnocarpus mertensii (Grev.) Kuetzing 1849 887; 1886: 19, pl. 55d-h.

Delesseria plocamium var. *procerum* C. Agardh 1823: 181; 1824: 251.

Thamnophora procera (C. Agardh) J. Agardh 1841: 10. Harvey 1844: 447.

Plocamium procerum (C. Agardh) Hooker & Harvey 1845: 542; 1847: 404. J. Agardh 1852: 400; 1876: 347. De Toni 1900: 600. Guiler 1952: 90. Harvey 1847: 122; 1855a: 553; 1859b: 318; 1862: pl. 223 (incl. var. *mertensii*); 1863, synop.: 39 (incl. var. *mertensii*). Kuetzing 1849: 886; 1866: 19, pl. 54a-d? (may be *P. patagiatum*). Levring 1946: 222. Lucas 1909: 35; 1929a: 19; 1929b: 50. Lucas & Perrin 1947: 214, fig. 79. May 1965: 372. Mazza 1921: 1547 (No. 768). Reinbold 1897: 52. Sonder 1853: 682; 1880: 19. Tate 1882: 19. Tisdall 1893: 507. Wilson 1892: 178.

Plocamium procerum var. *nidificum* Harvey 1863: synop.: 39 (nomen nudum).

Plocamium nidificum Harvey ex J. Agardh 1876: 346; 1894: 131. De Toni 1900: 599; 1924: 317. De Toni & Forti 1923: 32, pl. III. 6-7. Levring 1946: 222. Lucas 1909: 35; 1929b: 50 Lucas & Perrin 1947: 213. May 1965: 372. Reinbold 1897: 52; 1899: 45. Sonder 1880: 19. Tate 1882: 19. Tepper 1883: 66. Tisdall 1893: 507. Wilson 1892: 178. Womersley 1950: 170; 1953: 38.

Thallus (Figs. 17, 18) to 50 cm high, much branched with spreading laterals. Erect axes (1-)2-3(-5) mm broad, thin and delicate in younger regions which are usually broader than older parts of axes. Ramuli in alternate pairs; upper ramulus divided, often developing into a lateral branch, lower ramulus subulate, (¾-)1-1½(-5) mm long and usually less than ½ mm broad at its base, entire or serrate in its upper part either on the abaxial edge only or on both edges; lower ramulus frequently becoming divided and often proliferating into dense clusters of sub-dichotomous pinnules which may occur commonly on older branches (Fig. 18), or on occasional branches, or be totally absent in some plants (Fig. 16). *Cystocarps* in axils of either of the two ramuli, 1-2(-3) maturing, globular and pedicellate, ½-¾(-1) mm diam., arising on small branchlets in the axils (Fig. 19). *Spermatangia* covering the surface of terete branchlets in dense axillary clusters (Figs. 20, 21). *Stichidia* in dense hemispherical clusters arising from a pad of tissue in the axil of either ramulus, or of laterals (Fig. 22); individual stichidia (Fig. 23) simple or branched basally only, linear, ½-¾(-1) mm long and (50-)75-100(-125) µm broad, becoming curved as they elongate; occasional old, elongate stichidia become branched near their apex. Tetrasporangia in 1 or 2 series, ovate, 50-75 µm long and 25-50 µm broad

Type locality — "Novae Hollandiae" (*Fraser*).

Type—Herb. Greville, E.

Distribution—From Nickol Bay, north-west of W. Aust. to San Remo, Vic. and around Tasmania. Found on coasts of strong to moderate wave action and known from shaded pools near low tide level and depths down to 50 m

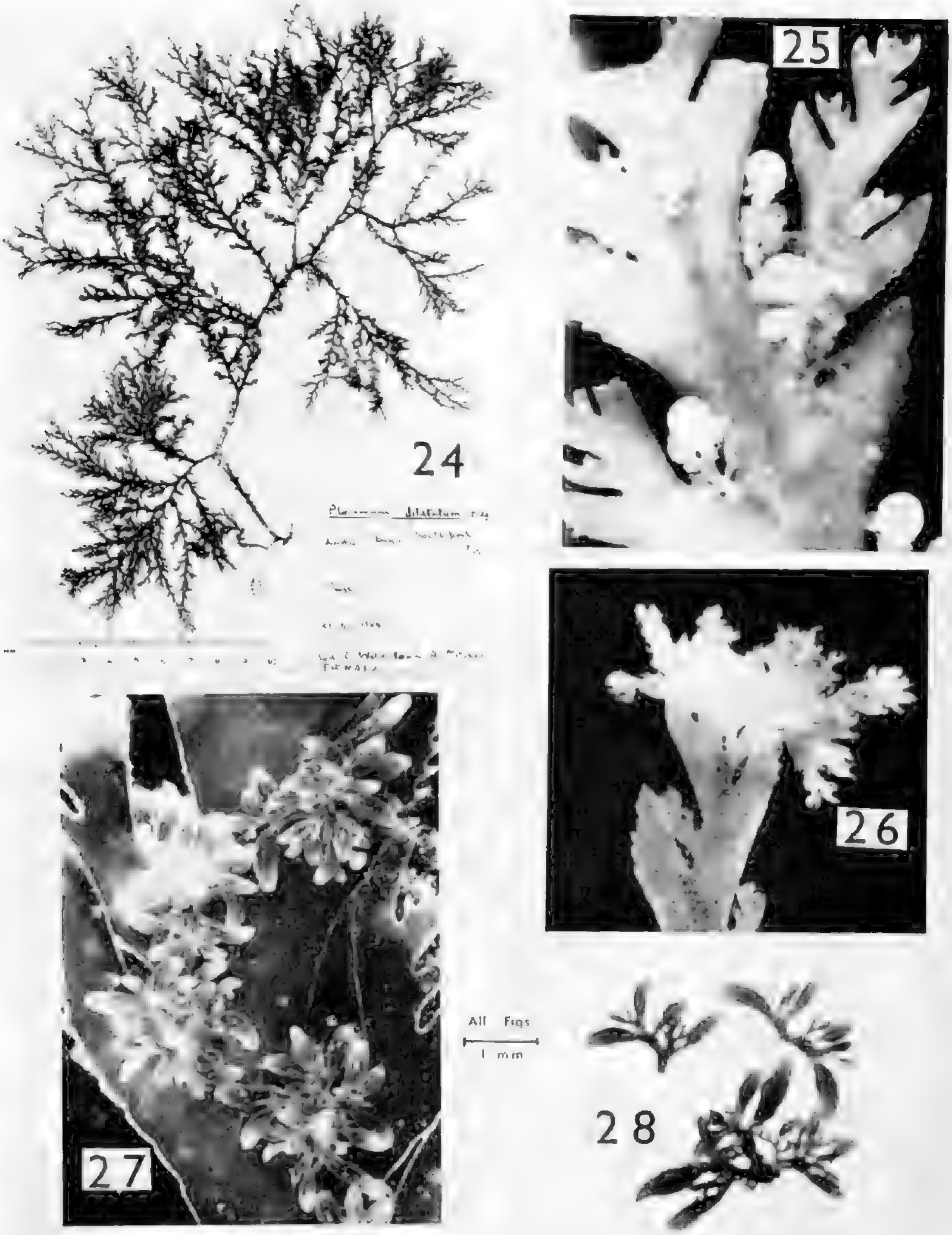
The range of variation in this species is considerable though most specimens are readily recognised. The frequent presence of much-divided ramuli (the lower of each pair) forming conspicuous tufts, characterises many specimens which were described as a separate variety or species, *nidificum*. However, many plants are totally without such tufts, while others form them only occasionally or on certain branches. The type specimens of *P. mertensii* and of *P. procerum* are essentially without such tufts.

Apart from this variable feature, *P. mertensii* is characterised by its much branched, rather thin, thallus with relatively broad axes pedicellate cystocarps and unbranched, linear or curved and relatively long and slender stichidia. The spermatangia are borne on much branched tufts in the axils of the upper ramulus of each pair, as distinct from the vegetative tufts developing from the lower ramulus. Cystocarps normally originate on only slightly branched axillary branchlets, but in one specimen from Geographe Bay, W. Aust. (in MEL) cystocarp bearing tufts are densely branched, similar to those bearing spermatangia.

P. mertensii is most closely related to *P. patagiatum*; differences are discussed under the latter species.

This species, as *P. procerum*, has been credited to other countries. The earliest description, as *Delesseria plocamium* var. *procerum* C. Agardh, was based on specimens from Western Australia and South Africa, but J. Agardh (1841, p. 10) in raising this variety to specific rank excluded the South African specimen. J. Agardh's species was, however, then pre-dated by *Th. mertensii* Greville 1830.

The combination *P. procerum* (C. Agardh) Hooker & Harvey (1845, p. 542) was established for a New Zealand record, but the presence of this taxon in New Zealand has not



Figs. 24-28. *P. dilatatum*. Fig. 24.—Habit. Lady Bay, Southport, Tas. (*Wollaston & Mitchell*, 27.ii.1964; ADU, A27528). Fig. 25.—Branch with cystocarps in axils of ramuli. Point Roadknight, Vic. (*Womersley*, 6.vi.1953; ADU, A18789). Fig. 26.—Male branchlets at apex of a branch. Marion Bay, Tas. (*Shepherd*, 13.ii.1970; ADU, A35637). Fig. 27.—Stichidial branch (A35637). Fig. 28—Stichidia (A35637).

been satisfactorily established although it is recorded by several authors (e.g. Harvey 1855b, p. 246, Laing 1927, p. 160; 1939, p. 155).

5. Plocamium dilatatum J. Agardh 1876: 347. De Toni 1900: 601. Guiler 1952: 90. Lucas 1909: 35; 1929a: 19; 1929b: 50. Lucas & Perrin 1947: 215. May 1965: 372. Reinbold 1898: 46. Sonder 1880: 19. Tate 1882: 19. Tisdall 1893: 507.

FIGS. 24-28

Thallus (Fig. 24) erect, robust, much branched, to 25 cm high from the prostrate base. Erect axes (1½-)2-2½(-3½) mm broad, centrally thickened and becoming costate below. Ramuli in alternate pairs; lower ramulus robust, (1½-)2-3(-4) mm long and about 1 mm broad at its base, with the adaxial side usually straight and the abaxial side convex with coarse, short serrations. *Cystocarps* arising from small axillary branchlets (Fig. 25), appearing pedicellate, globular and smooth surfaced. *Spermatangia* (observed in one specimen only) covering the surface of small but normal branchlets arising in the axils of upper ramuli (Fig. 26). *Stichidia* in clusters (Fig. 27) to 1½ mm high in axils of ramuli, basally branched only; individual stichidia (Fig. 28) clavate, with a relatively slender pedical, ¾-1 mm long and about 250 μm broad. Tetrasporangia in two distinct series, 90-150 μm long by 60-80 μm broad.

Lectotype locality—Tasmania.

Type—Herb. Agardh, LD

Distribution—From Encounter Bay and "Adelaide", S. Aust. to Port Phillip Bay, Vic., and around Tasmania (doubtfully from New Zealand). Found on coasts of strong to moderate wave action and known from depths of 3-22 m.

In his original description, J. Agardh gave both New Zealand and Tasmania as localities, and Laing (1927, p. 159) credits it to New Zealand but later expresses doubt (1939, p. 154). J. Agardh's formal description included the stichidia only but in the discussion he referred to pedicellate cystocarps as well as the characteristic stichidia. The Tasmanian specimens in Herb. Agardh bear stichidia as described by J. Agardh, whereas the New Zealand specimen (from Otago, LD, 28210) is cystocarpic. Since the original description (as distinct from the discussion) covered only stichidia, and the species is based largely on, and characterised by, these structures, one of the stichidial Tasmanian specimens should be regarded as lectotype of the species.

Only one cystocarpic southern Australian specimen of *P. dilatatum* has been seen (ADU, A18789 from Point Roadknight, Vic.). Here the cystocarps arise from small axillary branchlets of normal form and the slender branchlet forms the stalk of the cystocarp. No stichidial specimens (similar to the Australian ones) from New Zealand have been seen and it remains to be established that *P. dilatatum* does occur in New Zealand.

P. dilatatum is characterised by the massive stichidia borne on slender pedicels in axillary clusters. It is superficially similar to *P. costatum* (which has slenderer, branched stichidia), but the thallus of *P. dilatatum* is more robust with somewhat larger ramuli. Experience with these species permits their separation on thallus features alone.

6. Plocamium preissianum Sonder 1845: 54; 1846: 192; 1853: 682. J. Agardh 1852: 399; 1876: 342. De Toni 1900: 594; 1924: 316. De Toni & Forti 1923: 32. Harvey 1855a: 553; 1859a: pl. 63; 1863, synop.: 39. Kuetzing 1849: 885; 1866: 19, pl. 53d-f (fig. as *P. preissii*). Levring 1946: 222. Lucas 1909: 34; 1929b: 50. Lucas & Perrin 1947: 211, fig. 75. May 1965: 372. Mazza 1908: 227 (No. 213). Reinbold 1898: 46, Sonder 1853: 682; 1880: 18. Tate 1882: 19. Tisdall 1893: 507. Wilson 1898: 178. Womersley 1950: 170. 1966: 147.

FIGS. 29-35

Thallus (Fig. 29) robust, to 50 cm high. Erect axes (1-)1½-2(-3) mm broad, usually long and irregularly branched, becoming

Figs. 29-35. (*opposite page*) *P. preissianum*. Fig. 29.—Habit. West Is., S. Aust. (*Shepherd*, 13.vi.1970; ADU, A35912). Fig. 30.—Branch with sessile, verrucose, cystocarps. West Is., S. Aust. (*Shepherd*, 1.i.1969; ADU, A33242). Fig. 31.—Male branch with spermatangial branchlets at apex (A33242). Fig. 32.—Branchlets bearing spermatangia (A33242). Fig. 33.—Branch with typical axillary clusters of stichidia (A35912). Fig. 34.—Branch with stichidia extending along margins of branch and ramuli (A33242). Fig. 35.—Stichidia (A35912).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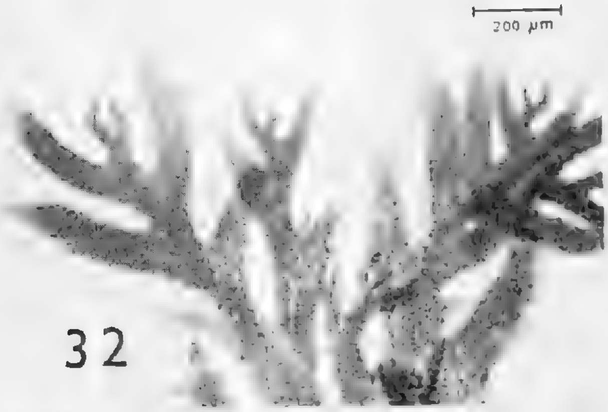
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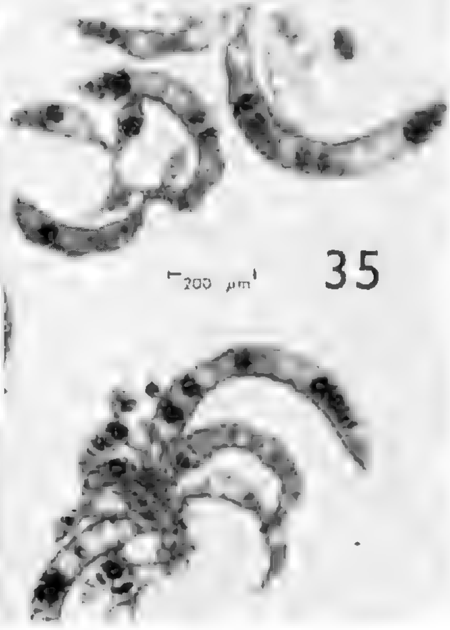
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thickened and sometimes appearing costate in older parts. Ramuli in alternating series of 3(-4), occasionally with some in pairs in certain plants, the uppermost ramulus (occasionally the upper two) usually developing into a lateral branch; lower ramuli subulate to linear, (1½-)2-3(-4) mm long and (200-)300-400 (-500) μm broad at their base, usually strongly serrate abaxially (rarely entire). *Cystocarps* single or occasionally adjacent, sessile on the axis or on either margin of the ramuli or sessile in comparable positions on small axillary branchlets, ¾-1(-1½) mm across, globular and becoming strongly verrucose (Fig. 30). *Spermatangia* covering extensive areas on both surfaces of young apices and ramuli in male plants (Figs. 31, 32). *Stichidia* in dense axillary clusters (Fig. 33) and frequently extending along the margins of the adjacent axis and ramuli (Fig. 34); individual stichidia (Fig. 35) simple or basally branched only, linear-arcuate (100-)200-500 μm long (sometimes continuing growth to 1½ mm long) and (25-)50-75(-100) μm broad. Tetrasporangia in 1-2 series, ovoid, 53-66 μm long and 40-53 μm broad.

Type locality—"austro-occidentale Novae Hollandiae" (*Preiss*).

Type—MEL, 1005964.

Distribution—from the Abrolhos Islands and Geraldton, W. Aust. to Wilson's Promontory, Vic. Common on coasts subject to rough wave action and known from depths of 2 to 50 m.

P. preissianum is one of the most distinctive of the Australian species of *Plocamium* and is readily recognised when sterile by its robust, relatively broad thallus and series of three ramuli. The sessile, verrucose cystocarps and spermatangial areas covering ramuli are also distinctive compared to other robust species but the stichidia are rather similar to those of *P. mertensii*.

This has probably always been a well-understood species, though Kuetzing (1866, pl. 53d-f) used the name *P. preissii* for his illustration (only) and Harvey (1847, p. 122) incorrectly placed it as a synonym of *P. costatum*, later (Harvey 1859a, pl. 63) recognising *P. preissianum* as distinct.

7. **Plocamium cartilagineum** (L.) Dixon 1967: 58.

FIGS. 36-39

Plocamium coccineum (Hudson) Lyngbye. J. Agardh 1852: 395; 1876: 339. Harvey 1846: pl. 44; 1847: 123; 1855a: 553; 1859b: 317; 1863, synop.: 39. Kylin 1923: 49, figs. 34, 35, 1944: 53, pl. 10, fig. 37. Levring 1945: 17; 1946: 221. Sonder 1880: 18. Tisdall 1893: 507. Womersley 1966: 147.

Plocamium pusillum Sonder 1845: 54; 1846: 192; 1880: 18. J. Agardh 1852: 405. Harvey 1847: 123. Kuetzing 1849: 884. Tisdall 1893: 507. Wilson 1892: 178.

Plocamium angustum β pusillum (Sonder) Harvey 1863, synop.: 39.

Plocamium leptophyllum sensu Lucas 1929a: 19; 1929b: 50. Lucas & Perrin 1947: 210, fig. 74 (in part, excl. fig. c). Reinbold 1899: 45. Sonder 1853: 683? Womersley 1950: 170.

Thallus (Fig. 36) slender and much branched, to 20 cm high. Erect axes (½-)1-1½ mm broad. Ramuli normally in alternate series of 3-4, occasionally in pairs or as many as 5-10; normally all ramuli except the lowest are branched, with the uppermost and sometimes the second developing as long laterals; lowest ramulus subulate to almost linear, often curved, entire, 1-2(-2½) mm long and about ¼ mm or less broad at its base. *Cystocarps* sessile, globular, smooth, ½-¾ mm diam., borne singly or several adjacent in the axils or on the margins of ramuli (Fig. 37). *Spermatangia* covering the surface of ramuli and axis in apical regions (Fig. 38). *Stichidia* borne in the axils of ramuli or grouped on the upper margin of ramuli and along the axis (Fig. 39), usually simple and lanceolate at first but becoming branched at wide angles near their upper ends, sometimes subdichotomously branched 1-4 times lower down; individual stichidia (150-)250-400(-1000) μm long and

Figs. 36-39. *P. cartilagineum.* Fig. 36.—Habit. West Is., S. Aust. (*Shepherd*, 30.vi.1970; ADU, A35979). Fig. 37.—Branch with sessile cystocarps (A35979). Fig. 38.—Male branch with spermatangial areas (A35979). Fig. 39.—Stichidial branch (A35979).

Figs. 40-42. *(opposite page)* *P. leptophyllum.* Fig. 40.—Habit. West Is., S. Aust. (*Shepherd*, 1.i.1969; ADU, A33238) Fig. 41.—Upper part of a branch with adventitious ramuli and hooked branch ends and lower ramuli. West Is., S. Aust. (*Shepherd*, 5.vii.1970; ADU, A36017). Fig. 42. Branch bearing stichidia (A36017)

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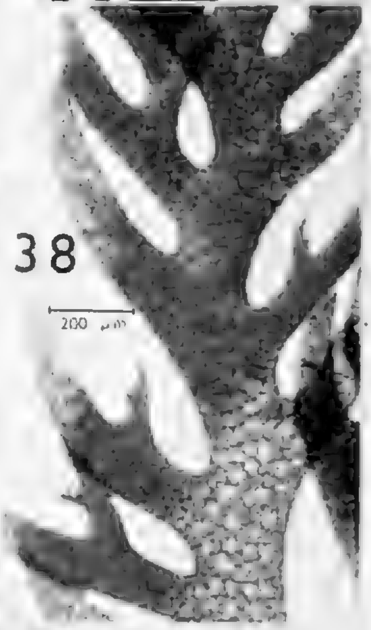

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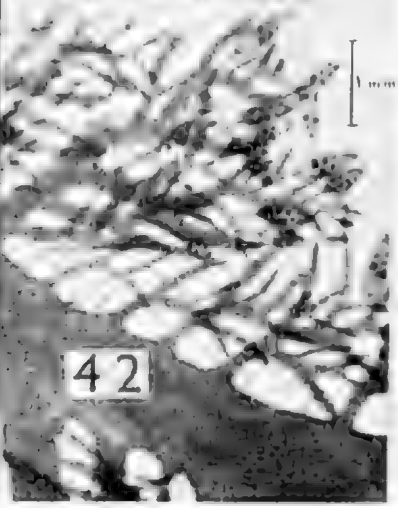

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about 100 μm diam., with a short pedicel. Tetrasporangia biseriate, ovoid, 40-55 μm long and 27-32 μm broad.

Type locality—Northern Europe.

Type—L. 910, 184 . . . 14 (see Dixon 1967).

Distribution—From Rottnest Is., W. Aust. around southern Australia to Newcastle, N.S.W. (probably to Caloundra, Qld.) and around Tasmania. Found on coasts of strong to moderate wave action and known from depths of 2-26 m. Widespread in most temperate and cold waters of both northern and southern hemispheres.

Dixon (1967, p. 58) has shown that the well-known name *P. coccineum* has to be replaced by *P. cartilagineum*. Previous to this, it had been known for some years as *P. vulgare* Lamx. (see Dixon).

The type of *P. pusillum* Sonder (MEL 1005815) includes young, sterile fragments under 3 cm high, with ramuli in series of 2 or 3. It is similar to better developed specimens in PERTH which agree well with *P. cartilagineum*

P. cartilagineum is the only very widespread species of *Plocamium*, being recorded from many temperate seas. The Australian forms compare well in habit with those from Europe and are distinctly less robust than the Pacific North American forms distinguished previously as *P. coccineum* var. *pacificum* J. Ag. While there is considerable variation in habit and dimensions within the complex, the consistent branching pattern, sessile cystocarps and the morphology of the stichidia distinguish the species.

Several varieties of *P. cartilagineum* (as *P. coccineum*) have been described (J. Agardh 1852, p. 395; 1876, p. 339) and these included plants from Australia. Most of them (e.g. var. *australe* J. Agardh 1852, p. 395) are apparently forms within *P. cartilagineum*, but var. *flexuosum* Hooker & Harvey (1847, p. 404), based on Gunn 1335, is *P. leptophyllum* Kuetzing. J. Agardh (1852, p. 396) gave var. *flexuosum* as a variety of *P. coccineum* and in 1876 (p. 339) gave this variety under *P. leptophyllum*. Harvey's Alg. Aust. Exs. 356 I. as *P. coccineum* var. *flexuosum*, is also *P. leptophyllum*, but his illustration (1847, pl. 43, as *P. flexuosum*) is faulty in that it does not show the adventitious ramuli which are present on both Gunn's and Harvey's specimens.

Var. *uncinatum* J. Agardh (1852, p. 396), recorded by J. Agardh from many areas, including Tasmania, appears to be based on specimens with recurved ramuli near the base of the thallus. Such recurved ramuli occur in several species as part of the basal prostrate, attachment system, but are distinct from the frequent hooked ramuli on the upper parts of *P. leptophyllum*.

P. cystophyllum J. Agardh is a nomen nudum in Wilson (1892, p. 178) and Tisdall (1893, p. 507). Wilson's specimens so named in MEL are of *P. cartilagineum*, and some named as *P. cystophyllum* var. *flexuosum* are *P. leptophyllum*.

Relationships with *P. leptophyllum* are further discussed under this species.

8. Plocamium leptophyllum Kuetzing 1849: 885; 1866: 16, pl. 45a-c. J. Agardh 1852: 405; 1876: 338 (probably excluding var. *strictum*). De Toni 1900: 589; 1924: 314. Levring 1946: 222. Lucas 1909: 34. Lucas & Perrin 1947: 210 (in part?). Reinbold 1897: 52. Sonder 1853: 683; 1880: 18 (excluding some loc.). Tisdall 1893: 507 Wilson 1898: 178

FIGS. 40-42

P. leptophyllum var. *flexuosum* J. Agardh 1876: 339. De Toni 1900: 589.

P. coccineum var. *flexuosum* Hooker & Harvey 1847: 404. J. Agardh 1852: 396. Guiler 1952: 90. Harvey 1847: 124, pl. 43; 1859b: 317. Kuetzing 1849: 884. Yendo 1915: 114.

P. flexuosum (Hooker & Harvey) Sonder 1853: 682. Lucas 1929a: 19; 1929b: 50.

Thallus (Fig. 40) delicate, usually epiphytic on other algae, densely branched with clustered fronds from indefinite entangled bases, to 15 cm high. Axes often slightly to distinctly flexuous and frequently bearing hooked branchlets corresponding to the branch apex or the lowest ramulus of a series; axes about ½ mm broad above, becoming slightly thickened and subterete below. Ramuli in alternate series of (3-)4-5, sub-linear, commonly all branched except the lowest, with short, adventitious ramuli developing on the margin of the axis between the series (Fig. 41) and also between ramuli of the series, frequently forming an almost continuous fringe of ramuli along the branches; lowest ramuli in the series 1-1½ mm long and about 50(-100) μm broad at their base. Sexual plants unknown. *Stichidia* 200-250(-750) μm long and 75-100 μm broad, borne singly or in groups in the axils or on the upper edge of the ramuli (Fig. 42), simple or branched at wide angles in their upper parts, lanceolate with a short pedicel and usually with an acute, sterile tip. Tetrasporangia in one or two rows, ovoid, about 40 μm long.

Type locality — Georgetown, Tasmania (*Gunn* 1335). Two isotype specimens are in NSW.

Type—L, 941, 181 . . . 471.

Distribution—From West Is. (Encounter Bay), S. Aust. to Wilson's Promontory, Vic., and around Tasmania. Usually epiphytic on other algae on coasts of strong wave action and known from depths of 2-25 m.

P. leptophyllum Kuetzing 1849 is the earliest valid name for this species, though Hooker and Harvey (1847, p. 404) and Harvey (1847, p. 124) had distinguished it previously as *P. coccineum* var. *flexuosum* [Harvey (1847, pl. 43) uses the name *P. flexuosum* under his illustration but not in the text]. Both *P. leptophyllum* Kuetzing and *P. coccineum* var. *flexuosum* Hooker & Harvey are based on Gunn 1335 from Georgetown, Tasmania.

P. leptophyllum is most closely related to slender forms of *P. cartilagineum* but is readily distinguished by the presence of adventitious ramuli and usually by the hooked ends to branches and some lower ramuli. No sexual plants have been recorded and few tetrasporangial plants are known. *P. leptophyllum* is normally an entangled epiphyte on other species of *Plocamium* or other bushy algae.

However, *P. cartilagineum* and *P. leptophyllum* have frequently been confused in southern Australian records. Reinbold's (1899, p. 45) record of the latter from Investigator Strait, S. Aust., as represented by specimens in ADU, is slender *P. cartilagineum*. Probably other references to *P. leptophyllum* are based on specimens which include *P. cartilagineum*, at least in part. Comparisons such as those of De Toni (1900, p. 590) and Lucas (1919, p. 13) are based only in part on true *P. leptophyllum* and involve mainly forms of *P. cartilagineum*. *P. leptophyllum* in the key of May (1965, p. 372) does not involve the essential characters and includes mainly *P. cartilagineum*. The record of Lucas (1931, p. 55) from Rockingham Bay, Qld., probably applies to *P. cartilagineum*, as does that of Lucas (1935, p. 221) from Lord Howe Is.

P. leptophyllum var. *strictum* J. Agardh (1876, p. 338), is probably a form of *P. cartilagineum*. Var. *recurvatum* J. Agardh (1876, p. 339) from "Tasmania and New Zealand" needs investigation from the type material.

P. leptophyllum has been recorded from New Zealand (Laing 1927, p. 159; 1939, p. 155) and specimens in ADU (such as Lindauer's Alg. Nov.-Zel. Exs. 193) show the form and presence of adventitious ramuli characteristic of this species; hooked ramuli, however, are virtually absent in the ADU specimens. Comparison of further fertile material is needed to confirm the presence of *P. leptophyllum* in New Zealand. The record from the Auckland Islands (Papenfuss 1964, p. 36) is unlikely to be *P. leptophyllum*.

P. leptophyllum has been recorded also from Japan (Yendo 1915, p. 113), and as *P. leptophyllum* var. *flexuosum* by Okamura (1913, p. 14, pl. 103 (6-7)), Arasaki (1964, p. 99, fig. 355) and Segawa (1956, p. 86, fig. 408). The illustrations and descriptions of these authors indicate that the Japanese plants are probably forms of *P. cartilagineum* and not true *P. leptophyllum*, and although Yendo (1915, p. 114) in also recording *P. coccineum* var. *flexuosum* comments on the presence of adventitious ramuli as characteristic in this variety, there is no statement that they occur in Japanese plants.

Biogeography of Plocamium in Southern Australia

Eight species of *Plocamium* occur along southern Australia, but only two extend throughout this region, viz. the widespread *P. cartilagineum* and also *P. mertensii*. The next most widespread species, *P. preissianum*, occurs all along southern Australia (to central Victoria) but not in Tasmania. Only these three species are found in southern Western Australia.

All eight species occur in the eastern region, i.e. in eastern South Australia and in Victoria. *P. angustum* and *P. costatum* are found as far west as the west coast of Eyre Peninsula, S. Aust. and in the east extend into N.S.W. Three species, *P. dilatatum*, *P. leptophyllum* and *P. patagiatum* are apparently limited to the region from about Victor Harbor, S. Aust. to Wilson's Promontory, Vic. and around Tasmania.

This distribution is in general agreement with that of many other southern Australian marine algae, with a strong eastern group, moderate general southern Australian group and smaller western group of species.

The range of species of *Plocamium* up the N.S.W. coast is not well known. This applies particularly to *P. angustum* and *P. cartilagineum*. Occurrence of southern Australian species outside Australia (e.g. in New Zealand) must also be regarded with doubt, but on the basis of the above descriptions of the southern Australian species it is hoped that comparisons with fertile, liquid-preserved material will establish the relationships of Australian and New Zealand species.

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LARGE GASTROPODS OF THE FAMILIES DIASTOMATIDAE AND CERITHIIDAE (MOLLUSCA: GASTROPODA) IN SOUTHERN AUSTRALIA

BY N. H. LUDBROOK

Summary

The stratigraphical and geographical distribution of species of *Diastoma* (Miocene to Recent), *Campanile* (Miocene to Recent), *Jetwoodsia* (Eocene to Miocene), *Thericium* s.str. (Pilocene), *Thericium (Chavanicerithium)* (Lower Micene to Pleistocene) in sedimentary basins of southern Australia are determined.

Three species of *Diastoma, D. adelaidense* Ludbrook sp. Nov., *D. melanioides* (Reeve) and *D. provisi* Tate; three species of *Campanile, C symbolicum* Iredale, *C. triseriale* Basedow and *C. virginiese* Ludbrook sp. Nov.; two species of *Jetwoodsia* gen. Nov., J apheles (Tenison Woods) and *J. nullarborica* (Chapman & Crespin); *Thericium (T.) fallax* (Ludbrook), ad eight species of *Thericium (Chavanicerithium), T. (C.) adelaidense* (Howchin & Cotton), T. (C.) *darraghi* Ludbrook sp. Nov., T. (C.) *flemingtonense (McCoy), T. (C.) pritchardi (Harris), T. (C.) tatei* Ludbrook sp. Nov., *T. (C.) torri* (Tate), *T. (C.) westraiense* Ludbrook sp. Nov. and *T?. (C?.) wynyardense* Tate) are described or noted.

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Introduction

Middle and late Cainozoic molluscan assemblages in the limestones and sandy limestones of the Eucla and St. Vincent Basins characteristically contain large bivalves, mostly *Miltha* and *Anodontia*, and gastropods *Campanile* and *Diastoma*, often only in the form of casts and moulds. Over a period of some ninety years rocks containing these genera have been correlated with one another, first as of Miocene age, and more recently as Pliocene.

It is now known that the association began in the Miocene of the Eucla and St. Vincent Basins, flourished in the late Pliocene of the St. Vincent Basin and early Pleistocene of the Eucla Basin, with the gastropods surviving in present seas of the western part of the Flindersian Province of southern Australia. Systematic revision of the large gastropods became necessary during a monographic study of Pleistocene molluscs from the Roe Plain at the western end of the Eucla Basin. Rich collections have recently been made along the Eyre Highway and from foundation holes excavated for the Hampton Microwave Repeater Tower site, 33 miles (53 kilometres) east of Madura.

The molluscan assemblage containing *Miltha* first appears in the Nullarbor Limestone (Ludbrook 1969), the Melton Limestone near Wallaroo, northern Yorke Peninsula, and the limestones at Deep Creek, 20 miles (32 kilometres) south-west of Whyalla, Whyalla 1: 250,000 geological sheet (Lindsay 1970), all of Miocene age. Great care must be exercised in assessing the stratigraphical position of rocks containing the *Diastoma-Campanile-Anodontia-Miltha* assemblage since some of the species such as *Diastoma adelaidense* and *Anodontia sphericula* are long-ranging and only the accompanying molluscs and foraminifera and the lithology will distinguish the Miocene from the Pliocene limestones.

From field observations and study of the microfaunas and lithologies, Lindsay (1970) has shown that limestone outcrops on northern Yorke and Eyre Peninsulas are of Miocene age, and not Pliocene as previously recorded, particularly by the present writer. Limestones of Miocene age in the Eucla Basin and those south of Whyalla and at Wallaroo and Tickera which have been recorded as Pliocene or correlated with units now known to be of Pliocene age are: the crystalline limestones at Tickera (Melton Limestone) and "Bunda Cliffs marbles" (Nullarbor Limestone) correlated by Tate (1879a, p. liii) with the "Upper Aldinga Series" (i.e. the Hallett Cove Sandstone); samples S1 and S3 from the surface near Koonalda, Abrakurrie and Weebubbie Caves determined by Crespin (*in* King 1949, p. 57) as Lower Pliocene, but presumably as Sample S2 from the Nullarbor Limestone; at the foot of Poynton Scarp and in Deep Creek (Miles

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1952, p. 96, pl. VII; Cotton *in* Miles 1955, p. 25; and Ludbrook *in* Miles 1955, p. 25); localities 2 and 3 of Ludbrook (1959, p. 220; 1963, fig. 1; 1967a, fig. 3); and of Crawford (1965, p. 36)—"6 feet of nodular limestone of Pliocene age near Wallaroo and Point Hughes".

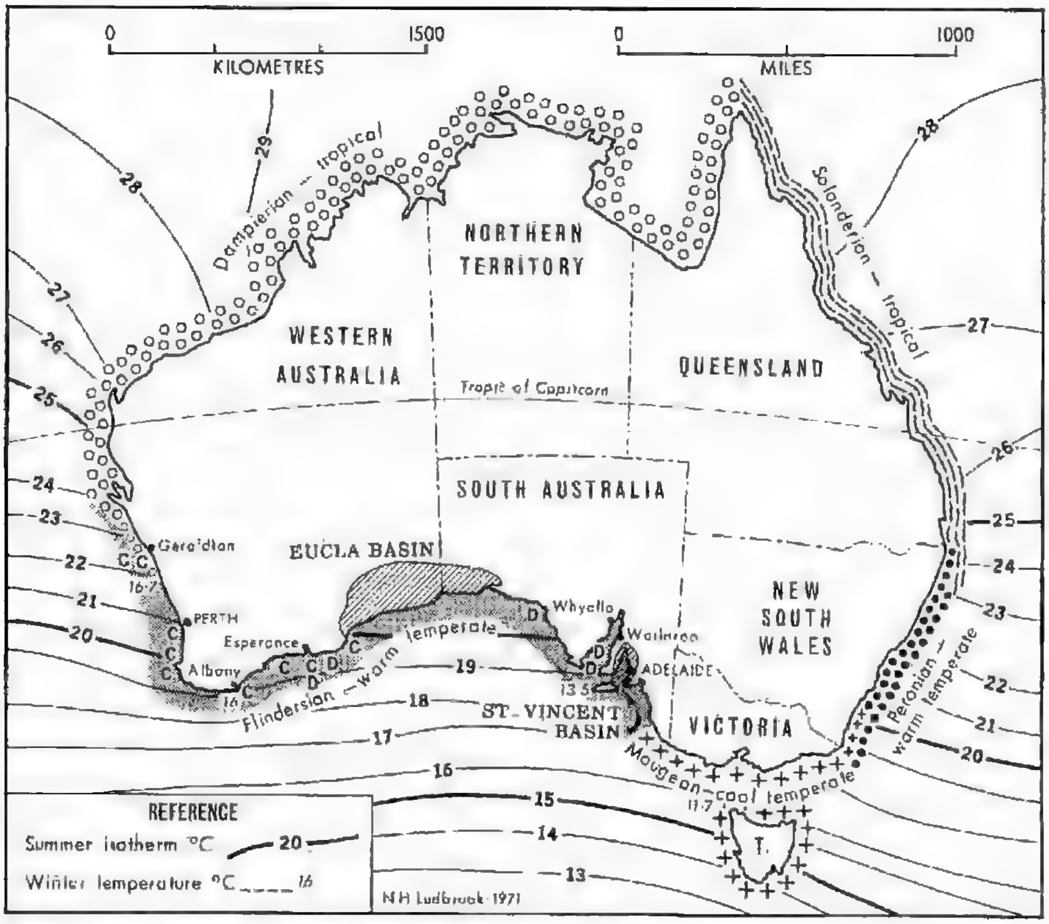

Fig. 1. Australian littoral provinces and the distribution of *Diastoma* (*D*) and *Campanile* (*C*).

Figure 1, showing the present distribution of *Campanile* and *Diastoma*, incorporates isothermal data adapted from charts of Sverdrup, Johnson and Fleming (1942) and of the Royal Netherlands Meteorological Institute (1949), and shows the littoral biogeographical provinces of Bennett and Pope (1953, p. 139). *Diastoma* and *Campanile* are now restricted to the Flindersian Province, partly equivalent to Crespin's (1950) Austral Indo-Pacific Province (Ludbrook 1959a). The Eucla and St. Vincent Basins fall within this province.

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Plate 3, figure 5. Mr. Richard Carver donated the specimen of *Campanile symbolicum*, M3231.

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Family **DIASTOMATIDAE** (emend. pro DIASTOMIDAE)

Genus DIASTOMA Deshayes, 1850

Diastoma is best known from the Eocene of the Paris Basin; it is now living only in a very restricted area in south-western Australia and off Eyre Peninsula in South Australia. The genus has been recorded (Wenz 1940, p. 750), as having a range of Upper Cretaceous (Senonian) to Recent, and occurring in Europe, Egypt, East Indies, North and South America, and Australia. However, small cerithiids such as those described from Southern California as *Diastoma fastigiata* Carpenter, *D. oldroydae* Bartsch, and *D. stearnsi* Bartsch (Bartsch 1911; Oldroyd 1927) and three cerithioid species from the Eocene of Peru, *D. geositta* Olsson, *D. furnaria* Olsson, and *D. elaenia* Olsson, placed doubtfully in *Diastoma* by their author, appear from the figures to differ from *Diastoma* in style of sculpture and in the possession of a broad siphonal canal, as also does *D. virginica* Henderson & Bartsch, of which the South Australian Museum has specimens in the Elliot Collection

From advice and material received from Cossmann, Tate (1894) was able to affirm that his *Diastoma provisi*, *Mesalia melanioides* Reeve ("*melanoides*" Tate, error for *melanioides*) and *Diastoma costellatum* Lamarck, the type species of *Diastoma*, were congeneric, and that *Diastoma* was present in the South Australian Pliocene and living in southwestern Australia. The distribution and evolutionary history of the genus have been subsequently obscured by the introduction of a separate genus for *D. melanioides*.

The genus *Diastoma* was described in considerable detail by Deshayes (1864) from four species——*D. costellata*, *D. variculosa*, *D. interrupta* and *D. inermis* from the calcaire grossier, sables moyens and sables inferieurs of the Paris Basin. Harris (1897) briefly but adequately described the generic characters as:

"Shell turriculate, varicose, with a high spire; aperture ovate, oblique, canaliculate and detached behind, sinuous, but not canaliculate in front; columella slightly concave, covered by a thin, shining and somewhat detached plate or an affixed callosity, and carrying, towards the middle, an oblique plication not always well marked."

Diastoma was placed in the Cerithiidae by Fischer (1884) and by Cossmann (1889).

Cotton (1932) introduced the genus *Neodiastoma* for the Recent shell *Mesalia melanioides* Reeve, the aperture of which was described as being "oblique, inner lip glazed, more thickly glazed anteriorly, the two degrees of glazing separated by a sharp columella plait; outer lip slightly notched anteriorly near the columella. . . . *Neodiastoma* differs from *Diastoma* in the anterior notch of the outer lip, and from *Mesalia* in being variced. . . . This genus had probably better be placed in the Family Cerithiidae for the present."

Wenz (1939), reproducing Reeve's figure of *Mesalia melanioides* showing no anterior notch, placed *Neodiastoma melanioides* (Reeve) in the Turritellidae near *Mesalia*, and *Diastoma* (type species *Melania costellata* Lamarck) in a separate family Diastomidae with *Sandbergeria* and several other genera of small shells such as *Obtortio*.

The close relationship between the Pliocene *D. provisi* and the Recent *N. melanioides* prompted Ludbrook (1941), Crespin *in* King (1949), and Cotton (1952) to list *D. provisi* in *Neodiastoma*.

Cossmann's early opinion was confirmed by Chavan in 1952 in correspondence with the writer: "*Neodiastoma provisi* that I have received from you belongs to *Diastoma sensu stricto*; this is not a *Neodiastoma* according to the characteristics of this unit." Ludbrook (1957) redescribed and figured *D. provisi* as a "restricted and typical fossil of the Dry Creek Sands and their equivalents". While this statement still applies to *D. provisi*, it is now obvious from the more abundant material available that *Diastoma* has been present in southern Australia in the Eucla and St. Vincent Basins from Lower Miocene to Recent times, reaching its maximum abundance in the late Pliocene and early Pleistocene, and that *Neodiastoma* is a synonym of *Diastoma*.

Although the species appears to be rare and very restricted in its present distribution, topotypes of *D. melanioides* do not exhibit any more conspicuous anterior notching of the outer lip than does *D. costellatum*, as is demonstrated by the specimens figured on Plate 1. Cotton appears not to have noticed the broken apertures of some of the specimens on which he based his diagnosis of *Neodiastoma*, one of which is illustrated in figure 18. *D. melanioides* usually lacks the tendency for the aperture to separate at the suture, but it may be present to a slight degree (figure 13). The median folding of the columellar lip is a common feature of all the species here placed in *Diastoma*.

Three species are recognized. *D. adelaidense*, the longest ranging, first appearing in the Lower Miocene Nullarbor Limestone and the youngest member of the Melton Limestone of Yorke Peninsula and its equivalents on Eyre Peninsula, and dying out in the Pleistocene of the Roe Plain; *D. provisi*, common in the Dry Creek Sands but restricted to the Upper Pliocene; and *D. melanioides*, abundant in the Pleistocene of the Roe Plain and surviving in a very restricted area between Cheyne Beach, 50 miles (80 km) NE of Albany, and Duke of Orleans Bay, 275 miles (443 km) ENE of Albany, and also at depths of less than 20 fathoms (37 m) off islands off the coast of Eyre Peninsula.

Diastoma adelaidense Ludbrook sp. nov.

PL. 1, FIGS. 3-7; PL. 6, FIGS. 9, 10.

Diastoma provisi Ludbrook, 1957: 22 (in part), 1959: 221 (in part) (*non* Tate).

Shell of moderate size and thickness, elongate, turreted, with a small dome-shaped protoconch of one-and-a-half turns, adult whorls 14, all more or less variced, often with three strong varices per whorl; whorls obliquely axially plicate, with from 15 to 20 plicae per whorl, surmounted by fine spiral lirae increasing from 3 in the early whorls to about 20 in the penultimate whorl, with fine secondary lirae between them; suture deep, imbricating; aperture oblique, loop-shaped, with a short adapical channel, columellar lip thickened and divided medially by a sharp thin columellar fold, reflexed anteriorly to the basal lip which is broadly reflected in a slight siphonal canal.

Dimensions: height 48, diameter 14 mm.

Types: holotype GSSA M 609, Mitchell's Bore, sec. 353, hd. Yatala, 420-499 feet (127-151 m); paratype GSSA M 611, Kooyonga Golf Club Bore 1932, sec. 2028, hd. Adelaide, 390-478 feet (118-145 m); WAM 69.487 Hampton Microwave Repeater Tower site.

Type locality: Mitchell's Bore, sec. 353, hd. Yatala, 420-499 feet (127-151 m), Adelaide Plains Sub-Basin, St. Vincent Basin, Dry Creek Sands, Upper Pliocene.

Material: 253 specimens from sludges from depths varying from 238 to 507 feet (72-154 m) of 21 bores, in the Adelaide Plains Sub-Basin between West Beach and Salisbury, drilled into the Dry Creek Sands; 11 specimens WAM 69.487 from the Pleistocene of the Roe Plain at Hampton Microwave Repeater Tower; external moulds in sandy limestone on Kangaroo Island, 11 miles (17 km) WSW of Kingscote, sec. 268, hd. Menzies; external moulds from the Melton Limestone at Wallaroo, Port Hughes, and 1 mile (1.61 km) NE of Myponie Point on Yorke Peninsula and from Deep Creek and Murninnie on NE Eyre Peninsula.

Stratigraphical range: Lower to Middle Miocene of the Melton Limestone to Pleistocene of the Roe Plain (Eucla Basin) in Western Australia.

The species resembles *Diastoma hypermeces* Cossmann from the Oligocene of Rennes. It may be readily distinguished by the relatively few axial plicae per whorl and by its tendency to be strongly varicate; it has the longest range and is the most widely distributed *Diastoma* in southern Australia.

Diastoma melanioides (Reeve).

PL. 1, FIGS. 12-21.

Mesalia melanioides Reeve, 1849: pl. *Mesalia*, fig. 3, sp. 3.

Diastoma melanoides (err. pro *melanioides*) Reeve; Tate, 1894: 177.

Mesalia exilis Sowerby, 1913: 236, pl. iii, fig. 9.

Neodiastoma melanioides Reeve; Cotton, 1932: 541.

Shell of moderate size, turreted, with a protoconch of 2 smooth whorls; adult whorls 12 in a height of 42 mm, early whorls rather irregularly variced, the varices becoming obsolete towards the last whorl; the first two adult whorls are finely spirally lirate, the number of lirae increasing from 6 on the first two whorls to 12 primary and numerous secondary lirae over the last whorl and base; third and following whorls axially plicate, with about 30 plications on each whorl weakly tuberculated at the intersections with the primary spiral lirae; suture linear, imbricating, base rounded.

Aperture oblique, loop shaped, with an adapical channel, outer lip thin, basal lip reflected anteriorly towards the columella; columellar lip with 2 distinct calloused areas divided by a sharp columellar fold; the anterior part is reflected to the basal lip which is reflected or has a slight broad shallow siphonal canal.

Colour white, flecked with chestnut spots on the spiral ribs.

Dimensions: height 42, diameter 14 mm.

Types: hypotypes WAM 70.1145, Esperance; SAM D 14994, 14995, 14997 Esperance; D 14996 St. Francis Island, South Australia. WAM 70.1088, 0·4 miles (0·65 km) north of Hampton Microwave Repeater Tower; GSWA F 6920 (1-3), 13 miles (21 km) northeast of Eyre.

Type locality: Esperance, Western Australia.

Material: 7 topotypes and 19 other specimens from localities in southwestern Australia and off Eyre Peninsula; 310 specimens from 16 localities in the Pleistocene of the Roe Plain.

Stratigraphical range: abundant in the Pleistocene of the Roe Plain, rare in Recent shallow water to 20 fathoms (37 m).

Geographical Distribution: In the Pleistocene of the Eucla Basin from 38 miles (61 km) east to 4 miles (6·5 km) southwest of Madura; Recent, Esperance, Cheyne Beach, and Duke of Orleans Bay in Western Australia; St. Francis Island in the Nuyts Archipelago, South Australia. Cotton (1932) recorded the species also from Thistle Island, Spencer Gulf, Sir Joseph Banks Island and Petrel Bay.

Diastoma provisi Tate.

PL. 1, FIGS. 8-11.

Diastoma provisi Tate, 1894: 177; pl. x, fig. 6; Ludbrook, 1957: 22 (in part), pl. 1, fig. 4 (synonymy); Ludbrook, 1969b: Fig. 96, 12.

Shell thick, solid and heavy, large and broad for the genus, protoconch of 2½ high, convex, smooth whorls, adult whorls 12 in a height of 46 mm, usually without varices, sculptured with fine somewhat sinuous oblique axial plicae, about 40 per whorl, crossed by from 5 in the early whorls to about 24 spiral lirae in the last whorl and base. Aperture oblique, loop-shaped; outer lip thin, incurved posteriorly, columellar lip calloused, the posterior callus thin, the anterior callus separated from the posterior by a thin sharp columellar fold, which is accentuated in the adult; basal lip reflected.

Dimensions: height 46, diameter 14 mm.

Types: holotype T 1541B and hypotypes T 1541 E.G on tablet T1541A-P all from Dry Creek Bore; GSSA M2727.

Type locality: Dry Creek Bore, sec. 980, hd. of Port Adelaide, 320-400 feet (97-121 m); Dry Creek Sands.

Material: 357 specimens from sludges from 6 bores in the Adelaide Plains Sub-Basin between Kooyonga Golf Links and Two Wells, drilled into the Dry Creek Sands. Moulds in limestone from the Pliocene of Wardang Island and Redbanks on the River Light, sec. 5, hd. Grace.

Stratigraphical range: Upper Pliocene of the Dry Creek Sands and Hallett Cove Sandstone and of Wardang Island, south tip.

D. provisi is a heavy thick shell with 40 axial plicae per whorl in contrast with about 30 in *D. melanioides* and from 15 to 20 in *D. adelaidense*. It is very rarely varicate.

Family **CERITHIIDAE**

Genus CAMPANILE Bayle *in* Fischer, 1884

A geographical and stratigraphical distribution map of *Campanile* was published by Wrigley (1940); its present distribution in Australian waters is shown on Figure 1.

Campanile symbolicum Iredale.

PL. 2, FIGS. 1-7.

Cerithium leve Quoy & Gaimard, 1834: 106, pl. 54, figs. 1-3 (non *Cerithium laevis* Perry, 1810).

Campanile symbolicum Iredale, 1917: 326, nom. nov. for *Cerithium leve* Quoy & Gaimard; Wrigley, 1940: 111; Cotton, 1950: 337; Hodgkin et al. 1966: 41, pl. 15, fig 6.

Shell large, thick, subulate, concave in profile, whorls numerous, about 30 in a height of 140 mm, flat except for slight constriction at the sutures; sutures imbricating; the first about 20 whorls sculptured with 2 spiral cords one at the abapical suture and a second immediately above it, below the adapical suture the whorl is weakly gemmulate; the spiral sculpture becomes obsolete in the adult whorls which are smooth except for sinuous axial growth striae faintly crossed by microscopic irregularly waving spiral striae; last whorl one-sixth height of shell, roundly angulate at the periphery, base moderately convex; aperture relatively low and narrow, about one-quarter of area of last whorl, subrectangular, slightly oblique, outer lip thin, columella concave, siphonal canal short, reflected, deep.

Dimensions: WAM 69.384 height (estimated) 140, diameter 47 mm. Recent and Pleistocene shells are as large as 200 mm high.

Types: holotype Mus. nat. Hist. Paris; hypotypes WAM 69.384, Pleistocene, 25 miles (40·25 km) east of Madura; WAM 61.54 (b) Pleistocene, 20 miles (32·2 km) east of Madura; GSSA M2564 Pleistocene, Madura Cave; M3231 Pleistocene, 0·4 miles

(0·6 km) north of Hampton Microwave Repeater Tower; M 3239, Recent, Israelite Bay; M 3240 Pleistocene, Madura Cave.

Type locality: King George Sound, Albany, Western Australia.

Material: 33 specimens from Rockingham, Geraldton, Israelite Bay, and other localities between Esperance and Geraldton; 55 specimens from 9 localities in the Pleistocene of the Eucla Basin.

Stratigraphical range: Pleistocene of the Roe Plain to Recent.

Geographical distribution: Pleistocene of the Roe Plain from 36 miles east of Madura to 4 miles (6·44 km) southwest of Madura; Recent, sublittoral, sandy bottoms, Recherche Archipelago to Geraldton (Hodgkin et al 1966).

Shell structure: Wrigley (1940, p. 99) described the unusual shell structure of *Campanile cornucopiae* (J. Sowerby) revealed by erosion of the shell: "On the inside there are two thick lamellar layers . . . next come two thinner compact layers and a thin outer layer of spongy substance. . . . The whole surface is pitted by minute holes arranged on incised lines." Fossil specimens of *C. symbolicum* and some Recent specimens have similar structures, shown on Plate 2, figures 1, 2, 6, 7. Erosion of the surface of GSSA M 3231 shows clearly a pitted layer and a thick cellular layer beneath it (Pl. 2, fig. 7). Unlike those attributed to *C. cornucopiae*, the pittings are for the most part irregular, although there are some on incised lines. The section through GSSA M 3240 (Pl. 2, fig. 6) shows the apparent cellular structure of the shell, but the fact that it extends to the columella and that the section through the Recent specimen GSSA M 3239 (Pl. 2, fig. 2) shows only partial boring, indicate that the cellular structure is not a primary feature but is produced by boring organisms. This type of boring is usually attributed to small sponges.

Campanile triseriale Basedow

PL. 3, FIGS. 1, 4.

Campanile triseriale Basedow, 1902: 130, pl. 2, fig. 1; Ludbrook, 1959: 231, pl. 5, figs. 2, 3, 4.

This species, with its three rows of spiral tubercles, is known only from the Upper Pliocene Hallett Cove Sandstone at Hallett Cove and O'Sullivan Beach and its equivalents at Edithburg and on section 140, hd. Moorowie, Yorke Peninsula, and the Dry Creek Sands of the Adelaide Plains Sub-Basin.

Campanile virginiense Ludbrook sp. nov.

PL. 3, FIGS. 2, 3.

Shell large, subulate, whorls numerous, estimated about 25 in a height of 150 mm, prominently sculptured with an adapical band of large tubercles, 20 per whorl, and an abapical band of small tubercles, about 26 per whorl, between and over which are numerous spiral threads, those on the adapical three-quarters of the whorl being regularly spiral and those on the abapical one-quarter undulating and interrupted by the axial growth striae; there is a conspicuous spiral striation separating the discrepant sculptures. Last whorl low, about one-fifth height of shell, aperture oblique, small, subrhomboid, outer lip thin, columella concave, thinly calloused with a fold at the base bordering the short deep siphonal canal.

Dimensions: holotype height (estimated) 156, diameter 47 mm; paratype GSSA M2013 indicates that the species must grow to a height of about 200 mm, diameter about 60 mm.

Types: holotype GSSA M 2360 Adelaide Plains Observation Bore A, Virginia; paratype GSSA M 2013, bore of F. Virgin, sec. 3224, hd. Munno Para, 238-350 feet (102-106 m).

Type locality: Adelaide Plains Observation Bore A, Virginia, sec. 3036, hd. Munno Para, 209-217 feet (63·3-65·8 m), Dry Creek Sands.

Distribution: Upper Pliocene of the Dry Creek Sands in the Virginia area.

C. virginiense is readily distinguished from *C. triseriale* by its one band of large and one band of small tubercles.

Campanile sp.

PL. 3, FIG. 5.

Casts and moulds of *Campanile* sp. in Nullarbor Limestone have been collected from railway ballast quarries on the Transcontinental Railway line at Watson, Naretha, Forrest and Loongana, and from GSWA localities 14265, Warbla Cave, and 12694C, "50-mile Claypan".

The "large species of *Cerithium* probably referable to the subgenus *Campanile* from Kadina, South Australia" (Harris 1897, p. 228) is probably the same species from the Melton Limestone.

The species attains the same height of 200 mm as *C. symbolicum*, but the shell itself is unknown.

Type: WAM 10448, Forrest, Western Australia, Nullarbor Limestone.

Genus THERICIUM Monterosato, 1890.

Subgenus THERICIUM s.str.

Thericium (Thericium) fallax (Ludbrook).

PL. 6, FIGS. 6, 7.

Terebralia fallax Ludbrook, 1941: 91, pl. 4, fig. 21.

Thericium (*Thericium*) *fallax* (Ludbrook), 1957: 28, pl. 1, fig. 5.

Only one species of the genus, with erect, angular plications and prominent spiral threads, occurs in the Cainozoic of southern Australia. It is known from some 88 specimens from 7 bores entering the Upper Pliocene Dry Creek Sands of the Adelaide Plains Sub-Basin.

Types: holotype AUGD T 1621, Abattoirs Bore; hypotypes AUGD F 15177 Pecze's Bore sec. 4251, hd. Munno Para, and GSSA M 2730, De Ruro Bore sec. 4259, hd. Munno Para.

Subgenus CHAVANICERITHIUM Ludbrook, 1957.

The subgenus, with type species *Terebralia adelaidensis* Howchin & Cotton, has a long range in the Cainozoic basins of southern Australia. The earliest representative is *Thericium* (*Chavanicerithium*) *pritchardi* (Harris) from the Lower Miocene (Longfordian) of Table Cape, Tasmania, and the latest are the two new species *T.* (*C.*) *darraghi* and *T.* (*C.*) *westraliense* Ludbrook from the Pleistocene of the Roe Plain. The affinities of *T.* (*C.*) *pritchardi* with the European Eocene *Cerithium* (*Vulgocerithium*) *semicostatum* Deshayes were noted by Harris (1897, p. 224); *Vulgocerithium* is a synonym of *Thericium*. The diagnostic features distinguishing *Chavanicerithium* from *Thericium* s.str. have been described (Ludbrook 1957, p. 30).

Thericium (Chavanicerithium) adelaidense (Howchin & Cotton).

PL. 4, FIGS. 7, 8.

Cerithium sp. Howchin, 1935: 90.

Terebralia adelaidensis Howchin & Cotton, 1936: 31, pl. 1, figs. 1, 2; Ludbrook, 1941: 100.

Campanile adelaidensis Howchin & Cotton; Cotton, 1952: 245.

Thericium (*Chavanicerithium*) *adelaidense* (Howchin & Cotton); Ludbrook, 1957: 29, pl. 1, fig. 3.

The species, restricted to the Upper Pliocene Dry Creek Sands of the Adelaide Plains Sub-Basin, is known from 22 specimens from 10 borings between the western suburbs of Adelaide and Salisbury. It has been fully described previously.

Types: holotype, SAM D 12852, Glanville Bore, 375-400 feet (113-121 m); hypotypes AUGD F 15178, Hindmarsh Bore, 450-485 feet (136·5-147 m); GSSA M 765A Cowandilla Bore, 485-507 feet (147-154 m); M 643 Kooyonga Bore 1932, 491-501 feet (149-152 m).

Thericium (Chavanicerithium) darraghi Ludbrook sp. nov.

PL. 5, FIGS. 7, 8.

Shell of moderate size, solid, elongate-conical, apical angle 17°, profile slightly convex, protoconch high, apparently of 3 turns, adult whorls 12 in a height of 53 mm, whorls convex, sculptured with slightly curved axial ribs increasing in number from 15 on the early whorls to 21 on the penultimate whorl, crossed by spiral threads of which there are 5 on the early whorls, the adapical 2 being finer and set in a constricted band below the suture, the abapical three producing weak tubercles on the axial ribs; finer secondary threads develop between the primary threads on succeeding whorls. Last whorl about two-fifths height of shell, base convex with about 5 irregularly spaced striae.

Aperture oblique, subovate, with a conspicuous parietal ridge on the parietal lip and a well-marked adapical channel, columellar lip smooth, outer lip thickened, siphonal canal deep.

Dimensions: WAM 69.457 height (estimated) 53, diameter 18 mm.

Types: holotype WAM 69.457.

Type locality: 0·4 miles (0·64 km) north of Hampton Microwave Repeater Tower, 33 miles (53 km) east of Madura, Western Australia.

Material: the holotype and 16 other specimens from the type locality and from Nurina and Madura Caves.

Stratigraphical range: Pleistocene of the Roe Plain, Eucla Basin.

Compared with *T.* (*C.*) *westraliense* this is a less attenuated shell with convex whorls, the axial ribs are stronger and fewer than those of *westraliense*; the spiral threads are fewer and not separated by incised striae on the later whorls.

Thericium (Chavanicerithium) flemingtonense (McCoy).

PL. 4, FIGS. 5, 6, 9, 10.

Cerithium flemingtonensis McCoy, 1876: 28, pl. XXVI, figs. 3-9.

Cerithium flemingtonense McCoy; Harris, 1897: 226; Gill & Baker, 1955: 40, pl. 1, figs. 3, 4.

Shell large, elongate-conical, spire angle about 25°, whorls about 15 in a height of 85 mm, flat, constricted just above the middle, sculptured with from 12 to 20 slightly sigmoidal primary axial ribs, more numerous on the early whorls, prominent in the abapical part of the whorl and abruptly cut off or rendered obsolete at the adapical constriction; between the primary ribs and continuing to the adapical suture there are numerous fine sigmoidal axial growth folds and on the early whorls an occasional varix; axial sculpture crossed by numerous spiral striae. Base convex with from 5 to 10 unequal spiral lirae. Aperture oval, columella concave, parietal lip with a parietal ridge, siphonal canal short.

Dimensions: height (estimated) 87, diameter 31 mm.

Types: syntypes NMV P 12141 A, B (figs. 3, 5), P 12142 (fig. 7), P 12146 (fig. 9), P 12145 (fig. 6); hypotypes NMV P 16831 (figured Gill & Baker, 1955); P. 27981-4; GSSA M 3234.

Type locality: Flemington, Melbourne, Newport Formation.

Material: 5 latex casts from the Newport Formation at Flemington and West Essendon (Aberfeldie); 3 latex casts from Melton Limestone, old flux quarry, Wallaroo.

Stratigraphical range: Lower to Middle Miocene of the Newport Formation, Melbourne District, Victoria, and youngest member of the Melton Limestone of northern Yorke Peninsula, South Australia.

Thericium (Chavanicerithium) pritchardi (Harris).

PL. 4, FIGS. 1-4.

Potamides semicostatum Tate, 1885: 226, non *Cerithium semicostatum* Deshayes; Pritchard, 1896: 116.

Cerithium pritchardi Harris, 1897: 225, pl. 7, fig. 3 (nom. nov. for *Potamides semicostatum* Tate non *Cerithium semicostatum* Deshayes).

Thericium (*Chavanicerithium*) *pritchardi* (Harris); Ludbrook, 1957: 30; Ludbrook, 1967b: 67, pl. 4, fig. 15.

(Description slightly modified from Harris, 1897.) Shell large, solid, elongate-conical, tapering, of 12 slightly convex to flat whorls much widened abapically; suture undulating, slightly incised; sculptured with strong, distant, elevated, rather oblique obtuse costae extending over the abapical half of the whorls only, 10 to 11 on the penultimate whorl, the whole surface of the whorls covered by close, irregular, spiral striations, interrupted by very fine growth corrugations which in the adult whorls may border the adapical sutures as fine obsolete tubercles; last whorl with a large variciform swelling.

Aperture oblique, ovate, columella concave, columellar lip thick, narrow, reflected over the columella, outer lip expanded, slightly thickened, a conspicuous parietal ridge and narrow deep adapical channel, siphonal canal deep, strongly reflected.

Dimensions: height 110, diameter 33 mm; AUGD F 15482 from the Bookpurnong Beds has an estimated height of 120 mm.

Types: holotype, Tasmanian Museum, Hobart, B 83; hypotypes British Museum (Natural History) G 9491, AUGD T 356, F 15482, F 15488.

Type locality: Table Cape, Tasmania; Table Cape Group, Freestone Cove Sandstone, Longfordian, Lower Miocene.

Material: 10 topotypes; one specimen from Bookpurnong Beds, AUGD F 15482.

Stratigraphical range: Lower Miocene (Longfordian) of Table Cape to Lower Pliocene (? Upper Miocene) of the Bookpurnong Beds.

Thericium (Chavanicerithium) tatei Ludbrook sp. nov.

PL. 5, FIGS. 3, 4.

Thericium (*Chavanicerithium*) *torri* Ludbrook, 1957: 30 (in part), pl. 1, figs. 1, 2 (not of Tate, 1899); 1969b: fig. 96, 13.

Shell of moderate size for the genus, solid, elongate-conical, whorls slightly convex, constricted in the adapical one-third, sutures imbricating; sculptured with from 11 to 15 oblique and slightly curved axial ribs per whorl: in the early whorls the ribs are uninterrupted but in the middle whorls are first interrupted by the adapical constriction and in the last 3 whorls are broken into three or four rows of tubercles; the whole surface is microscopically spirally lirate in the early whorls but the lirae weaken and are replaced by faint spiral striae and numerous microscopic axial growth striae in the later whorls; early whorls usually variceate, a large variciform swelling in the last whorl; base short, convex, spirally lirate. Aperture oval, columella concave, columellar lip calloused and reflected over the columella with a well-marked parietal ridge and adapical channel; siphonal canal short, reflected.

Dimensions: height 80, diameter 21 mm.

Types: holotype GSSA M 3224, hypotypes AUGD F 15175, F 15176.

Type locality: Adelaide Plains Observation Bore A, Virginia, sec. 3036, hd. Munno Para, 209-217 feet (63·3-65·8 m), Dry Creek Sands, Upper Pliocene.

Material: 90 specimens from 14 borings entering the Dry Creek Sands of the Adelaide Plains Sub-Basin.

Stratigraphical range: Upper Pliocene of the Dry Creek Sands.

T. (C.) tatei is a smaller shell with fewer axial ribs than *T. (C.) torri.*

Thericium (Chavanicerithium) torri (Tate).

PL. 5, FIGS. 1, 2.

Cerithium torri Tate, 1899: 109, pl. 1, fig. 2 (not *Thericium (Chavanicerithium) torri* Ludbrook, 1957: 30, pl. 1, figs. 1, 2; 1969b: Fig. 96, 13).

Shell large, solid, elongate-conical, whorls flat, sculptured with 25 moderately sigmoidal axial costae interrupted by a constriction in the adapical one-third of the whorl; in later whorls the costae tend to become nodulose in as many as 3 spiral bands, the whole surface finely sculptured by microscopic spiral striae and axial growth striae; suture imbricating. Aperture oval, not completely known as the outer lip is broken in the two specimens, columella concave, a weak parietal ridge and an adapical channel; siphonal canal short, reflected.

Dimensions: holotype height (estimated) 120, diameter 31 mm; paratype height (estimated) 140, diameter 31 mm.

Types: holotype AUGD T 1618, paratype AUGD T 832.

Type locality: "River Murray Desert", i.e. Bookpurnong Beds, probably from boring at Mindarie, South Australia. In the table (1899, p. 104), Tate records both *C. torri* and *C. pritchardi* from Tareena, New South Wales. Since the tablets T 832 and F 15482 on which these are mounted are similar and the age of both given as Eocene? it may be assumed that T 832 came from Tareena. T 1618 is differently mounted and the age given as Post-Eocene: it may be assumed that the holotype T 1618 is from Mindarie.

Material: the holotype and paratype only, both from borings in the Murray Basin penetrating the Bookpurnong Beds, the characteristic lithology of which is confirmed by matrix in the apertures of the two specimens.

Stratigraphical range: Lower Pliocene (?Upper Miocene) of the Bookpurnong Beds, Murray Basin.

Thericium (Chavanicerithium) westraliense Ludbrook sp. nov.

PL. 5, FIGS. 5, 6.

Shell of moderate size, but rather small for the genus, solid, elongate-conical, apical angle 15°, with 15 adult whorls in a height of 71 mm, early whorls convex, later whorls flat to slightly convex, sculptured in the early whorls with about 10 axial ribs on the abapical part, which become weaker and more numerous in the later whorls; the axial ribbing is discrepant between the adapical and abapical parts of the whorl, in the earlier adult whorls the ribs are more numerous in a constricted band about one-quarter the width of the whorl immediately below the suture; in the later whorls additional ribs rise in the abapical one-third between the primary ribs which become more oblique and sinuous, about 30 on the penultimate whorl, crossed by spiral threads which are convex in the early whorls and flat in the later whorls, separated by linear striae; the axial ribs produce slight undulations on the linear sutures.

Aperture oblique, subovate, with a conspicuous parietal ridge on the parietal lip and a well-marked adapical channel; columellar lip smooth, outer lip thickened, siphonal canal deep, strongly reflected.

Dimensions: height 71, diameter 18 mm.

Types: holotype WAM 70.14.

Type locality: Hampton Microwave Repeater Tower, 33 miles (53 km) east of Madura, Western Australia, Roe Plain, Pleistocene.

Material: holotype and 7 topotypes; 1 specimen from Nurina Cave, surface.

Stratigraphical range: Pleistocene of the Roe Plain.

Thericium (Chavanicerithium) wynyardense (Tate).

PL. 6, FIGS. 8, 11.

Potamides pyramidale Tate, 1885: 226.

Potamides wynyardense Tate, 1896: 135, nom. nov. for "*P. pyramidale* Tate non ——".

Shell large, biconical, broad, with an apical angle of 30° to 40°, whorls flat, about 10 in a height of 95 mm, last whorl half height of shell, sculptured with from 10 to 12 large nodular axial ribs on the abapical part of each whorl, weak or absent on the adapical part; and about 10 fine spiral threads per whorl, about 16 over the last whorl and convex base; last whorl with a large variciform swelling above the columella. Shape of the aperture and outer lip not known from the material available; columella concave, columellar lip thickened and reflected over the columella; a parietal ridge on the parietal lip and a small adapical channel.

Dimensions: height 95, diameter 53 mm.

Types: holotype missing; hypotypes AUGD F 15483, F 15484.

Type locality: Table Cape, Tasmania; Table Cape Group, Freestone Cove Sandstone, Longfordian, Lower Miocene.

Material: the two hypotypes only. Tate Collection.

Stratigraphical range: Lower Miocene (Longfordian) of Table Cape.

The nomenclature of this species is doubtful in all respects. Describing it originally as *Potamides pyramidale*, Tate (1896) changed the name to *P. wynyardense* because the name was preoccupied by an unnamed author. Careful search has so far failed to locate the prior *P. pyramidale*, but Tate's substitute name is tentatively accepted. The generic and subgeneric location of the broadly biconical species is also in doubt, but the available material is too poor and scarce for a firm opinion to be formed. The species has some features in common with the New Zealand Upper Eocene genus *Speightia* Finlay, but there appears to be no evidence of the sinus on the shoulder slope linking the Speightiidae with the Turridae. The apertural features and the variciform swelling on the last whorl link it with the Tertiary cerithiids.

Genus JETWOODSIA Ludbrook, gen. nov.

Type species—*Cerithium apheles* Tenison Woods

Generic characters: shell turreted or subulate, with a high polystrophic protoconch and numerous whorls which are slightly convex at first but become gradually more convex; axial sculpture dominant, of curved oblique ribs crossed by fine spiral striae, more prominent in the early whorls and tending to become obsolete in the later. Last whorl with a prominent variciform swelling. Aperture ovate, columellar lip thick and reflected over the columella, a conspicuous parietal ridge and short adapical channel, siphonal canal short, reflected.

The genus is named for the Reverend Father J. E. Tenison Woods, a pioneer of southern Australian geology and palaeontology, who described the species. It seems to have been relatively short lived, first appearing in the Upper Eocene and dying out in the Middle Miocene (Balcombian).

Jetwoodsia apheles (Tenison Woods).

PL. 6, FIGS. 1-3.

Cerithium apheles Tenison Woods, 1879: 232, pl. XX, fig. 15; Harris, 1897: 224, pl. VII, figs. 1, 2.

Shell fairly large, subulate, with about 24 whorls in a height of 118 mm; first whorls nearly flat, then becoming convex, protoconch of 4 smooth whorls with an erect tip; the first 6 to 8 whorls are sculptured with about 20 axial ribs crossed by 12 fine spiral striae, in the next about 6 whorls the axials weaken or become obsolete, but in the adult stage the axials become fewer and more prominent on the convex whorls where they are usually restricted to the median part of the whorl; both adapically and abapically the whorls are constricted; the early whorls are more or less varicate, the adult costate whorls rarely so except for the last whorl on which there is a large variciform swelling; base convex, last whorl and base with 6 spiral lirae.

Aperture ovate, columella slightly concave, columellar lip thick and reflected over the columella, a conspicuous parietal ridge and short adapical channel, outer lip expanded, slightly thickened, siphonal canal short, reflected.

Dimensions: height 118, height of last whorl 26, diameter 23 mm.

Types: holotype Australian Museum F 1704; hypotypes British Museum (N.H.) G 4154, AUGD F 15485, F 15489, F 15490.

Type locality: Muddy Creek, Hamilton, Victoria; Muddy Creek Marl, Miocene (Balcombian).

Material: 19 topotypes, 3 specimens from the Balcombe Clay, Fossil Beach and Schnapper Point, 7 from Gellibrand Marl, Gellibrand River, Victoria.

Stratigraphical range: Middle Miocene (Balcombian) of the Otway Basin and Port Phillip Sunkland (Melbourne Basin).

Jetwoodsia nullarborica (Chapman & Crespin)

PL. 6, FIGS. 4, 5.

Cerithium nullarboricum Tate, 1879b: 107, nom. nud.

Pyrazus aldingense Tate & Dennant, 1896: 127, nom. nud.

Potamides nullarboricum Chapman & Crespin, 1934: 123, pl. XI, figs. 31-33.

Shell rather small, thin, turreted, with a high protoconch of three smooth turns and 15 adult whorls sculptured with narrow slightly oblique curved axial ribs, from 13 to 15 per whorl, and fine microscopic spiral striae and axial growth striae; suture undulating, incised, last whorl with a large variciform swelling, earlier whorls with an occasional varix; base convex to flatly oblique, spirally microscopically lirate.

Aperture obscured or broken in all available specimens, columella concave, columellar lip calloused and reflected over the columella, with a parietal ridge, outer lip expanded.

Dimensions: height (estimated) 43, diameter 13 mm.

Types: holotype Dennant Collection, National Museum of Victoria, 13674, paratype 13675; hypotypes GSSA M 3237, M 3238.

Type locality: Blanche Point, Aldinga Bay, South Australia; Blanche Point Marls, Upper Eocene.

Material: 24 topotypes, 1 specimen Kent Town ("Adelaide") Bore.

Stratigraphical range: Upper Eocene (Aldingan) Blanche Point Marls of the St. Vincent Basin and Plantagenet Beds of southwestern Australia.

Nomenclature: Chapman & Crespin (1934, p. 123) named the species from a Tate manuscript name in the Dennant Collection. The manuscript name *Pyrazus aldingense* given to the species in the Tate Collection, University of Adelaide, was published in Tate and Dennant's list (1896) of the Eocene fossils from Aldinga and Adelaide.

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EXPLANATION OF PLATES

PLATE 1

All figures X 1

1, 2. *Diastoma costellatum* (Lamarck). AUGD F 15487, Middle Eocene, Lutetian, Chaussy.

3-7. *Diastoma adelaidense* Ludbrook. 3, 4. GSSA M 609A, holotype; Upper Pliocene, Dry Creek Sands, sec. 353, hd. Yatala, 420-499 feet (127-151 m); 5, 6. WAM 69.487, paratype, Pleistocene of the Roe Plain, Hampton Microwave Repeater Tower; 7, paratype, GSSA M 611, Kooyonga Golf Club Bore 1932.

8-11. *Diastoma provisi* Tate. 8. AUGD T 1541B, Upper Pliocene, Dry Creek Sands, Dry Creek Bore, sec. 980, hd. Port Adelaide, 320-400 feet (97-121 m); 9. AUGD T 1541G, hypotype from type series; 10. AUGD T 1541E hypotype from type series; 11, GSSA M 2727, hypotype, Upper Pliocene, Dry Creek Sands, Kooyonga Golf Club Bore 4, sec. 2028, hd. Adelaide, 500 feet (152 m).

12-16. *Diastoma melanioides* (Reeve). Pleistocene of the Roe Plain; 12. GSWA F 6920(2); 13. GSWA F 6920 (1). 14. WAM 70. 1088, 0·4 miles (0·65 km) north of Hampton Microwave Repeater Tower; 15, GSWA F 6920 (1); 16, GSWA F 6920 (3) locality 5439, 13 miles (21 km) NE of Eyre.

17-21. *Diastoma melanioides* (Reeve). Recent; 17-20 from type locality Esperance; 17, SAM D 14997; 18. D 14994, with broken aperture; 19. WAM 70.1145 a; 20, SAM D 14995; 21. SAM D 14996 St. Francis Island, South Australia.

PLATE 2

All figures X 2/3

1-7. *Campanile symbolicum* Iredale. 1-2, Recent GSSA M 3239, dead specimen. Israelite Bay, 1, showing surface pattern of borings; 2, axial section, only one side of shell is extensively bored, presumably where it has been lying in the substratum; 3-7, Pleistocene of the Roe Plain; 3, WAM 69.384, 25 miles (40 km) east of Madura; 4, 61.54 B, juvenile showing sculpture on early whorls, 20 miles (32 km) east of Madura; 5, GSSA M 2564, Madura Cave, intermediate between *C. triseriale* Basedow and *C. symbolicum* in its retention of 3 faint spiral ribs on the whorls; 6, GSSA M 3240, axial section showing shell and part of the columella extensively bored and giving the appearance of primary shell structure, Madura Cave; 7, GSSA M 3231 showing surface pitting and cellular under layer due to extensive boring, 0·4 miles (0·65 km) north of Hampton Microwave Repeater Tower.

PLATE 3

Figures 1-4, X 1, figure 5, X 0.5

1, 4 *Campanile triseriale* Basedow, Upper Pliocene, Hallett Cove Sandstone: 1, AUGD F 15480 Edithburg, topotype: 4, AUGD F 15481 Hallett Cove.

2, 3. *Campanile virginiense* Ludbrook, Upper Pliocene, Dry Creek Sands; 2, GSSA M 2360, holotype, Observation Bore A, Virginia, sec. 3036, hd. Munno Para, 209-217 feet (63·3-65·8 m); 3, GSSA M 2013, paratype, F. Virgin Bore, Sec. 3224, hd. Munno Para, 338-350 feet (102-106 m).

5. *Campanile* sp. Lower Miocene, Nullarbor Limestone, WAM 10448, Forrest, Western Australia. Western Australian Museum photo.

PLATE 4

All figures X 1

1-4. *Thericium (Chavanicerithium) pritchardi* (Harris); 1-3, from type locality, Table Cape Tasmania, Table Cape Group, Freestone Cove Sandstone, Longfordian, Lower Miocene; 1, AUGD T 356; 2, 3, AUGD F 15488; 4. AUGD F 15482, from "Murray Desert", i.e. Bookpurnong Beds, Lower Pliocene (? Upper Miocene), boring at Tareena, New South Wales.

5-6, 9-10. *Thericium (Chavanicerithium) flemingtonense* (McCoy), all latex casts; 5-6, 10, from Newport Formation, ? Balcombian, Middle Miocene; 5, NMV P 27981, Flemington; 6, NMV P 16381, West Essendon, figd. Gill & Baker, 1955; 10, NMV P 27984 West Essendon; 9, GSSA M 3234 upper part of Melton Limestone, old flux quarry, Wallaroo, South Australia.

7-8. *Thericium (Chavanicerithium) adelaidense* (Howchin & Cotton), Upper Pliocene, Dry Creek Sands; 7, GSSA M 765A, Cowandilla Bore, sec. 92, hd. Adelaide, 485-507 feet (147-154 m); 8, GSSA M 643, Kooyonga Bore 1932, sec. 2028, hd. Adelaide, 491-501 feet (149-152 m).

PLATE 5

All figures X 1

1, 2. *Thericium* (*Chavaniceritliium*) *torri* (Tate), "Murray Desert", i.e. Bookpurnong Beds, Lower Pliocene (? Upper Miocene); 1, AUGD T 1618, holotype, Boring at ? Mindarie, South Australia; 2, AUGD T 832, paratype, boring at ? Tareena, New South Wales.

3, 4. *Thericium* (*Chavaniceritliium*) *tatei* Ludbrook. Upper Pliocene, Dry Creek Sands; 3, GSSA M 3224, holotype, Observation Bore A, Virginia, sec. 3036, hd. Munno Para, 209-217 feet (63·3-65·8 m); 4, AUGD F 15486, paratype, A. H. Kinnish, Direk, Bore 2, sec. 3076, hd. Munno Para, 265 feet (80 m).

5, 6. *Thericium* (*Chavaniceritliium*) *westraliense* Ludbrook, Pleistocene of the Roe Plain; 5, WAM 70.14, holotype, Hampton Microwave Repeater Tower; 6, WAM 70.1133 paratype, same locality.

7, 8. *Thericium* (*Chavaniceritliium*) *darraghi* Ludbrook, Pleistocene of the Roe Plain; WAM 69.547, 0·4 miles (0·65 km) north of Hampton Microwave Repeater Tower.

9. *Thericium* (*Chavaniceritliium*) sp.cf. *T.* (*C.*) *darraghi* Ludbrook, Pleistocene of the Roe Plain, WAM 69.483, Hampton Microwave Repeater Tower.

PLATE 6

All figures X 1

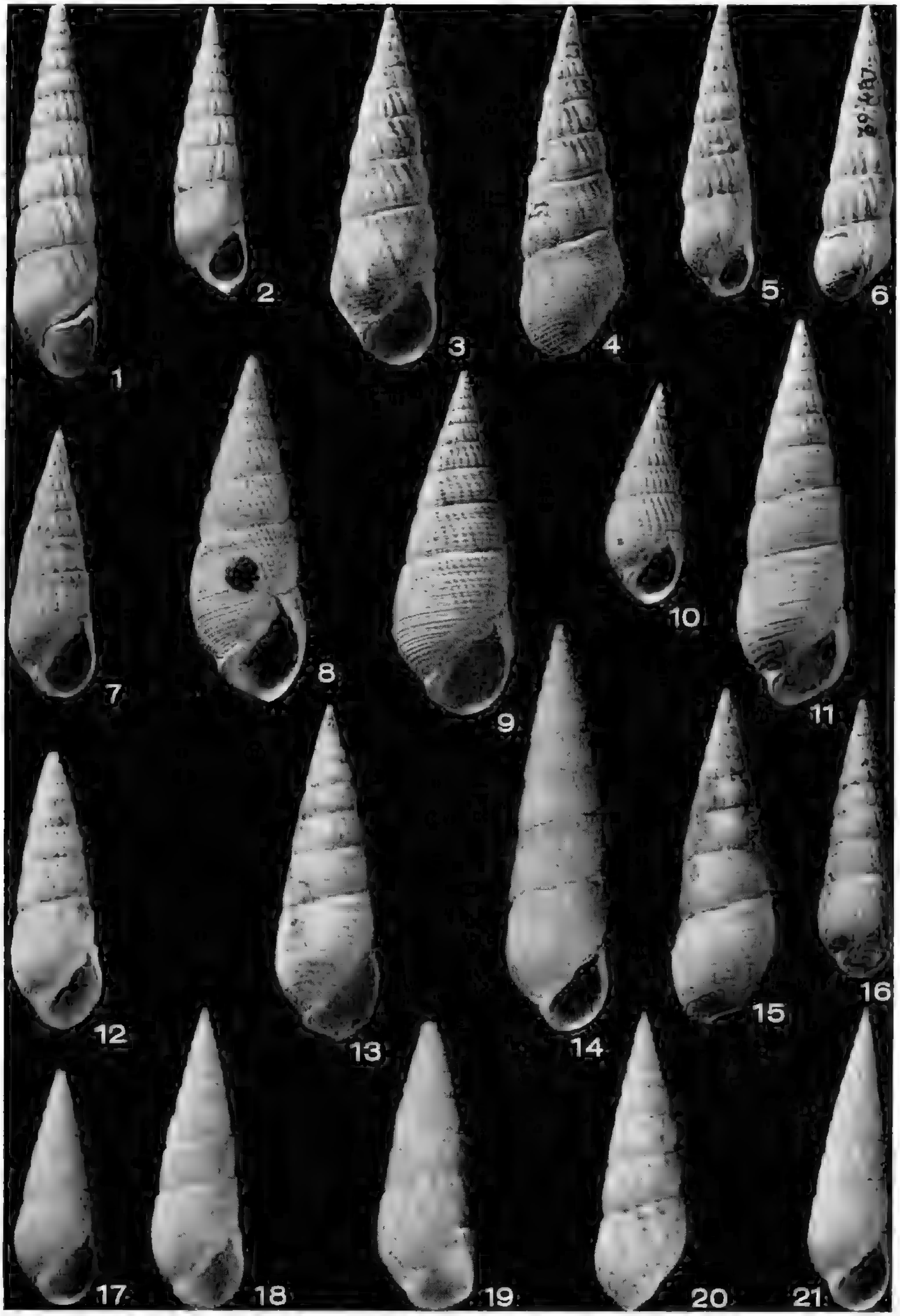
1-3. *Jetwoodsia apheles* (Tenison Woods), Balcombian, Middle Miocene, Victoria; 1, AUGD F 15485, Balcombe Clay, Fossil Beach, Mornington; 2 AUGD F 15489, Muddy Creek Marl, Muddy Creek, Hamilton, juvenile, close to holotype; 3, AUGD F 15490 Muddy Creek Marl, showing varicate early whorls and development of sculpture.

4, 5. *Jetwoodsia nullarborica* (Chapman & Crespin), Aldingan, Upper Eocene, Blanche Point Marls, Blanche Point, Aldinga Bay; 4, GSSA M 3238; 5, GSSA M 3237.

6, 7. *Thericium* (*Thericium*) *fallax* Ludbrook, Upper Pliocene, Dry Creek Sands, GSSA M 2730, De Ruro Bore, Waterloo Corner, sec. 4259, hd. Munno Para, 240-245 feet (72·8-74·3 m).

8, 11. "*Thericium* (*Chavaniceritliium*) *wynyardense*" (Tate); Longfordian, Lower Miocene, Table Cape Group, Freestone Cove Sandstone, Table Cape, Tasmania; 8, AUGD F 15484 juvenile; 11, AUGD F 15483.

9, 10. *Diastoma adelaidense* Ludbrook; Lower to Middle Miocene, upper part of Melton Limestone, Wallaroo, latex casts; 9, GSSA M 3241; 10, GSSA M 3242.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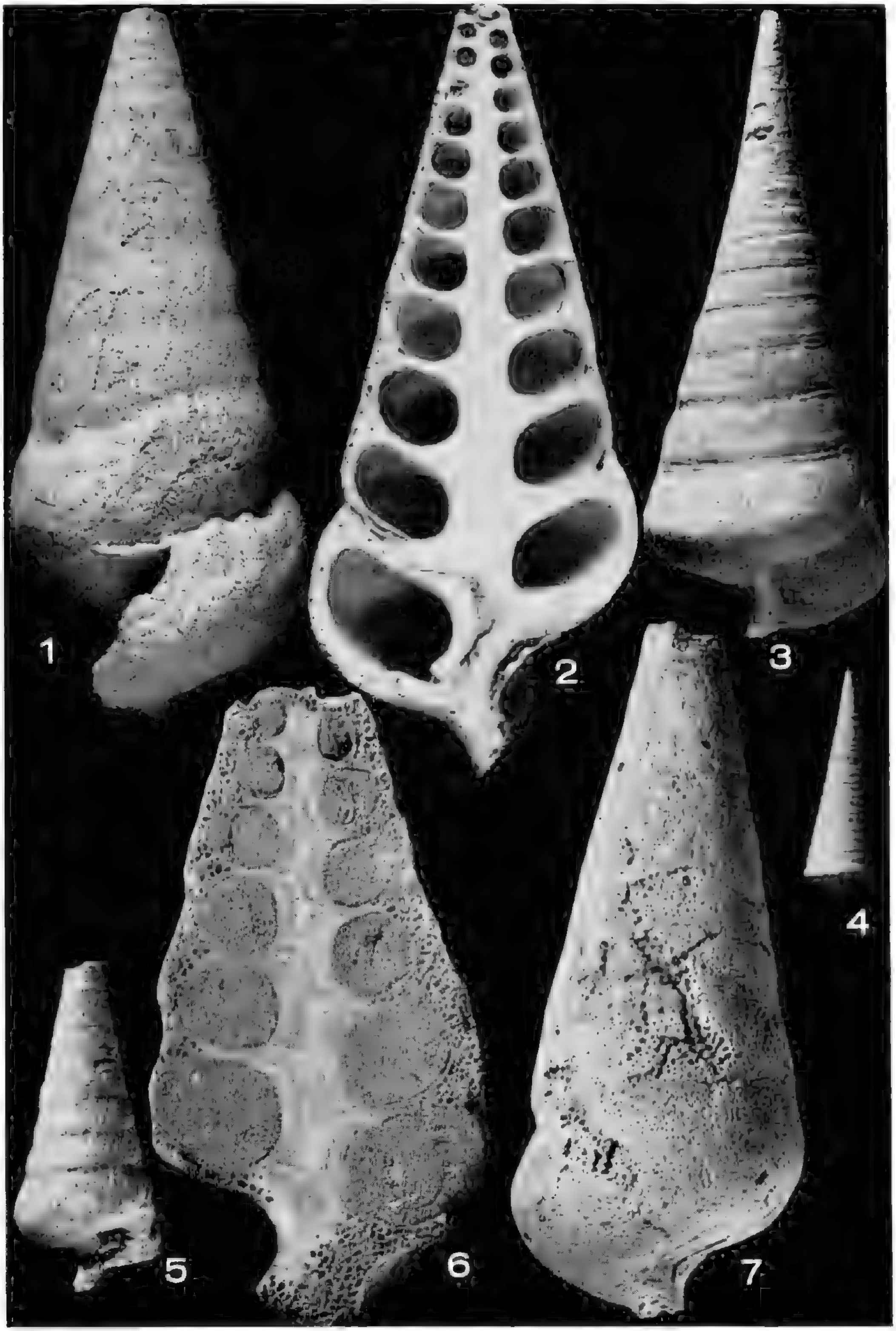
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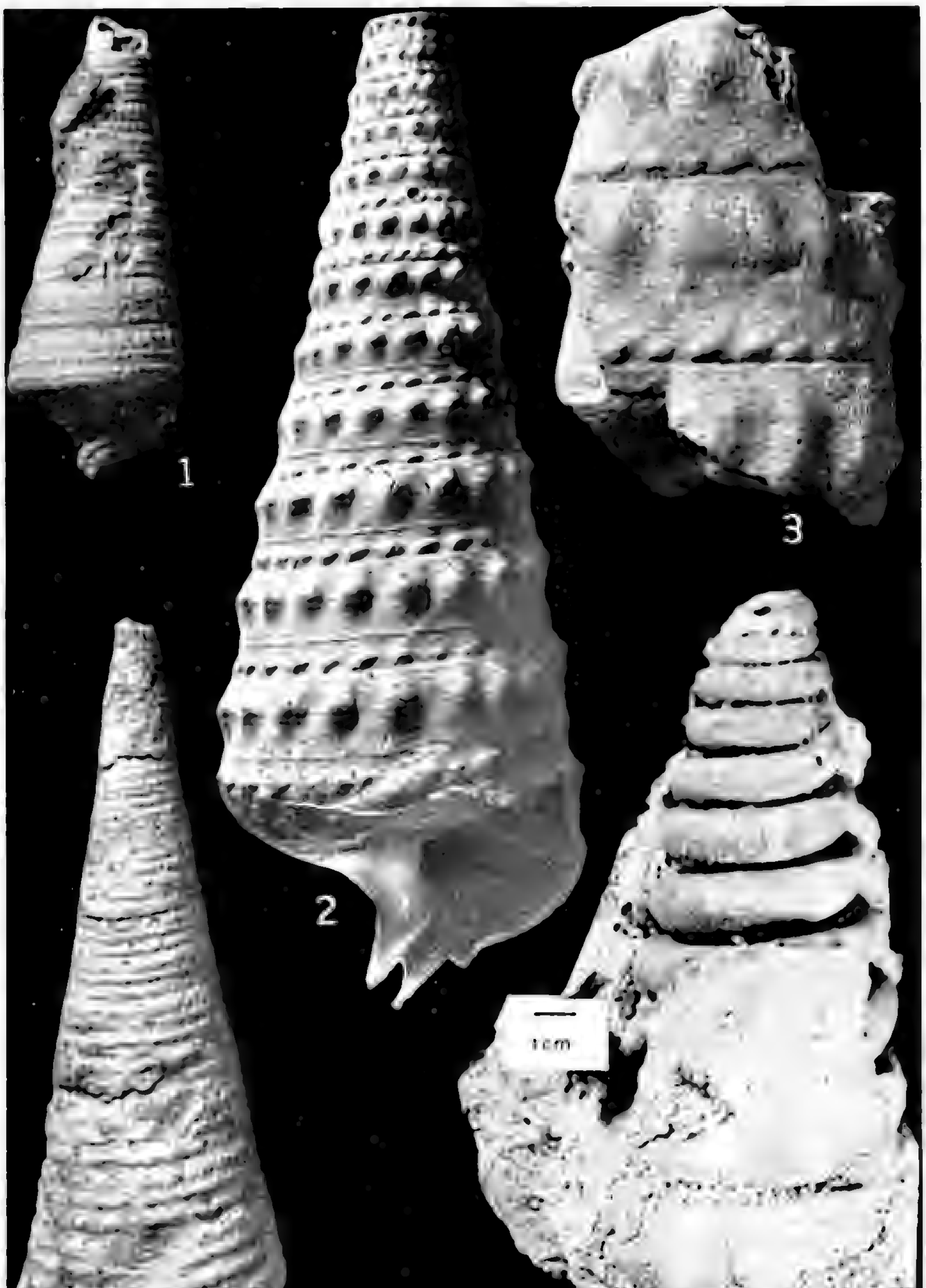
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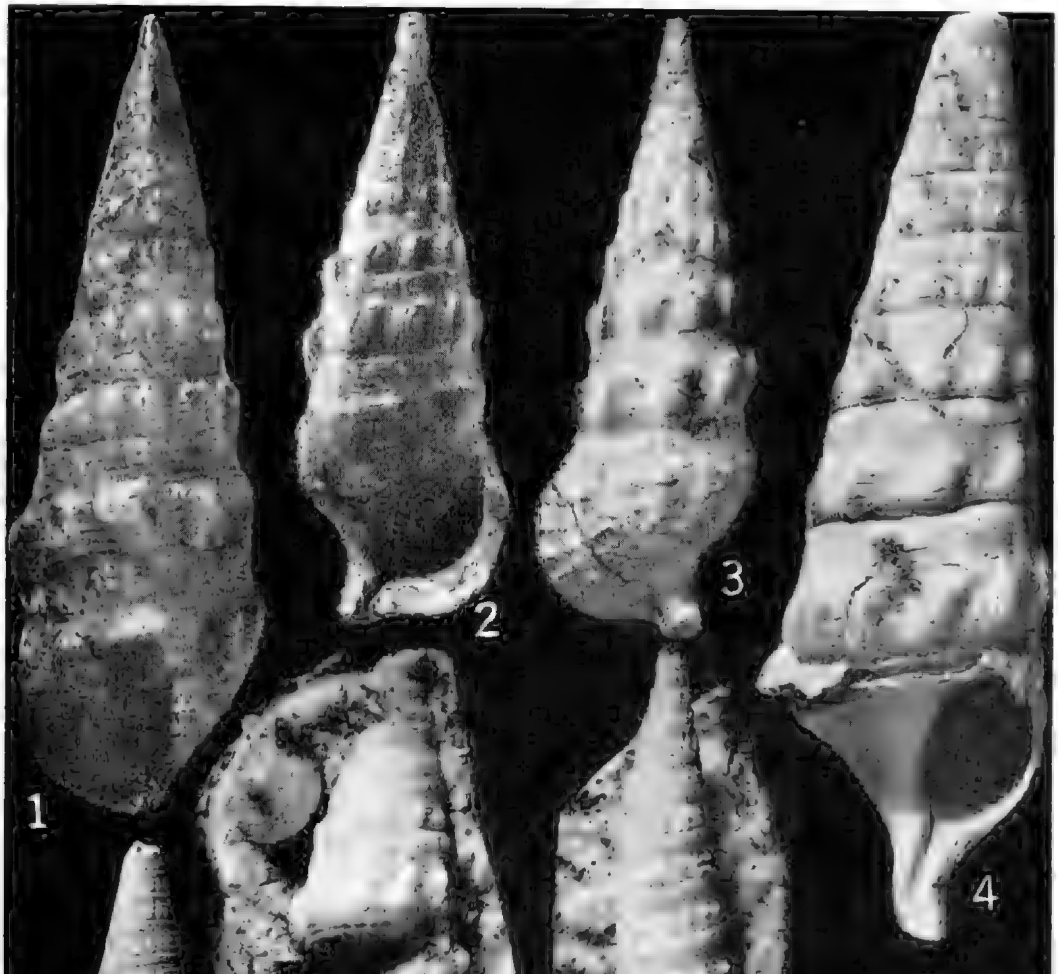
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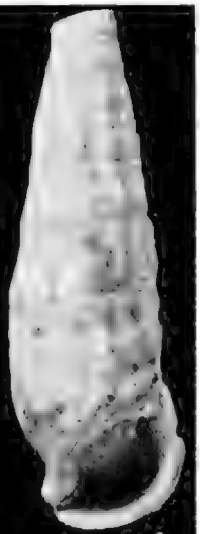

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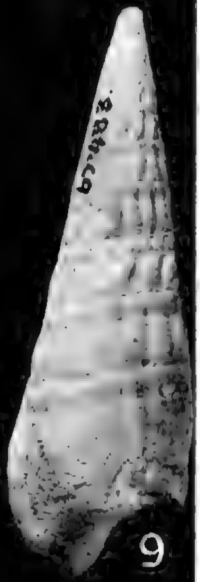

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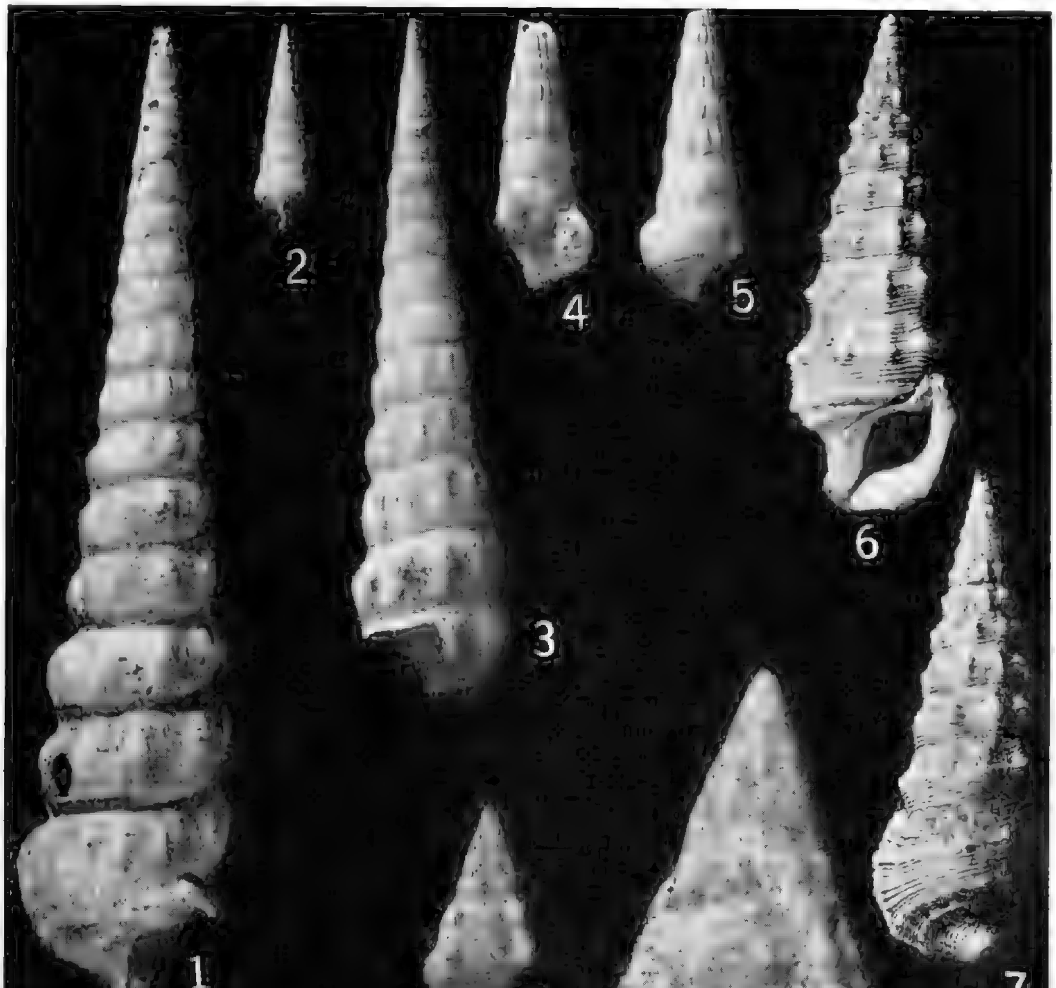
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VOLUNTARY CONTROL OF THE SHAPE OF THE INFLATED VOCAL SAC BY THE AUSTRALIAN LEPTODACTYLID FROG LIMNODYNASTES TASMANIENSIS

by M. J. TYLER*

Summary

Individuals of the Australian leptodactylid frog *Limnodynastes tasmaniensis* were observed to voluntarily modify the shape and position of the inflated vocal sac structure. A study of the anatomy of superficial mandibular features was correlated with profile sketches of the positions occupied by the inflated vocal sac structure. In the absence of audibly detectable differences in mating calls emitted from partially or completely inflated vocal sacs, it was concluded that neither shape nor position of the vocal sac structure influence call composition.

Introduction

The sounds produced by male frogs to advertise their territorial inclinations or sexual aspirations have been the subject of study by many workers. Recognition of the specificity of mating calls has resulted in numerous analyses of the calls, and of their role in pre-mating isolating mechanisms. In contrast, data on the actual mechanics of sound production, and particularly of the role of the inflated vocal sac are insufficient to substantiate some widely accepted assumptions.

It may be inferred from the behaviour of species lacking vocal sacs that such structures amplify sounds produced in the larynx. For example, Moore (1961) noted that such a species, *Litoria* (*Hyla*) *lesueuri*, had "a peculiar soft call that I found difficult to detect beyond ten feet". Whether the vocal sac contributes to detectable call parameters (spectral composition) is uncertain, although in *Rana catesbiana*, Capranica (1965) concluded that variation in capacity did not.

One would expect differences in the gross morphology of the sac, and particularly its shape and position in relation to the larynx, to influence call structure. Whether this is in fact the case remains uncertain.

In the course of studies on the morphology and function of anuran vocal sac structures, some individuals of the Australian leptodactylid frog *Limnodynastes tasmaniensis* were observed to be capable of voluntarily modifying both the shape and position of the inflated vocal sac structure. Comparable observations have not been reported on any other anuran species. The modification could be distinguished from partial inflation of the entire structure, and indicated the existence of a refined mechanism of control of the muscles or skin underlying the vocal sac.

Detailed attention was therefore paid to *L. tasmaniensis* to establish the morphology of the submandibular region, the positions of submandibular structures during vocal sac distension, the mechanism by which changes in the shape and position of the inflated vocal sac structures are effected, and the influence of shape and position of the vocal sac structure on the emitted call.

Material and Methods

Over a period of several years observations were made on *Limnodynastes tasmaniensis* calling in static or very slowly running water, in the vicinity of Adelaide and the adjacent Mt. Lofty Ranges. Specimens in breeding condition were transferred to vivaria in the laboratory in early August 1969 where they continued to call during the daytime.

Profile drawings were prepared of specimens observed to exhibit the control of the vocal sac structure described in this paper. The same specimens were then killed in a 5% solution of urethane, fixed in 60% alcohol, and the position of the superficial mandibular muscles and of the vocal sac subsequently determined by dissection with the aid of a low-power binocular microscope.

"Vocal sac" is here used to refer to the inflatable diverticula intruding between the superficial ventral mandibular muscles, and the deeper musculature of the tongue and hyoid apparatus. The vocal sac together with the Musculus intermandibularis, M. inter-

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hyoideus and the skin ventral to these muscles are collectively referred to as the "vocal sac structure".

Morphology of the Vocal Sac Structure

A description of anuran vocal sac structure has been presented elsewhere (Tyler, 1971). The musculature of *L. tasmaniensis* is atypical in that the most anterior fibres of the intermandibularis do not follow the customary transverse path, but pass forwards and attach upon the ventral surface of the submentalis (Fig. 1) so obscuring much of the latter muscle from the ventral aspect. The most antero-medial segment of the intermandibularis is aponeurotic.

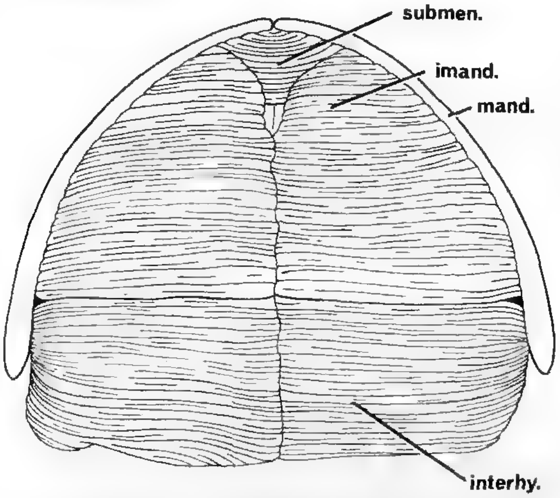

Fig. 1. Superficial mandibular musculature from ventral aspect. imand. = Musculus intermandibularis; interhy. = M. interhyoideus; mand. = Mandible; submen. = M. submentalis.

The only myo-integumental attachment in the submandibular region is via the postmandibular septum.

The innervation of the superficial mandibular musculature corresponds to that described by de Watteville (1875) in *Rana esculenta*. The skin underlying the intermandibularis is innervated by the inframaxillary branch of the fifth cranial nerve, and the skin beneath the interhyoideus by the seventh.

The vocal sac extends antero-medially to the posterior border of the intermandibularis and antero-laterally to the limits of the elongate vocal sac apertures.

Calling Behaviour

Two races of this species are recognised on the basis of differences in mating call: a southern call race characterised by "a short single pulsed mating call", and a northern call race characterised by "a mating call composed of two to five pulses" (Littlejohn and Martin, 1965; Littlejohn, 1967). The frogs which I studied are members of the northern call race.

Limnodynastes tasmaniensis usually calls from an exposed position in water. The frog floats with the body submerged and the limbs extended. Prior to inflation of the vocal sac the long axis of the body is horizontal.

Inflation of the vocal sac alters the buoyancy of the individual. The head and chest are raised so that the vocal sac structure lies above the level of the water. The longitudinal axis of the body is tilted to an angle of approximately sixty degrees from the horizontal, and the trunk submerges.

The mating call of this species is customarily emitted with the entire mandibular region grossly distended. In profile the vocal sac structure extends beyond the anterior portion of the sternum (Fig. 2A); when viewed from above the vocal sac structure extends laterally beyond the mandibles.

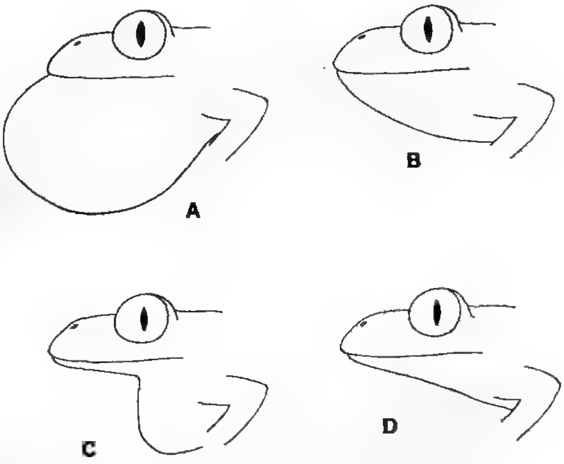

Fig. 2. Profile views of inflated vocal sac. A = fully inflated; B = partially deflated; C = posteriorly inflated; D = entirely deflated.

Following completion of vocal activity the vocal sac structure is usually rapidly and entirely deflated (Fig. 2D). On occasions however it is either partially but uniformly deflated (Fig. 2B), or the anterior portion of the structure is completely deflated whilst the posterior remains inflated (Fig. 2C). Intermittent vocal activity is occasionally resumed with the vocal sac structure thus incompletely deflated. There was no audibly detectable difference between the calls emitted with the vocal sac maximally inflated or incompletely deflated.

Discussion

Studies on the disposition of submandibular vocal sacs in other anuran genera indicate that they occupy one of two positions; they extend anteriorly above the interhyoideus and intermandibularis, or lie above the interhyoideus but do not extend anteriorly beyond the border of the intermandibularis.

From the observation that when the vocal sac of *L. tasmaniensis* is maximally inflated the entire submandibular region is distended, this species could be anticipated to possess a vocal sac of the former type, with the intermandibularis composing the muscular lining of the anterior segment of the inflated vocal sac structure. The vocal sac is however of the latter type and so is not free to intrude above the intermandibularis. Vocal sac inflation cannot therefore direct any portion of this muscle into a position above the intermandibularis.

Although the hyoid plate lying above the intermandibularis can be considerably raised or depressed in freshly killed frogs, it is attached posteriorly via the postero-medial processes to the larynx, which is attached via other processes to the oesophagus, heart and lungs. Thus the hyoid may depress the intermandibularis, but the possibility of the former being also capable of forcing the latter against the anterior segment of the skin during maximal inflation can be excluded. It is therefore concluded that during maximal inflation the interhyoideus passes forwards to underly the intermandibularis (Fig. 3).

The anterior margin of the posteriorly inflated vocal sac structure correlates perfectly with the position of the border between the intermandibularis and interhyoideus, and indicates quite clearly that in this form of inflated structure the interhyoideus is by some means prevented from intruding beneath the intermandibularis. The profile view also reveals that the intermandibularis is not depressed. Thus the skin covering the intermandibularis appears to be responsible for restricting the inflated interhyoideus to a posterior position.

The term "elastic" has been applied to a submandibular skin which is recognised to contribute to the potential distension of the vocal sac structure (Inger, 1956; Blair, 1964). The extreme and prolonged distension of submandibular skin, such as occurs during vocal activity associated with the breeding season, stretches it and may result in loss of the ability to contract fully. The skin becomes irregularly pleated and hangs loosely in species that lack direct myo-integumental contact (e.g. many Neotropical *Hyla* spp.).

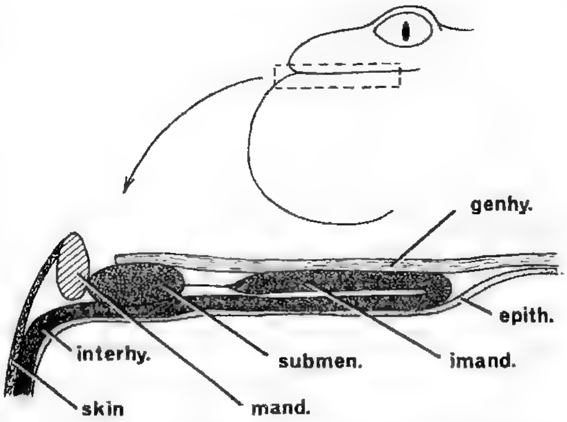

Fig. 3. Interpreted position of superficial mandibular muscles during maximal inflation of vocal sac structure. Enlargement represents sagital section. epith. = epithelial lining of vocal sac; genhy. = Musculus geniohyoideus. For Key to other abbreviations see caption to Figure 1.

The tissue most likely to produce skin contraction is the thin layer of muscle at the base of the corium. In view of the difference in innervation of the skin beneath the intermandibularis from that beneath the interhyoideus, the existence of a nervously mediated mechanism for constricting one portion and not the other, so producing the effect observed in *L. tasmaniensis*, is indicated.

The absence of any audibly detectable difference between the calls of *L. tasmaniensis* emitted with the vocal sac completely or partially inflated, suggests that neither shape nor position in relation to the larynx influence spectral call composition.

Although the observations are subjective, the conclusion is supported by Blair's (1959) arrangement of anuran species into groups on the basis of similarities in mating-call structure, instead of the customary means of resemblance in internal or external morphology. Blair so divided thirteen species of *Hyla* occurring in the U.S.A. into several species groups. This resulted in associating the species *baudini* with the *H. versicolor* group, although he noted that whereas *versicolor* and the other species had a customary submandibular ("subgular") vocal sac structure, *baudini* possessed a sac with paired posterior lobes. Starrett

(1960) placed *baudini* in the redefined genus *Smilisca*, so indicating that call similarities are of little value in establishing the higher groupings of species.

Acknowledgements

I am greatly indebted to Dr. W. G. Inglis, Director of the South Australian Museum, for constructive criticism of the manuscript.

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VISCUM KATIKIANUM (VISCACEA), A NEW SPECIES OF MISTLETOE FROM NEW GUINEA

BY B. A. BARLOW

Summary

A new species, *Viscum katikianum*, is described. It is known only from a single collection made near Wau, New Guinea. It belongs in section *Mesandrum* Tiegh., but differs from the Asian-Australian species of the section in its large ovate leaves and perhaps by its minutely spotted fruits.

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A new species, *Viscum katikianum*, is described. It is known only from a single collection made near Wau, New Guinea. It belongs in section *Mesandrum* Tiegh., but differs from the Asian-Australian species of the section in its large ovate leaves and perhaps by its minutely spotted fruits.

Viscum katikianum Barlow, sp. nov.

Glaber. *Frutex* gracilis ad omni nodum ramosus sed caulibus individuis distincte monopodialibus; surculi laterales non valde divaricati. *Folia* opposita; lamina anguste ovata, 6-10 cm longa, 2·5-4·5 cm lata, tenuis, apice leniter attenuata obtusa vel late acuta, basi in petiolum infirme distinguibilis 0·5-1 cm longum attenuata, curvinervis nervis tres vel quinque longitudinalibus utrinque distinctis et in petiolum distinctis remanentibus et anastomose supra distincta. *Inflorescentiae* e nodis deinceps evolutae, ad basim omni prophylliis binatis c. 1 mm longis subtentis; pedunculus teres, c. 4 mm longus, 1 mm crassus sed in fructum accrescens, apice duo bracteae in naviculam 2-3 mm longam connatae praeditae; cymae triflorae. *Flos masculus* centralis, globosus, c. 1·5 mm diam., 4-merus; perigonii segmenta triangulares, c. 1 mm longae; antherae ad perigoniorum segmenta sessiles, depressae pyramidalis, 6- vel 8-cellulares. *Flores feminei* in triadum laterales, cylindricae, c. 2 mm longae, 4-merae; perigonii segmenta triangulares; c. 0·7 mm longae; stigma depressum conicum, c. 0·3 mm longum. *Fructus* fusiformis ellipsoideus, c. 5 mm longus, stigmate persistenti coronato, laevis sed minute sparsim maculatus.

TYPUS: Wau forestry area, Morobe District, New Guinea, c. 1360 m elev., parasitic on *Amyema strongylophyllum* (*Barlow* 948). *Barlow* 947, 11.ii.1965 (AD 97046179, holotypus; CANB; LAE).

Glabrous, *Slender shrub*, branching at every node but with the individual stems distinctly monopodial; lateral shoots not strongly divaricate. *Leaves* opposite; lamina narrow ovate, 6-10 cm long, 2·5-4·5 cm wide, thin, weakly attenuate and obtuse or broadly acute at the apex, attenuate at the base into a weakly differentiated petiole 0·5-1 cm long; venation curvinervous with three or five longitudinal veins distinct on both sides and remaining distinct in the petiole; reticulate venation distinct on the upper surface. *Inflorescences* developing successively at the nodes, each subtended at the base by a pair of triangular prophylls c. 1 mm long; peduncle terete, c. 4 mm long and 1 mm thick but enlarging in fruit, bearing at the apex a boat-shaped pair of connate bracts 2-3 mm long which subtends a triad of flowers. *Male flower* central in the triad but apparently deciduous, globular, c. 1·5 mm in diameter, 4-merous; perianth segments triangular, c. 1 mm long; anthers sessile on the perianth segments, depressed-pyramidal, 6- to 8-celled. *Female flowers* lateral in the triad, cylindrical, c. 2 mm long, 4-merous; perianth segments triangular, c. 0·7 mm long; stigma depressed-conical, c. 0·3 mm long. *Fruit* fusiform-ellipsoidal, c. 5 mm long, crowned by the persistent stigma, smooth but minutely and sparsely dark-spotted.

SPECIMENS EXAMINED: Type collection only.

Discussion

Viscum katikianum belongs in section *Mesandrum* Tiegh., which is distinguished by its inflorescences in which the central flower is male (van Tieghem, 1896). In the most recent revision of the Indomalayan species of *Viscum*, Danser (1941) recognised four species which can be placed in this section, although he did not employ infra-generic categories. These are *V. trilobatum* Talbot and *V. capitellatum* Smith from India and *V. bancroftii* Blakely and *V. whitei* Blakely from Queensland. To these has been added the recently described *V. flexicaule* from the Northern Territory (Barlow, 1970). *Viscum katikianum* is thus the first species of this group to be recognised from New Guinea. It

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differs from all of the abovementioned related species in its much longer leaves and perhaps in its minutely spotted fruits, which have not been mentioned in accounts of the other species. Like the other members of the group it is probably almost exclusively parasitic on mistletoes of the family Loranthaceae.

The herbarium specimens on which the description is based are unfortunately sterile. A small amount of flowering and fruiting material was collected in alcohol, and was lodged with the holotype in AD.

The species is named in honour of Mr. Paul Katik, Division of Botany, Department of Forests, Lae, New Guinea, who has provided willing assistance on my field trips to New Guinea, and who assisted in making the collection cited above.

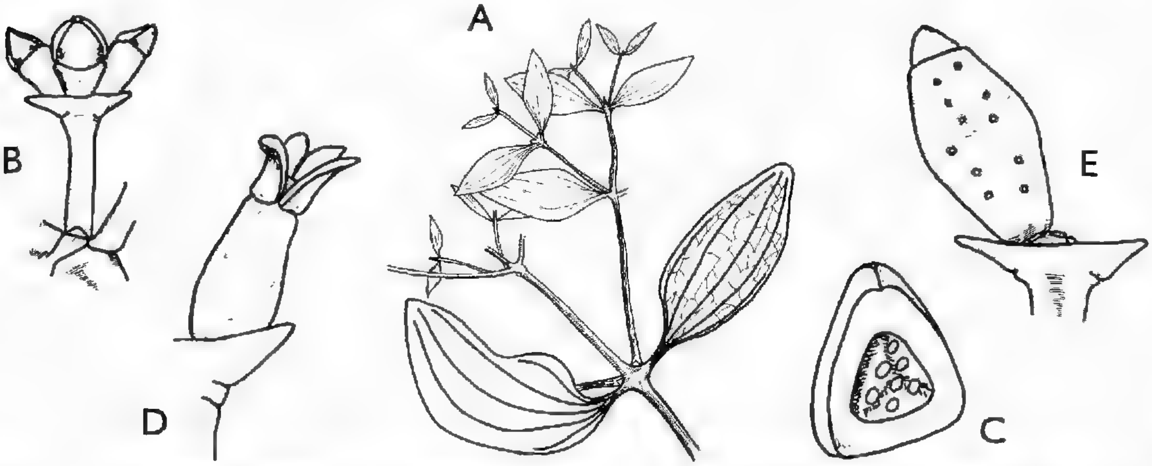

Fig. 1. A, portion of plant, x ⅛; B, inflorescence, x 3; C, perianth segment of male flower, with anther, x 12; D, female flower, x 11; E, fruit, x 5·5.

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BY S. J. EDMONDS

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Three new species of acanthocephalans are described from Australian hosts. A note on *Arhythmorhynchus johnstoni* Golvan, 1960 (= *A. frassoni* of Johnston and Edmonds, 1951) is also included. The new species are - (1) *Pseudoacanthocephalus perthensis* from *Litoria moorei* (Copeland) and *Limnodynastes dorsalis* (Gray), (2) *Neoechinorhynchus aldrichettae* from *Aldrichetta forsteri* (Cuvier and Valenciennes), and (3) *Arhythmorhynchus limosae* from *Limosa lapponica* (Linnaeus) .

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Pseudoacanthocephalus perthensis n. sp.

FIGS. 1-5

Pseudoacanthocephalus Petrotschenko, 1956; Golvan, 1969: 286.

Host and Locality. About 9 specimens were collected from frogs at Rockingham, near Perth, Western Australia by Dr. W. G. Inglis of the South Australian Museum, 6 from *Litoria moorei* (20/8/66) and 3 from *Limnodynastes dorsalis* (26/4/66). The specimens were found in the intestine of the frogs.

Type specimens (male and female); Australian Museum, Sydney.

Description. The parasites are small and stout, the female being longer and more cylindrical. The trunk of both sexes is curved ventrally to a slight extent.

The trunk of the male specimens is 2·6-3·2 mm long and has a maximum width of 0·6-0·8 mm. The corresponding measurements of the female are 5·1-6·9 mm and 0·8-1·1 mm. The trunk lacks spines and its body wall is thick. The introvert is subcylindrical to ovoidal in shape and arises anteriorly on the ventral side of the mid line of the trunk. Its length is 0·35-0·40 mm and width 0·21-0·30 mm. It is armed with 12-14 rows of 4-5 hooks per row. The length of the hooks measured directly from the highest point on the curve of the hook to the tip of the hook is about 70-90 μm. All the hooks have well developed, posteriorly directed rooting processes. The sheath is double-walled and the cerebral ganglion lies at its base. The lemnisci are short and stout and about as long as the sheath.

The testes of the male lie either in tandem or so as to overlap slightly. There are three pairs of cement glands which in all but one specimen are pressed closely together. The male aperture is terminal. The female complex of uterine bell, uterus and vagina is about 0·7-0·9 mm long and the female aperture appears to be subterminal. The eggs are ellipsoidal and do not possess polar prolongations of the middle shell. They are 45-55 μm long and 20-25 μm wide.

Systematic position. This species differs from *P. bufonis* (Shipley), *P. betsileo* Golvan, Houin and Brygoo (*in* Golvan, 1969: 291), *P. bigueti* (Houin, Golvan & Brygoo, 1965), *P. bufonicola* (Kostylew) and *P. caucasicus* (Petrotschenko) largely in the number of hooks found on the introvert.

This species lacks polar prolongations of the middle shell. I have not been able to ascertain whether the integument of the acanthor bears spines over its entire surface (Golvan, 1969: 287).

Golvan (1969: 287) says, "Quant à la validité du genre *Pseudoacanthocephalus*, bien que j'en ai d'abord douté (Golvan, 1960) elle me paraît aujourd'hui parfaitement acceptable, et ce n'est pas l'un des moindres mérites de Petrotschenko de l'avoir établie".

Neoechinorhynchus aldrichettae n. sp.

FIGS. 6-9

Neoechinorhynchus Hamann, 1892; Golvan, 1959; 20.

Host and locality. About 70 live specimens were collected from the posterior gut of three specimens of the local mullet *Aldrichetta forsteri* (Cuv. and Val.) at Port Pirie, South Australia. The finding of acanthocephalans embedded in a mucous region of the posterior gut about 25 mm broad and about 35 mm anterior to the anal aperture is, as far as I know, unusual. The parasites were found in a similar position in the gut of each of the three fish and there is no

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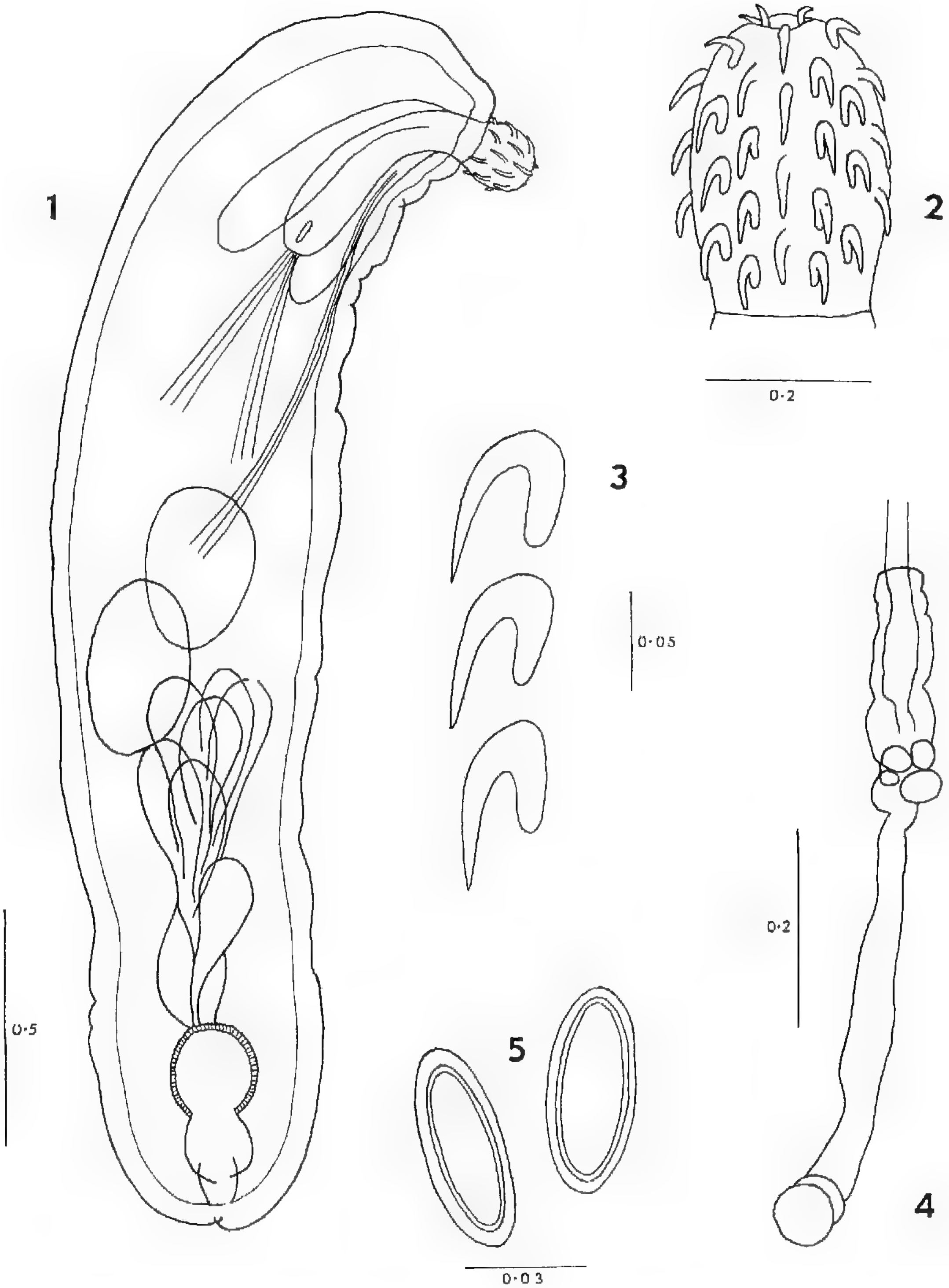

Figs. 1-5. *Pseudoacanthocephalus perthensis.* Fig. 1.—Male. Fig. 2.—Introvert. Fig. 3.—Introvert hooks. Fig. 4.—Female complex. Fig. 5.—Eggs. Measurements in mm.

doubt in my mind that they were attached to the gut in this region. The collection contained only seven males.

Type specimens (male and female); Australian Museum, Sydney.

Description. All specimens are less than 8·0 mm long and tapered slightly posteriorly. Anteriorly there is a small, globular introvert surmounted on a short, unarmed, truncated neck. The trunk lacks spines.

The length of the body of the males is 4·1-6·4 mm and the maximum width 0·3-0·6 mm. The corresponding measurements of the female are 4·8-7·8 and 0·5-0·7 mm. The posterior extremity of the female is capable of considerable invagination.

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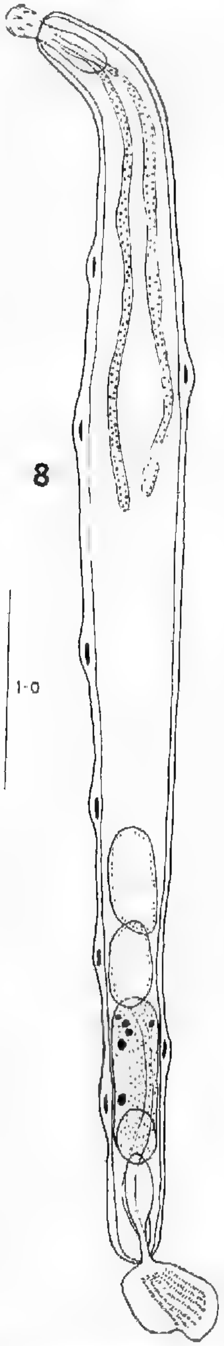

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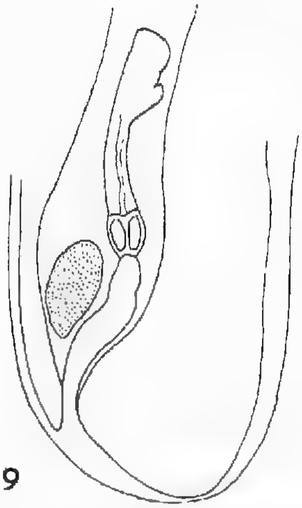

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Figs. 6-9. *Neoechinorhynchus aldrichettae.* Fig. 6.—Introvert. Fig. 7.—Introvert hooks. Fig. 8.—Male. Fig. 9.—Female complex. Measurements in mm.

Fig. 10. *Arhythmorhynchus johnstoni*—introvert.

The maximum length of the globular introvert is 0·09-0·13 mm in the male and 0·10-0·14 in the female. The maximum width is 0·11-0·15 mm in the male and 0·13-0·15 in the female. The width of the neck at its junction with the introvert is 0·09-0·13 and the length 0·05-0·08 mm.

The introvert hooks lie in six spiral rows of three hooks per row. The anterior-most hook of each row is largest and is 49-62 μm long, measuring in a straight line from the highest point on the hook to the tip of the hook. It bears a strong posteriorly directed rooting process. The length of the second hook is 29-34 μm and the third 18-25 μm.

A single-walled receptacle arises just posterior to the point of insertion of the last hook and is about 0·32-0·52 mm long. The cerebral ganglion lies at the base of the receptacle. The lemnisci are about one third as long as the trunk. There are clearly eight large subcuticular nuclei, six on one side and two on the other side of the body wall.

The position of the male reproductive structures varies. In the longest specimen they are placed in the posterior half of the animal but in others they are in the anterior half. The testes are 0·25-0·50 mm long and either overlap slightly or are in tandem. The cement gland is large and 0·5-0·9 mm long and syncytial. The number of nuclei which it contains has not been determined with certainty. There is a cement reservoir and Saeffitgen's pouch. The male aperture is terminal.

The posterior extremity of many of the females is invaginated. The female structures are comparatively short and about 0·2-0·4 mm long. The vaginal region is often marked by the presence of coagulated material. The eggs are small and measure 25-30 μm by 11-16 μm.

Systematic position. The specimens are nearest *N. agilis* Hamann, a species described from Mugilidae of Europe (Meyer, 1932: 172) and Japan (Yamaguti, 1935: 275). The introvert hooks of Hamann's specimens, however, are more than twice the size of the Australian species. This is also true of Yamaguti's specimens.

Southwell and McFie (1925) described a single immature acanthocephalan from Queensland as *N. magnus*. The host is unknown. Although the size of the hooks is comparable with those of *N. aldrichettae* the length of the body is given as 90 mm and the width 1·5 mm, that is the body length of *N. magnus* is more than ten times that of *N. aldrichettae*. The measurement of 90 mm appears to be correct because Southwell and McFie in their text state "the species differs from all other species in being much larger". *N. magnus*, then, appears to be different from the South Australian specimens.

Tripathi (1959) described a number of neoechinorhynchs from some Indian fish, including *N. bangoni* from *Mugil tade* and *N. elongatus* from *Mugil subviridis*. The lengths of the hooks of *N. bangoni* (0·026-0·038 mm) are considerably smaller than those of *N. aldrichettae* and the well developed rooting process on the third or last hook of each row of *N. bangoni* is not present in *N. aldrichettae*. Tripathi's figure of *N. elongatus* might well serve for *N. aldrichettae*. The two species, however, are different because Tripathi's figure 4 shows that only two subcuticular nuclei are present and because the egg of *N. elongatus* is 0·11 mm long and 0·0266 mm wide.

N. buttnerae Golvan, 1956 from *Myletes* is close but is described as possessing 5 + 2 subcuticular nuclei and not 6 + 2. *N. aldrichettae* resembles in many respects *N. octonucleatus* Tubangui, 1933, described, however, from a fresh-water fish.

Arhythmorhynchus limosae n. sp.

FIGS. 11-15

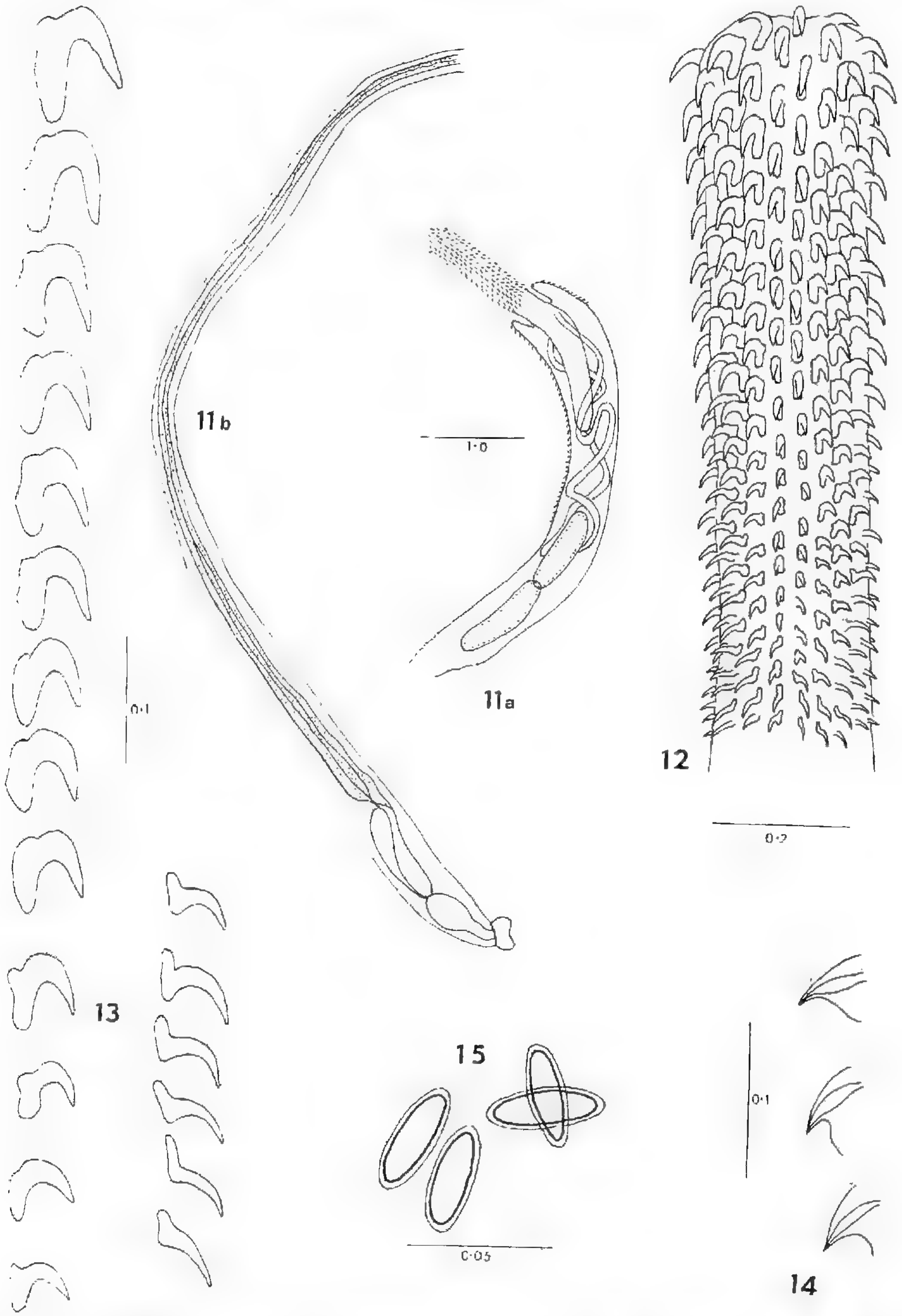
Arhythmorhynchus Lühe; Golvan, 1969: 382.

Host and Locality. Eight specimens collected by Dr. A. J. Bearup (School of Public Health and Tropical Medicine, Sydney) from the gut of the god-wit, *Limosa lapponica*, at Townsville, Queensland on 28/1/59.

Type specimens (male and female); School of Public Health and Tropical Medicine, Sydney.

Description. The specimens are long and slender but swollen slightly anteriorly. The length of the trunk of the males is 14-22 mm and that of the females 21-41 mm. The swollen anterior region of the trunk of the males is 0·5-0·7 mm wide and that of the females 0·5-1·0 mm. The surface of the swollen region is armed with numerous rows of body spines which extend over a greater area of the ventral than the dorsal surface. The rest of the trunk is cylindrical and unarmed and about 0·3-0·5 mm wide in females.

The armed portion of the introvert is 1·1-1·4 mm long and generally cylindrical; its width 0·25-0·3 mm (in some specimens its



Figs. 11-15. *Arhythmorhynchus limosae.* Fig. 11a-b.—Anterior and posterior regions of male. Fig. 12.—Introvert. Fig. 13.—Introvert hooks. Fig. 14.—Body spines. Fig. 15.—Eggs. Measurements in mm.

maximum width is at the anterior extremity). It arises from a short unarmed neck about 0·1-0·2 mm long. In most specimens the neck is retracted into the trunk. In none of the specimens is the introvert swollen near its mid-length, the condition in a number of species of the genus. The introvert is armed with about 19-20 rows of 20-21 hooks per row. The anterior-most hooks are stoutest and possess strong, posteriorly directed rooting processes. The hooks generally decrease in size the further they lie away from the tip of the introvert and their posteriorly directed rooting processes gradually disappear, an anteriorly directed process appearing in its place (Fig. 13). The posterior six 'hooks' of each row are more spiniform and have very well developed anterior rooting processes. The spines are slightly longer than the hooks which immediately precede them. The hooks on the dorsal and ventral surfaces of the introvert appear to be the same size and have the same shape. The introvert sheath is double-walled and its maximum length is 2·1 mm.

The testes lie in a very anterior position of the trunk, usually in the swollen part. They are 0·8-1·0 mm long and 0·20-0·28 mm wide. The cement glands are very long, slender and pressed closely together; they traverse the length of the trunk that lies posterior to the testes. Saefftigen's pouch is 1·0-1·3 mm long and the male aperture is terminal.

The length of the female complex in a specimen about 30 mm long is 4 mm. Ripe eggs are 76-80 µm long and 26-30 µm wide and, like those of *A. frassoni*, lack polar prolongations of the middle shell.

Systematic position. This species is different from *A. johnstoni* Golvan (= *A. frassoni* of Johnston and Edmonds, 1951), described from three male specimens that were collected from *Numenius cyanopus* in Queensland. At first sight *A. johnstoni* and *A. limosae* resemble each other closely. A re-examination of the three specimens shows that the two species differ most noticeably in the structure of the introvert hooks. Those of *A. johnstoni* are largest in the centre of the introvert, especially on the ventral side.

A. limosae differs from all other species of the genus in the spination of its introvert.

Arhythmorhynchus johnstoni Golvan.

FIG. 10

A. johnstoni Golvan, 1960: 384 = *A. frassoni* of Johnston & Edmonds, 1951.

Type specimen (male): Australian Museum, Sydney.

Johnston and Edmonds, 1951, described three male acanthocephalans from *Numenius cyanopus* as *A. frassoni* (Molin, 1858). *A. frassoni* has been reported from *Numenius arquatus* and *N. tenuirostris*. Golvan (1960) made the Australian specimens a new species. He gave no reasons for his action. This note is to record that the type material of Golvan's new species has now been lodged in the Australian Museum, Sydney. A figure showing the arrangement of the hooks on the introvert of *A. johnstoni* is included in the present paper. The drawing is made from a mounted specimen which is slightly damaged.

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TWO NEW SPECIES OF *RICTULARZA* (NEMATODA) FROM AUSTRALIAN RODENTS

BY PATRICIA M. MAWSON

Summary

Two new species of *Rictularia*, the first of the genus to be recorded from Australia, are described. In R. *carstairsi*, from *Rattus villosissimus* (Northern Territory), the mouth is rounded; the female is up to 68 mm long, with cuticular spines (37-42 pre-vulvar, 17-35 post-vulvar) restricted to the anterior half or less; the male is 10.1-15.5 mm long, with 54-69 cuticular spines, and equal spicules 80- 90 urn long. In R. *mackerrasae* from *Rattus fuscipes assimilis* (northern Queensland) the mouth is slit-like and the buccal capsule dorsoventrally compressed; only females are present; these are up to 82 mm long, with cuticular spines (30-33 pre-vulvar, up to 11 post-vulvar) restricted to the anterior quarter or less of the body.

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Introduction

There is no record of a valid *Rictularia* sp. from an Australian animal. *Rictularia disparilis* Irwin-Smith, 1922 was described from an Australian lizard but was placed by Dollfus and Desportes (1945) in a new genus *Pseudorictularia* and may be related to *Pneumonema tiliquae* Johnston.

However, the genus *Rictularia* is not uncommon in native rats. A large collection of male worms as well as females was recently given to me by Mr. J. Carstairs (Zoology Department, Monash University, Melbourne) who found them commonly in the long-haired rat, *Rattus villosissimus*, which he is studying. Dr. M. J. Mackerras has given me four collections from *Rattus fuscipes assimilis* from Northern Queensland. In *Rattus fuscipes murrayi* from Pearson Island, South Australia, *Rictularia* sp. was present in two of four rats dissected in 1969 and in one dissected in 1923. The specimens from the first two of these hosts are described in this paper, those from the third will be described shortly, with other nematodes from Pearson Island animals. I am most grateful to Dr. Mackerras and to Mr. Carstairs for providing the nematodes.

Rictularia carstairsi n. sp

FIGS. 1-7

Host and locality: *Rattus villosissimus*, Brunette Downs Station, Northern Territory. The collector, Mr. Carstairs, found the worms usually in the duodenum just behind the pyloric sphincter but sometimes in the stomach.

This is a very long species, the female worms reaching 68 mm, the males 15·5 in length. Among about 150 females there are 15 males. Although the female worms are all very similar, two of the males differ from the other 13, and these are described separately. In all specimens the buccal capsule is wider than deep, its anterior border bears about 28-32 small pointed teeth (in both sexes), more or less evenly distributed around the edge. The mouth opening is at about 45° to the long axis of the worm. The head bears the typical cephalic papillae, an inner ring of six papillae and behind these four submedian double papillae. The amphids lie postero-dorsally to the lateral papillae of the inner circle. The excretory pore is slightly in front of, and the cervical papillae usually behind, the junction of glandular and muscular parts of the oesophagus.

In the female the sub-lateral spines do not extend as far as midlength of the body. The vulva, almost at the level of the posterior end of the oesophagus, is a transverse slit with salient lips, the cuticle for a short distance anterior and posterior to the vulva (but not on the salient lips) is raised into large irregularly disposed rounded bosses (Fig. 5). The pre-vulvar spines (37-42), are overlapping; the 17-35 post-vulvar spines become increasingly far apart, and after the first 10 they are very sparse and small, and the apparent variation in numbers is due probably to their small size.

In the male there are 54-69 pairs of spines extending from just behind the buccal capsule nearly to the cloaca. The first 35 pairs are overlapping, and have large thick bases; the rest become progressively further apart and more hook-like until in the last fifth of the body each is separated from the preceding by about a hook's length. There is usually one preanal

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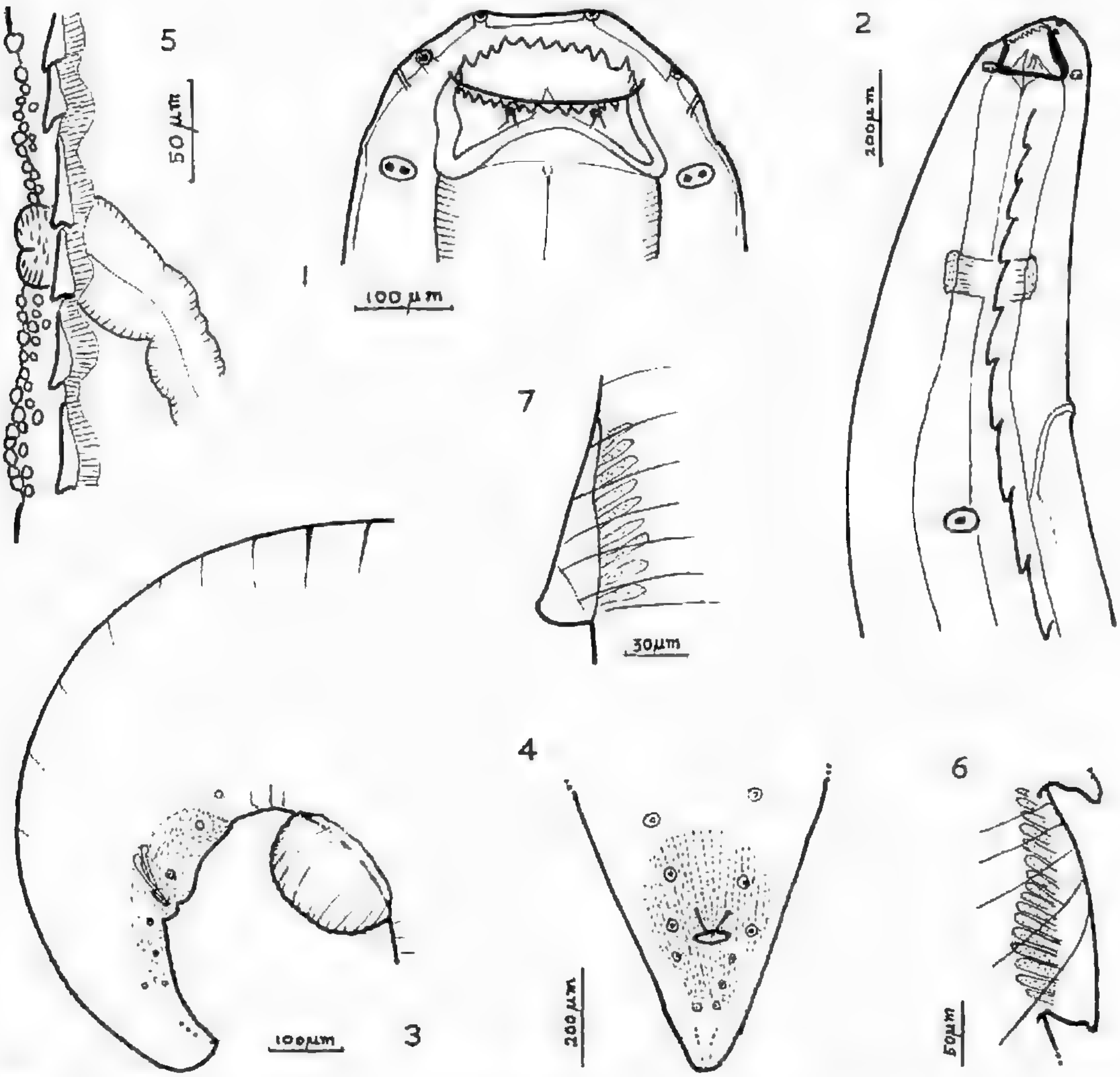


Figs. 1-7. *Rictularia carstairsi*. 1, head, dorsal view; 2, anterior end, lateral view; 3 and 4, lateral and ventral views of male tail; 5, region of vulva, lateral view; 6 and 7, the fourth and most posterior cuticular spine respectively.

fan, but in one specimen there are two, and in another none. The spicules are equal or nearly so; a gubernaculum is present. The ventral body surface around the cloaca is raised into broken longitudinal ridges. The extent of these and the arrangement of the cloacal papillae are indicated in Figs. 3 and 4. It is much as postulated for the genus (at least for the species from rodents) by Tiner (1948) except that there is an extra pair of preanal papillae.

Measurements—Male: 10·1-15·5 mm long, diameter to 900 µm. Anterior end to cervical papillae 710-1115 µm (7th-9th spine), to nerve ring 380-550 µm; oesophagus 2·4-3·4 mm (23rd-28th spine), its muscular part 480-750 µm. Spicule length 80-90 µm. *Female*: Length 35-68 mm, diameter to 1500 µm. Oesophagus 6·0-7·2 mm, its muscular part 1000-1250 µm. Anterior end to cervical papillae 1000-1250 µm (7th-9th spine), to nerve ring 590-800 µm, and to excretory pore 800-1050 µm. Tail 350-750 µm. Eggs 48-50 x 36-38 µm.

Among species of *Rictularia* of which the males have been described this one most closely resembles *R. harrisi* Baylis 1934. However, in *R. harrisi* the papillae of the male tail were not determined exactly, and the spicules are rather shorter. Among species of which the female only has been described, those with a similar number of spines anterior and posterior to the vulva are *R. caucasica*, Schulz, 1927 and *R. magna* Kreis, 1937. The available description of *R. caucasica* does not allow detailed comparison. In *R. magna* there are only 18 denticles around the anterior border of the buccal capsule.

Rictularia mackerrasae n. sp.

FIGS. 8-11

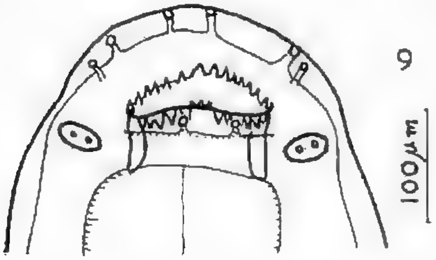
Host and locality: *Rattus fuscipes assimilis*; near Innisfail, northern Queensland.

Only females of this species are present in four collections. They were sent to me some time ago by Dr. M. J. Mackerras.

The worms are up to 82 mm long. The sublateral spines are restricted to about the first quarter (or less) of the body length; they are small and even the most anterior spines are hook-like rather than imbricate; each is well separated from the next. There are 30-33 spines between the head and the vulva, and up to 11 behind this.

The mouth opening is directed dorsally, and the cuticle on its ventral margin is very thick; the ventro-lateral and lateral cephalic papillae of the inner circle have long peduncles traversing this cuticle. The two pairs of large submedian papillae of the outer circle are probably double, but this is not clear. The amphids lie close to the lateral cephalic papillae, slightly dorsal and posterior to them.

The buccal capsule and mouth are dorsoventrally compressed. The dorsal oesophageal tooth is small and ventral teeth are absent. The nerve ring is at about midlength of the anterior muscular part of the oesophagus, the large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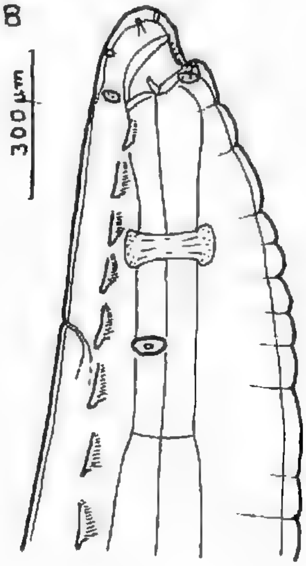
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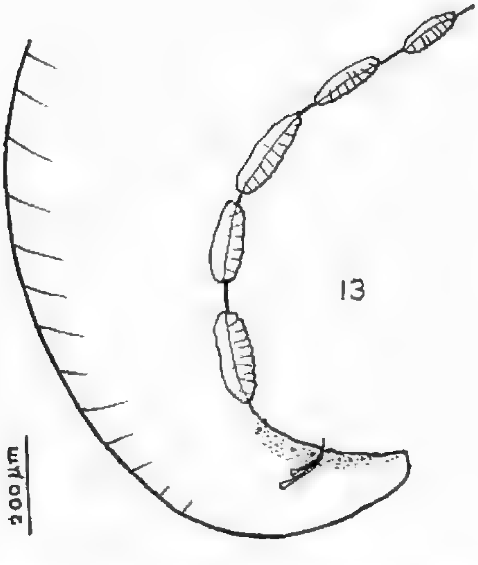
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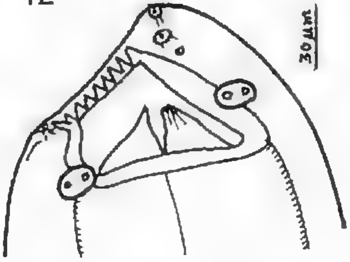
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Fig. 8-11. *Rictularia mackerassae*. 8, anterior end, lateral view; 9, head, dorsal view; 10, region of vulva, lateral view; 11, fifth spine from anterior end.

Figs. 12, 13. *Rictularia* sp. from *Rattus villosissimus*. 12, head, laterial view; 13, posterior end of male.

cervical papillae at three quarters its length (5th or 6th spine) and the excretory pore shortly in front of the cervical papillae.

The vulva is close to the posterior end of the oesophagus, it lies in a transverse depression of the body wall, and the lips are salient. The cuticle around, including the lips, is finely mammillated (Fig. 11).

Measurements—Female: length 65-82 mm; oesophagus 5·7-6·3 mm, its anterior muscular section 900-1300 µm; distance from anterior end to nerve ring 500-700 µm, to cervical papillae 810-1150 µm, and to excretory pore 800-1000 µm. Vulva 5·0-5·9 mm from head; eggs 46-50 x 30-31 µm. Tail 530-550µm.

Tiner (1948) notes that *Rictularia* spp. in American rodents are of two types, one in which the oral opening is circular and more anteriorly directed (e.g. *R. coloradoensis*) and another in which it is narrow, transverse and dorsally directed (e.g. *R. citelli*). Species from rodents belonging to the second type have been recorded from various parts of the world, *R. proni* Seurat (Africa and Europe), *R. amurensis* Schulz and *R. strumica* Dimitrova, Genov and Karapchanski (Europe), *R. elvirae* Parona (Burma), *R. oligepectinea* Wu and Hu (China), *R. dhanra* Inglis and Ogden (India) and *R. citelli* McLeod (? Syn. *R. halli* Sandground according to Tiner) from America. *R. mackerrasae* is now described from an Australian rat, it differs from others of the group chiefly in the number, size and arrangement of teeth on the anterior border of the buccal capsule.

Inglis and Ogden (1965) suggest that the extent to which the mouth is directed dorsally may depend on the degree to which it is opened or closed. This temporary movement however would not account for the greatly thickened cuticle anteriorly, or for the greater length of the median dorsal teeth on the anterior border of the buccal capsule, which appear to be associated with the more dorsal slit-like mouth in the species listed above. Moreover the fact that the condition is present in all specimens from a number of hosts of the same species in one locality (as is the case in the Australian specimens) suggests that it is a character with specific rather than temporary significance.

Rictularia sp.

FIGS. 12, 13

Host and Locality; *Rattus villosissimus*, Brunette Downs, Northern Territory.

Two male worms in the collection from this rat differed from those described as *R. carstairsi*, in that the spicules are distinctly unequal, the longer 145 µm and 150 µm, the shorter 70 µm and 75 µm, there are more preanal fans, three in one and four in the other. The worms are slightly shorter, 9·0 and 9·2 mm. Apart from these points, no real difference in the morphology from that of *R. carstairsi* can be found. As all the specimens from *Rattus villosissimus* had been put into one container, it is not known if these two males occurred alone, or with females and/or other males.

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MARINE ENOPLIDA (NEMATDA) FROM WESTERN AUSTRALIA

BY W. GRANT INGLIS

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Introduction

Among nematodes collected along the coast of Western Australia in 1966 and 1967, are the ten species of Enoplida described below. These species, of which seven are new, are referable to nine genera—*Anticoma*, *Leptosomella*, *Leptosomatum*, *Phanoderma*, *Paraphanoderma* nov., *Enoplus*, *Epacanthion*, *Eurystomina* and *Proonchelaimus*—of five families. The extension in the known range of these genera and the large number of new species is not unexpected. The collection's interest is that it contributes confirmatory evidence on some aspects of the general structure of marine Enoplida which was described in detail elsewhere (Inglis, 1962, 1963, 1966).

In particular the structure of the head in *Leptosomella* supports the view that the Family Leptosomatidae represents a sequence in which the cephalic ventricles are never well developed and in which oesophageal musculature extends anteriorly as a distinct lobe through those ventricles. In contrast the conditions in *Paraphanoderma* support the view that the Phanodermatidae are characterized by the presence of cuticular rods which are associated with the inner circle of cephalic sense organs. The relationships of the Phanodermatidae and Enoplidae are close and the unequal onchia in *Paraphanoderma* suggest the interesting possibility that the Enoplidae with unequal onchia originated from one group of Phanodermatidae while the equal onchiate forms arose from another. This would certainly resolve some of the problems in the analysis of the Enoplidae where at least two groups occur: the equal or reduced onchiate forms culminating in *Enoplus*, and the markedly unequal onchiate forms culminating in, or originating with, *Oxyonchus* and *Savaljevia*.

Holotype males of all new species are deposited in the Western Australian Museum while Paratypes are in that institution and the British Museum (Natural History).

Family

LEPTOSOMATIDAE

Anticoma cobbi sp. nov.

FIGS. 1-3

Locality. From among weed and bi-valves in rock pools just exposed at low tide; Hall's Head, Mandurah.

Measurements (mm)—*Male*: Body length: 1·82. Body breadth: 0·046. Oesophagus length: 0·342. Length of cephalic setae, long/short: 0·007/0·005. Distance from anterior end of amphid/excretory pore/cervical setae/nerve ring: 0·014/0·030/0·039/0·18. Length of spicules: 0·047. Length of gubernaculum: 0·011. Precloacal supplement, length/distance anterior to cloacal opening: 0·017/0·070. Tail length: 0·226. Cloacal diameter: 0·039.

The cephalic capsule is poorly developed and there are no onchia in the oesophastome. The sense organs form an inner circle of six, slightly thorn-like setae and an outer circle of ten long setae of which six are about a third longer than the remaining four. The excretory pore opens roughly as far posterior to the amphidial opening as that opening is from the anterior end of the body. There are four cervical setae lying posterior to the level of the excretory pore.

The tail ends in a long flagellate region and the pre-cloacal supplement is simple and slim. The spicules are fairly short and stout with narrow alae. The gubernaculum is a small, oblong mass enclosing the distal ends of the spicules. The usual series of stoutish setae lie between the cloacal opening and the pre-cloacal supplement.

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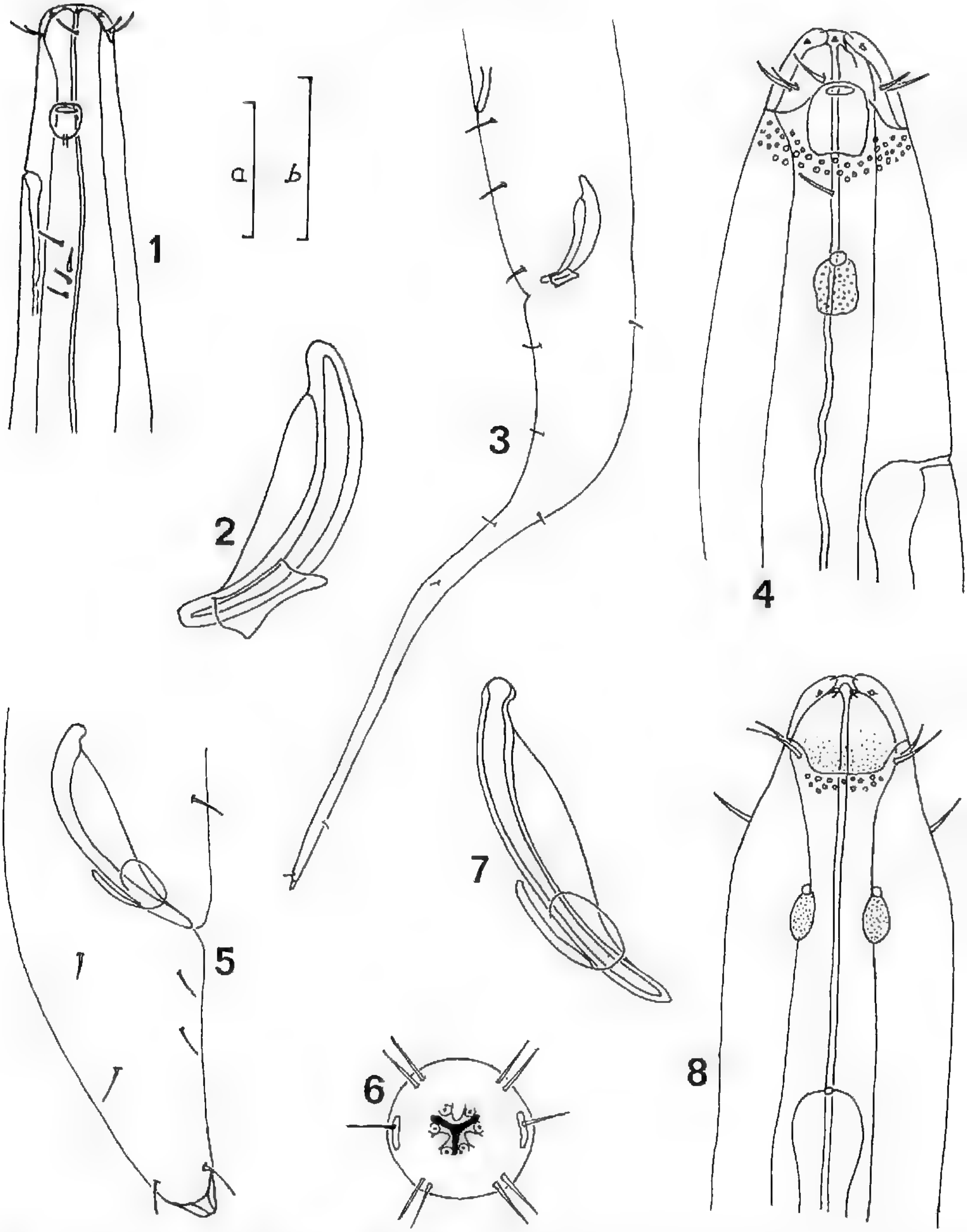


Figs. 1-3. *Anticoma cobbi.* Fig. 1.—Anterior end, lateral view. Fig. 2.—Spicule and gubernaculum detail. Fig. 3.—Posterior end male.

Figs. 4-8. *Leptosomella phaustra.* Fig. 4.—Anterior end, lateral view. Fig. 5.—Posterior end male. Fig. 6.—Head *en face*; note system of dense material surrounding nerves to sense organs and anterior lobes of oesophagus, mouth opening wholly black. Fig. 7.—Spicule and gubernaculum detail. Fig. 8.—Anterior end, ventral view. (Scale a = 0·02 mm in Figs. 1, 2, 4, 6, 7, 8; a = 0·05 in Fig. 3; b = 0·5 in Fig. 5.)

Discussion. This species resembles *A. arctica* Steiner, 1916 and *A. acuminata* (Eberth, 1863) in the position of the excretory pore but differs from both in the unequal cephalic setae and the relatively short spicules with blunt posterior ends.

Leptosomella phaustra sp. nov.

FIGS. 4-8

Locality. From weed and associated sand, without silt, on exposed beach in 25 cm water; Sarge Bay, Cape Leeuwin.

Measurements (mm)—*Males*: Body length: 1·85; 2·21; 2·32. Body breadth: 0·087; 0·092; 0·104. Oesophagus length: 0·494; 0·451; 0·494. Length of cephalic setae, long/short: 0·009/0·007; 0·013/0·011; 0·009/0·008. Cephalic capsule, length/posterior diameter: 0·013/0·026; 0·013/0·022; 0·014/0·021. Distance from anterior end of amphid/eye-spot/excretory pore/nerve ring: 0·011/0·036/0·063/0·175; 0·022/0·040/0·064/0·182; 0·021/0·039/0·068/0·187. Length of spicules: 0·056; 0·066; 0·058. Length of gubernaculum: 0·019; 0·022; 0·016. Pre-cloacal supplement, length/distance anterior to cloacal opening: 0·013/0·106; 0·016/0·131; 0·017/0·099. Tail length: 0·076; 0·092; 0·068. Cloacal diameter: 0·050; 0·057; 0·059. *Females*: Body length: 2·98; 3·29. Body breadth: 0·13; 0·15. Oesophagus length: 0·493; 0·548. Length of cephalic setae, long/short: 0·008/0·007; 0·008/0·007. Cephalic capsule, length/posterior diameter: 0·015/0·026; 0·016/0·028. Distance from anterior end of amphid/eye-spot/excretory pore/nerve ring: 0·013/0·043/0·057/0·183; 0·012/0·046/0·066/0·218. Tail length 0·091; 0·096. Anal diameter: 0·069; 0·073. Distance of vulva from anterior end of body: 1·69; 1·74.

The cuticle is thick and smooth with a few long setae on the body anterior to the nerve ring but very few posteriorly until the tail region in the male and the extreme tip of the tail in the female. In particular there are two setae, between the amphids and the eye spots, which are about the same length as the cephalic setae.

The head is relatively small and the cephalic capsule is long, prominent and simple with a series of small granulations along its posterior edge which continue round the body posterior to the amphids although the capsule itself stops anterior to the amphids (Fig. 4). The amphids are prominent with elongate openings. The mouth opening is triradiate and flanked by an inner circle of six slightly papillose sense organs. The remaining cephalic sense organs are ten setae in one circle, relatively far posterior in position, and all about the same length. Of these setae the lateral members are slightly dorsal in position.

The mouth leads into a triangular cheilostome and there are slight anterior lobes of the oesophagus lying wholly embedded within the surrounding tissue of the head. In *en face* view, there is what appears as a system of thickened rods, within each lip, of which the median rods form a distinct triangle while each nerve to the inner sense organs is surrounded by a curved rod (Fig. 6). I am unable to establish the conditions fully in view of the small size of the head but these structures appear to represent a system of dense material, seen in optical section, surrounding the nerves to the sense organs and possibly the surface of the anterior lobes of the oesophagus. They are possibly comparable to the system described by Timm (1953, 1960) and others in various members of the Leptosomatidae but they definitely do not form simple rods as in the Phanodermatidae (Inglis, 1962). In addition to these structures the dorsal wall of the cheilostome appears to be thickened to form an odontium-like structure which does not arise from the anterior end of the oesophagus.

Ocelli with lens are present. The excretory pore is prominent and leads into a very massive cervical gland which expands posteriorly over the posterior half of the oesophagus and displaces the oesophagus dorsally. In this feature the conditions agree with those described by Filipjev (1927) for *Leptosomella acrocerca* Filipjev, 1927. The oesophagus is not "cellular" in appearance posteriorly.

The tail is short in both sexes and a mid-ventral rod-like supplement is present on the male. The spicules are of an even width with distinct, slightly striated, alae. The gubernaculum is small with rounded, poorly chitinized lateral pieces. The caudal glands lie anterior to the cloacal opening or anus. The reproductive system is doubled and opposed in the females.

Discussion. This species appears to be most similar to *Leptosomella acrocerca* Filipjev, 1927, the type species of *Leptosomella* Filipjev, 1927, a genus to which I refer it with some reservations. The genera *Leptosomatum* Bastian, 1865, and *Leptosomatides* Filipjev, 1918 are both similar to *Leptosomella* but the latter genus appears to be characterized by setose cephalic sense organs, an obvious excretory system and a relatively prominent, but simple, cephalic capsule. If my generic reference of this new species *L. phaustra* is correct, *Leptosomella*, previously based on female characters only, is further delimited by the presence of a rod-like precloacal supplement and ocelli. The arrangement of the structures of the head can be easily interpreted as a simple stage of the typical *Thoracostoma*-type head, for example, in which the musculature of the anterior end of the oesophagus extends anteriorly as a median block from the anterior end of each sector of the oesophagus. Thus the central triangular shape in Fig. 6 represents the outer borders of the muscle block while the remaining two spaces represent the precursors of the cephalic ventricle.

Leptosomatum micoletzkyi sp. nov.

FIGS. 9-11

Locality. Among weed and associated hold-fasts on a rocky flat in about 10 cm water; Cowaramup Bay.

Measurements (mm)—*Male*: Body length: 5·0. Body breadth: 0·098. Oesophagus length: 1·03. Head diameter (posterior end cephalic capsule): 0·026. Length of cephalic setae, long/short: 0·005/0·004. Distance from anterior end of amphid/eye-spot/nerve ring: 0·073/0·11/0·29. Length of spicules: 0·083. Precloacal supplement, distance anterior to cloacal opening: 0·16. Tail length 0·078. Cloacal diameter: 0·069.

The body is covered by very thick smooth cuticle on which no setae could be found posterior to about the level of the nerve ring, except on the ventral surface and the extreme end of the tail. The head is rounded and slightly set-off with an indistinct cephalic capsule. There is no mouth cavity or modification at the anterior end of the oesophagus except for a slight flange bordering the edge of the mouth opening. The dorsal oesophageal gland opens at the level of the posterior edge of the cephalic capsule. There is an inner circle of six tiny, slightly setose sense organs and an outer circle of ten stout setae of which six are slightly longer than the remaining four.

The tiny, relatively far posterior, opening of the amphid leads into a prominent irregularly shaped pouch. The eye-spots have definite lens. The nerve ring is obvious; between it and the anterior end of the body is a series of setae in regular dorso- and ventro-lateral rows but irregularly scattered on the lateral surfaces. There do not appear to be any wholly dorsal and ventral in position. No excretory pore was found.

The tail is conical, short and bluntly rounded with a series of tiny setae near the posterior end. A papillose pre-cloacal supplement is present with a series of ventro-lateral setae between it and the cloacal opening just anterior and lateral to which are two pairs of tiny setae lying close together.

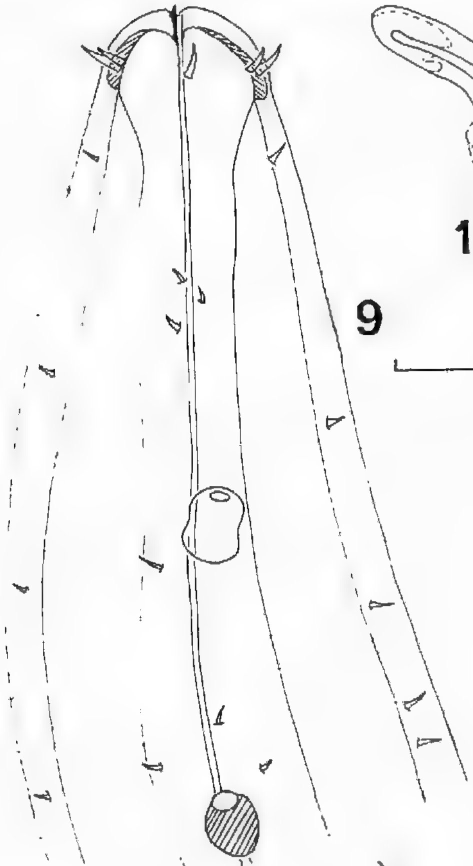
The structure of the spicules and gubernaculum is difficult to establish but the spicules appear to be relatively simple with median supporting ridges or flanges. They are slightly double bent and end distally in blunt tips. The gubernaculum is most strongly developed as a rod-like process which lies lateral and ventral to the spicules, enfolding them near their distal ends. More anteriorly or proximally the gubernaculum becomes much lighter in structure and more difficult to make out but appears to expand rapidly to form large poorly sclerotized membranes (Fig. 10).

Discussion. This species is most similar to *Leptosomatum keiense* and *L. steineri*, both Micoletzky, 1930 and *L. runjhai* Timm, 1960 in possessing a papillose pre-cloacal supplement. However it differs markedly in the posterior position of the amphids and eye-spots, the apparently relatively long cephalic setae, and in the shape and structure of the spicules and gubernaculum.

Figs. 9-11. *Leptosomatum micoletzkyi*. Fig. 9.—Anterior end, lateral view; note posterior position of small amphid. Fig. 10.—Spicule and gubernaculum detail, note prominent ventro-distal rod of gubernaculum. Fig. 11.—Posterior end male.

Figs. 12, 14, 16. *Phanoderma serratum*. Fig. 12.—Anterior end, lateral view. Fig. 14.—Posterior end male. Fig. 16.—Posterior end spicule and gubernaculum, detail.

Figs. 13, 15, 17-19. *Paraphanoderma robynae*. Fig. 13.—Detail of oesophastomal dentition, dorsal view (sketch). Fig. 15.—Head *en face*; note rods associated with inner cephalic sense organs. Fig. 17.—Anterior end, dorsal view. Fig. 18.—Posterior end male. Fig. 19.—Spicule and gubernaculum, detail.
(Scale = 0·02 mm in Figs. 9, 10, 12, 15, 16, 17, 19; Scale = 0·05 in Figs. 11, 14, 18.)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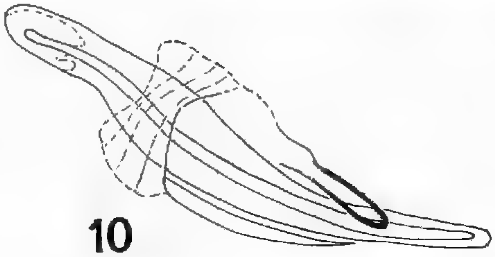
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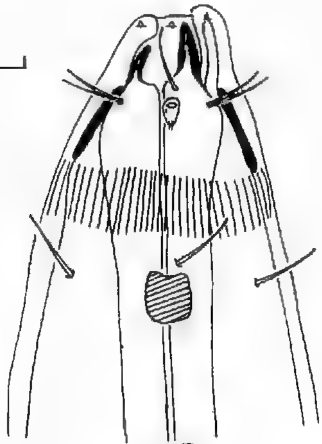
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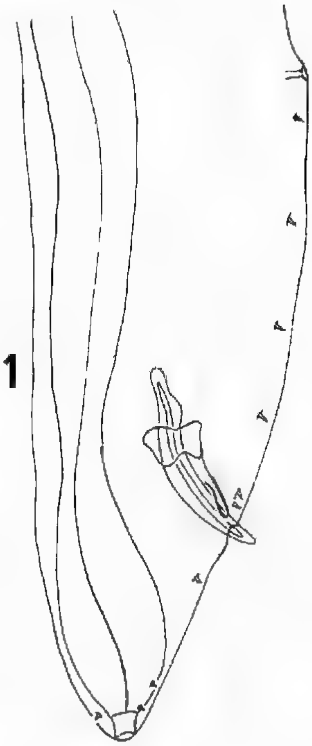
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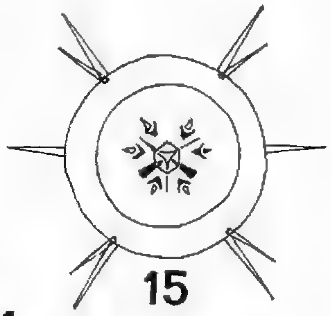
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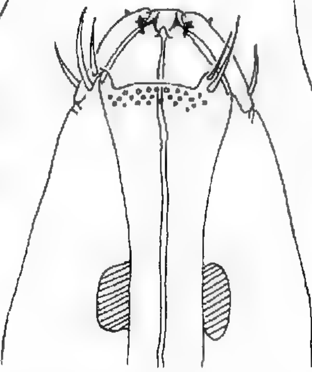
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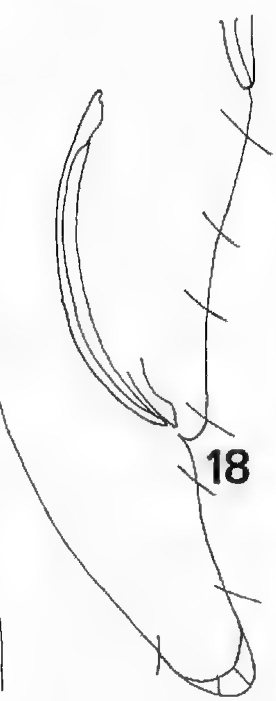
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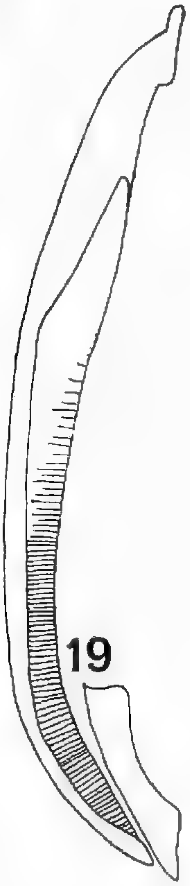
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Family PHANODERMATIDAE

Phanoderma serratum Ditlevsen, 1930

FIGS. 12, 14, 16

Localities. Weed and associated sand without silt on fairly exposed beach in 25 cm of water; Sarge Bay, Cape Leeuwin. Finger-like green sea-weed, in rocks awash at low tide: Bunker Bay, Geographe Bay. Weed and associated sand in hold-fasts, on exposed rocks; Goode Beach, Albany.

Measurements (mm)—*Males*: Body length: 3·09; 3·29; 3·42. Body breadth: 0·094; 0·110; 0·130. Oesophagus length: 0·74; 0·81; 0·78. Length of cephalic setae, long/short: 0·013/0·011; 0·013/0·011; 0·013/0·011. Cephalic capsule length: 0·030; 0·027; 0·033. Distance from anterior end of eye spots/excretory pore/nerve ring: 0·036/0·035/0·26; 0·046/0·046/0·31; 0·038/0·039/0·032. Length of spicules: 0·115; 0·155; 0·152. Length of gubernaculum: 0·039; 0·038; 0·039. Pre-cloacal supplement, length/distance anterior to cloacal opening: 0·027/0·13; 0·033/0·15; 0·033/0·13. Tail length: 0·083; 0·083; 0·083. Cloacal diameter. 0·046; 0·046; 0·052.

The head is typical (Inglis, 1962) with six buccal rods, two large ventral onchia and a small dorsal, plus a well marked, longitudinally striated region posterior to the cephalic capsule. Eye spots are present, fairly close to the posterior edge of the capsule and well anterior to the opening of the excretory pore.

The spicules are long and slim with a series of plate-like ridges on their distal ends, ends which have a slight swelling just anterior to the rounded tips. The gubernaculum is small and simple, rather like a cap round the end of the spicules. The tail is short and stoutish.

Discussion. This species is most easily characterized by the slim serrated spicules, the presence of eye-spots and the presence of a striated cervical capsule; all of which it has in common with *P. parafilipjevi* Allgén, 1939 (see Inglis, 1962).

It is, in fact, doubtful if these two species, *P. serratum* and *P. parafilipjevi*, can be distinguished and it should be noted that my measurement (Inglis, 1962) for the length of the male tail in *P. parafilipjevi* is wrong and should read 0·078 instead of 0·14.

Nevertheless I leave the two species distinct since the striated posterior region of the spicules of the Australain specimens in much greater than in *P. parafilipjevi*, the gubernaculum is a different shape, and the dorsal onchium is shorter than the ventral in *P. serratum* but almost equal in length in *P. parafilipjevi*.

This species was originally described by Ditlevsen (1930) from Bay of Islands, New Zealand.

Paraphanoderma robynae gen. et sp. nov.

FIGS. 13, 15, 17-19

Locality. From among sea-weed and fine sand, among rocks just awash and in rock pools; Bunker Bay, Geographe Bay

Measurements (mm)—*Males*: Body length: 4·50; 4·84. Body breadth: 0·11; 0·13. Oesophagus length: 0·91; 0·94. Cephalic setae, long/short: 0·012/0·009; 0·012/0·009. Cephalic capsule, posterior diameter: 0·025; 0·035. Distance from anterior end of excretory pore/eye spots/nerve ring: 0·039/0·039/0·29; 0·034/0·044/0·30. Length of spicules: 0·127; 0·131. Length of gubernaculum: 0·027; 0·026. Pre-cloacal supplement, length/distance anterior to cloacal opening: 0·027/0·133; 0·026/0·146. Tail length: 0·102; 0·132. Cloacal diameter: 0·068; 0·079. *Females*: Body length: 5·89. Body breadth: 0·21. Oesophagus length: 1.01. Cephalic setae, long/short: 0·013/0·011. Cephalic capsule, posterior diameter: 0·026. Distance from anterior end of excretory pore/eye spot/nerve ring: 0·043/0·049/0·33. Tail length: 0·142. Anal diameter: 0·099. Distance of vulva from anterior end of body: 3·25. Size of eggs (spherical;diameter) 0·102.

The cephalic capsule is poorly developed and there is some slight dotting of the cuticle posterior to it. The mouth opening is small and hexagonal and is surrounded by six thorn-like setae which are supported by six buccal rods (Fig. 15). The outer setae are in two circles of six and four of which the more posterior four are longer. The amphid is small and typical in shape. Eye spots without lenses are present and the excretory pore opens on a level with or anterior to them. There are two poorly developed, thin, sharp, somewhat needle-like ventro-lateral onchia and a similar, but very small, dorsal onchium in the female, although its presence in the male is uncertain. The lateral cephalic setae lie slightly dorsal of the amphid and the lips of the excretory pole are prominent and slightly swollen. The tail is stout and roundish and the caudal glands lie anterior to the cloacal opening.

The spicules are fairly stout with simple alae. A simple, rod-like pre-cloacal supplement is present and the gubernaculum is a simple plate-like structure lying slightly ventral and lateral to the spicules (Fig. 19).

The female reproductive system is doubled, and opposed with reflexed ovaries. The uteri contain large numbers of eggs packed in two or three rows.

Discussion. Difficulties arise in placing this species because of the unsatisfactory descriptions of many of the type species and the diagnoses of many of the genera referred to the Phanodermatidae. Of those for which it is possible to reach some reasonable conclusions this species is most like *Phanoderma* itself and *Phanodermopsis* Ditlevsen, 1926, with a slight chance that it may resemble *Phanodermella* Kreis, 1928. However it differs most markedly from *Phanodermopsis* in the presence of a pre-cloacal supplement and eye spots and from *Phanoderma* in the extreme simplicity of the cephalic dentition and the poorly developed cephalic capsule. The description of *Phanodermella longicaudata* Kreis, 1928, the type species of *Phanodermella*, is such that it is impossible to compare it in detail but that species appears to lack onchia and I suspect that it is probably a species of *Anticoma* in which the cephalic capsule is prominent.

I therefore propose to refer the Western Australian species to a new genus, thus:

PARAPHANODERMA gen. nov.

Phanodermatidae: cephalic capsule poorly developed; poorly developed onchia present, two ventro-laterals needle-like and small and no or a poorly developed dorsal; eye spots present; Male: pre-cloacal supplement present; spicules alate; tail bluntly rounded.

Type Species: Paraphanoderma robynae sp. nov.

It is just possible that *Phanodermopsis necta* Gerlach, 1957 is referable to this genus since it is not happily referable to *Phanodermopsis*.

Family ENOPLIDAE

Enoplus meridionalis Steiner, 1921.

FIGS. 20-26

Locality. Weed and sand associated with hold-fasts in 30 cm water; Radar Reef, Stickland Bay, Rottnest Island.

Measurements (mm)—*Males*: Body length: 3·16; 3·28. Body breadth: 0·093; 0·116. Oesophagus length: 0·51; 0·52. Diameter of head: 0·045; 0·042. Length of mandibles: 0·018; 0·017. Length of cephalic setae, long/short: 0·017/0·015; 0·017/0·014. Spicule length: 0·108; 0·100. Gubernaculum length: 0·036; 0·034. Pre-cloacal supplement, length/distance anterior to cloacal opening: 0·065/0·19; 0·062/0·23. Tail length: 0·175; 0·162. Cloacal diameter: 0·078; 0·083. *Females.* Body length: 3·46; 3·72. Body breadth: 0·135; 0·127. Oesophagus length: 0·51; 0·53. Diameter of head: 0·047; 0·048. Length of mandibles: 0·018; 0·019. Tail length: 0·22; 0·24. Anal diameter: 0·079; 0·081. Distance of vulva from anterior end of body: 2·08; 2·31. Size of eggs (spherical:diameter): 0·089 (13 present); 0·087 (11 present).

The head is typical with the openings of the amphids slightly anterior to the posterior edge of the cephalic capsule and with masses of lateral pigment at the anterior end of the oesophagus.

The male tail is relatively stout and is curved ventrally in fixed specimens. There is a single, median papilla-like organ on the posterior lip of the cloacal opening which is the external expression of an internal tube (Figs. 24 & 26). There is a raised region, on which are borne two barb-like setae, about two thirds of the length of the tail posterior to the cloacal opening. The pre-cloacal supplement is slightly trumpet shaped (Fig. 23) and there is a number of prominent ventro-lateral setae between it and the cloacal opening.

The spicules are massive and roughly the same breadth throughout their lengths except towards the posterior ends where they narrow evenly to end in points which are curved outwards. As a consequence the spicules terminate posteriorly as hooks. The gubernaculum is relatively small and pear-shaped with distinct lateral flanges near the posterior end.

Discussion. This species was described by Steiner (1921) as a variety of *Enoplus communis* Bastian, 1865 but differs from that species markedly in the less pronounced pre-cloacal supplement and the form of the spicules. As a consequence Allgén (1947) and Wieser (1953) recognize *E. meridionalis* as a distinct species.

The specimens described above agree very well with the original description given by Steiner (1921) and the species is well characterized by the slightly trumpet-shaped supplement, the massive spicules with their hooked posterior ends, the post-cloacal papilla-like structure and the pair of hook-like setae on the tail. The structure of the gubernaculum also appears to be characteristic and is the only discordant feature since Steiner illustrates a slightly different shape. It should be noted that the structure of the spicules was established after dissection.

This species was described originally from the Canary Islands in the North Atlantic but has since been found at Port Willunga in South Australia (Mawson, 1953) and by Chitwood (1936) from the coast of North America. Both these reports are supported by descriptions which leave little doubt that the same species was studied. *E. meridionalis* is, therefore, a very widespread species which may be cosmopolitan.

E. meridionalis is also reported and described from La Jolla, California by Allgén (1947) but the illustrations and descriptions are such that it is impossible to know what species was studied.

Enoplus alpha sp. nov.

FIGS. 27-31

Locality. Weed and sand associated with holdfasts, in 30 cm water; Radar Reef, Stickland Bay, Rottnest Island.

Measurements (mm)—*Males*: Body length: 2·39; 3·19. Body breadth: 0·096; 0·109. Oesophagus length: 0·43; 0·48. Diameter of head: 0·043; 0·043. Length of mandibles: 0·016; 0·017. Length of cephalic setae, long/short: 0·014/0·010; 0·014/0·010. Spicule length: 0·109; 0·149. Gubernaculum, length/breadth: 0·030/0·021; 0·038/0·024. Pre-cloacal supplement, length/distance anterior to cloacal opening: 0·029/0·11; 0·039/0·12. Tail length: 0·198; 0·202. Cloacal diameter: 0·074; 0·081.

The head is typical and the amphids open slightly anterior to the posterior edge of the cephalic capsule. Masses of pigment are present on the lateral sides of the oseophagus near the anterior end. The tail is relatively long with a distinctly raised region about half way along its length from which two spine-like setae arise. Two papilla-like structures, on one oval base, occur on the posterior lip of the cloacal opening. The pre-cloacal supplement is simple and rod-like, at right angles to the ventral surface of the body.

The spicules are stout with "doubled" anterior ends due to an infolding of their dorsal surface (Figs. 28, 30, 31) and also bear a barb-like flange about two thirds from the anterior end. The gubernaculum is small with rounded lateral pieces in lateral view and paired median pieces which carry hair-like processes on their posterior ends.

Discussion. This species shows similarities to *E. benhami* Ditlevsen, 1930; *E. paralittoralis* Wieser, 1953 and *E. michaelseni* Linstow, 1896 but differs from them all in the combination of a simple rod-like pre-cloacal supplement, a pair of post-cloacal papillae, a small gubernaculum and the shape of the infolded spicules with only one barb-like plate on the ventral surface.

Epacanthion georgei sp. nov.

FIGS. 33-37

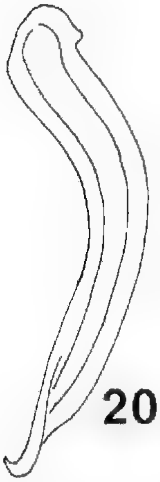
Locality. Beach sand in about 20 cm of water, exposed to breaker action; Cowaramup Bay.

Measurements (mm)—*Male*: Body length: 3·28. Body breadth: 0·074. Oesophagus length: 0·72. Cephalic capsule, posterior diameter: 0·047. Length of cephalic setae, inner/outer short/outer long: 0·013/0·027/0·033. Spicule length: 0·046. Gubernaculum length: 0·029. Tail length: 0·242. Cloacal diameter: 0·049. *Females.* Body length: 3·95; 4·26; 4·43. Body breadth: 0·11; 0·092; 0·10. Oesophagus length: 0·77; 0·82; 0·87. Cephalic capsule, depth/posterior diameter: 0·029/0·055; 0·026/0·053; 0·028/0·056. Length of cephalic setae, inner/outer short/outer long: 0·017/0·017/0·039; 0·018/0·016/0·033; 0·017/

Figs. 20-26.—*Enoplus meridionalis.* Fig. 20.—Spicule, inner surface. Fig. 21.—Spicule and gubernaculum, outer surface. Fig. 22.—Distal tip pre-cloacal supplement. Fig. 23.—Pre-cloacal supplement. Fig. 24.—Oblique view posterior ends spicules and gubernaculum, with cloacal opening and post-cloacal pore-like sense organ. Fig. 25.—Head *en face*. Fig. 26.—Posterior end male.

Figs. 27-31. *Enoplus alpha.* Fig. 27.—Gubernaculum detail. Fig. 28.—Spicule, outer surface. Fig. 29.—Posterior end male. Fig. 30.—Spicule, inner surface. Fig. 31.—Spicules and gubernaculum with doubled post-cloacal sense organ, ventral view.

Fig. 32 *Prooncholaimus mawsonae.* Posterior end male.
(Scale a = 0·05 mm in Figs. 26, 29; b = 0·02 in Figs. 22, 25; c = 0·05 in Figs. 20, 21, 23, 24, 27, 28, 30, 31, 32.)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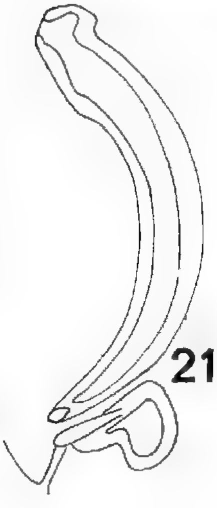
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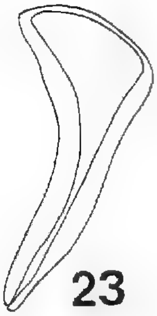
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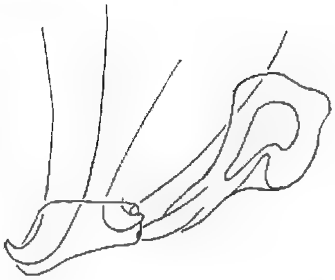


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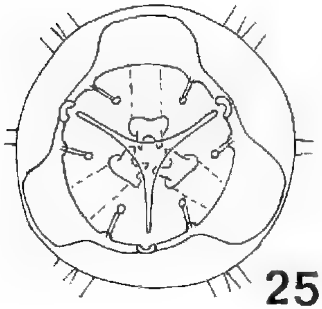
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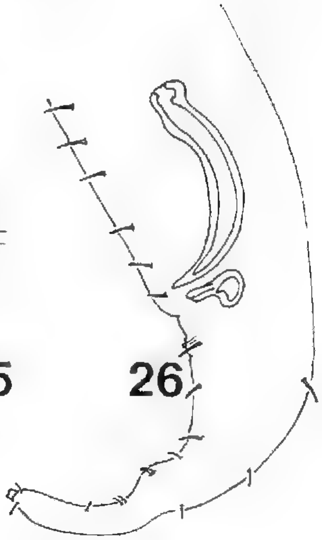
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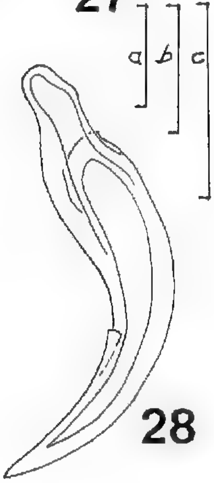

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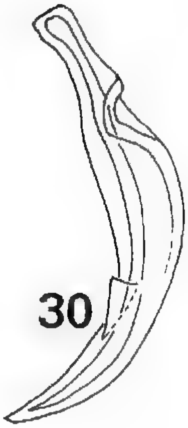
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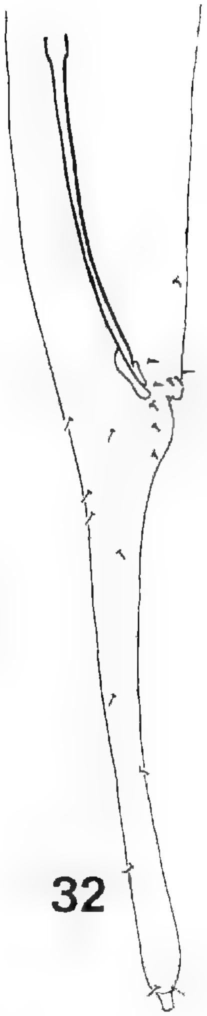
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0·017/0·036. Length of tail: 0·312; 0·377; 0·374. Anal diameter: 0·069; 0·063; 0·066. Distance of vulva from anterior end of body: 2·13; 2·39; 2·41. Size of eggs: 0·325 × 0·066 (in 4·26 mm specimen only).

The head bears three high, narrow lips with semi-lunar striations. The setae of the inner circle are fairly long while the six of the intermediate circle are very long with the four of the outer circle much shorter and lying immediately posterior to the dorso- and ventro-lateral components of the intermediate circle. The small pockets of the cephalic slits are almost wholly lateral in position while the amphids are small and typical.

The mandibular:onchial complex is represented by mandibles which appear, in optical section, to consist of two hooked rods joined by a thin central sheet of cuticle. The usual squarish blocks of dense material, developed in the outer body cuticle, lie on a level with the anterior ends of the mandibles. The onchia are subequal in size, with the dorsal slightly smaller, and lie on the level of the posterior edge of the mandibles, thus approximating the conditions described for *E. multipapillatum* (Wieser, 1959). There are no obvious onchial plates (Figs. 33-34).

In the female there is one circle of short cervical setae just posterior to the posterior edge of the cephalic capsule. The total number of these setae varies from specimen to specimen but they form six groups dorso-, and ventro-lateral and wholly lateral in position. The conditions in the male are more complex with a circle of twenty-four setae in twelve pairs lying posterior to the outer cephalic setae. About the same distance posterior to this circle of cervical setae as this circle is from the anterior end of the body lies another circle consisting of setae arranged in roughly the same twelve groups but there are not always two setae per group. Almost immediately posterior to this circle again is a series of four patches of about ten setae dorso- and ventro-lateral in position. Immediately posterior to these patches is yet another circle of setae arranged roughly in twelve groups (Fig. 37). Setae become scarcer on the body posterior to this level but occur sporadically over the length of the body.

The tail is long and slim in both sexes and there is no pre-cloacal supplement or other modifications on the male. The spicules are short and stout with expanded proximal ends and there is a small plate-like gubernaculum.

Discussion. This species is characterized by the distribution of the cervical setae, by the short, stout spicules in association with the long slim tail, the small gubernaculum and the absence of any pre-cloacal supplement(s). In the characters of the male tail it resembles most closely *E. oliffi* Inglis, 1966 and *E. multipapillatum* (Wieser, 1959) but differs from both in the spicules, which are not serrated posteriorly, and in the number and arrangement of the cervical setae. In addition *E. oliffi* lacks a gubernaculum while in *E. multipapillatum* the gubernaculum has a slight, hook-like apophysis.

Family ENCHELIDIIDAE

Eurystomina eurylaima (Ditlevsen, 1930).

FIGS. 38-40

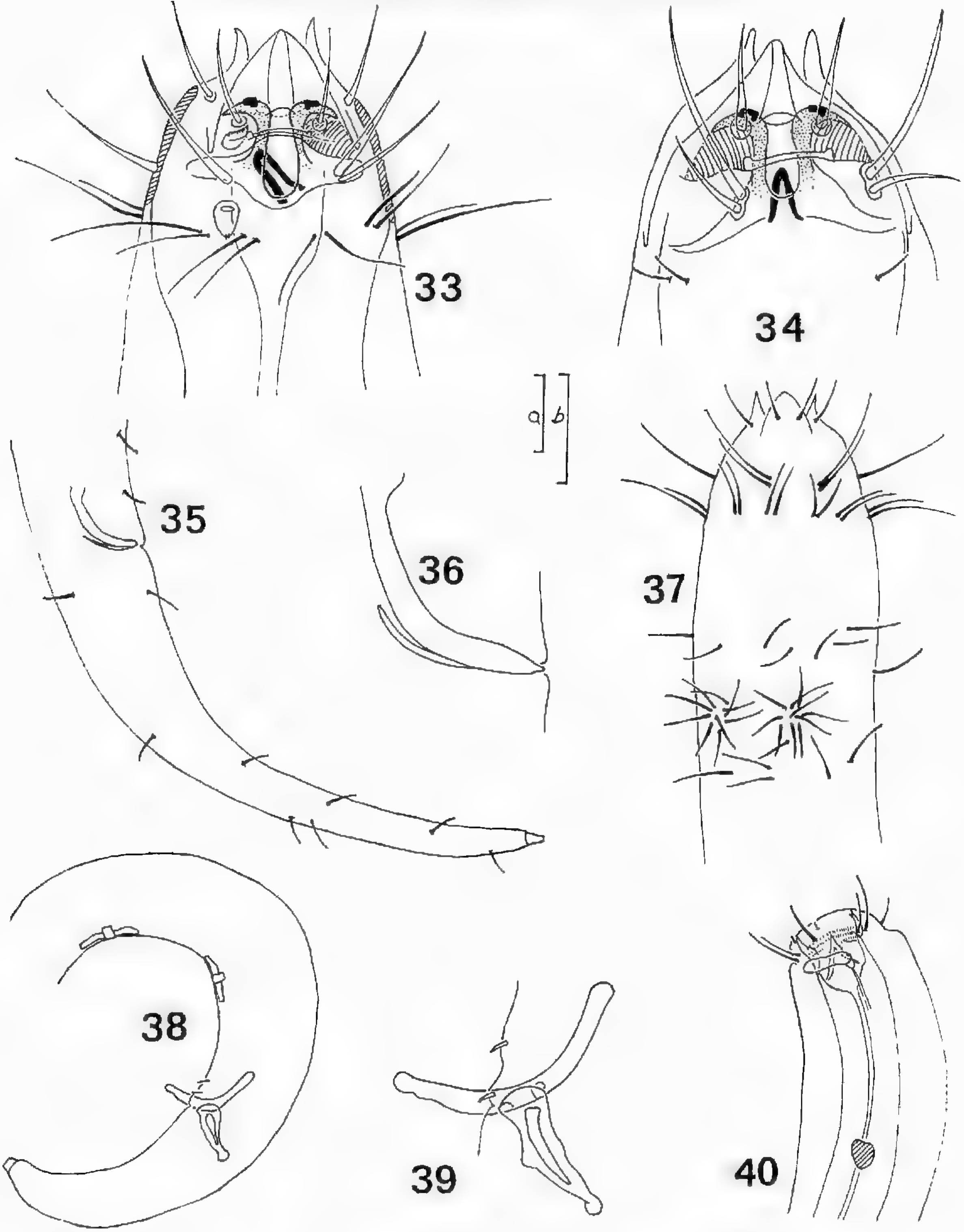
Marionella eurylaima Ditlevsen, 1930.

Localities. Among gravel and weed in 5 metres of water; off Woodman's Point in Cockburn Sound. Weed and sand in 1 metre of water; Radar Reef, Strickland Bay, Rottnest Island.

Measurements (mm)—*Male*: Body length: 2·13; 3·94. Body breadth: 0·040; 0·049. Oesophagus length: 0·55; 0·65. Length of cephalic setae, long/short: 0·008/0·005. Buccal cavity, total length/breadth anterior chamber: 0·013/0·005; 0·016/0·009. Distance from anterior end of eye spot/nerve ring: 0·044/0·205; 0·048/0·216. Chordal length of spicules: 0·046; 0·059. Gubernaculum length: 0·027; 0·029. Pre-cloacal supplements, distance anterior to cloacal opening, anterior/posterior: 0·11/0·054; 0·13/0·081. Tail length: 0·099; 0·113. Cloacal diameter: 0·035; 0·043.

The head is typical with three rings of small denticles in the buccal cavity of which the posterior ring is incomplete, lacking denticles opposite the right ventro-lateral onchium. The amphids are in their typical dorso-lateral position, with the nerves entering them from the lateral end, and an eye spot is present. The six cephalic sense organs of the inner circle are slightly setose and in the outer ring of ten setae six are longer than the remaining four.

The tail is relatively short and the usual two pre-cloacal supplements are present with anteriorly and posteriorly directed "wings". The spicules are evenly curved and of an even width throughout their lengths except for a slight constriction before the distal tip which is rounded and bulb-like. The gubernaculum is



Figs. 33-37. *Epacanthion georgei.* Fig. 33.—Male head, ventro-lateral view. Fig. 34.—Female head, dorsal view. Fig. 35—Posterior end male. Fig. 36—Spicule and gubernaculum. Fig. 37—Anterior end male showing distribution of cephalic and cervical setae.

Figs. 38-40. *Eurystomina eurylaima.* Fig. 38.—Posterior end male. Fig. 39—Spicule and gubernaculum. Fig. 40.—Anterior end, lateral view.
(Scale a = 0·02 mm in Fig. 37; b = 0·02 in Figs. 33, 34, 36, 39, 40; b = 0·05 in Figs. 35, 38.)

prominent, roughly triangular in lateral outline and ends in a rounded, slightly bulb-like tip.

Discussion. In his original description Ditlevsen (1930) was unable to find any cephalic setae, amphids or eye-spots and the pre-cloacal supplements lacked "wings". This latter feature has been reported from other species as an abnormality and the remaining "missing" structures could easily have been lost during preservation, as Ditlevsen himself points out.

The similarities between the specimens described here and the description given by Ditlevsen are great, with the same shape of spicule with its posterior swelling and a very similar gubernaculum. The greatly discordant feature is, however, in the lengths of the specimens since Ditlevsen's male was 6·3 mm long. I assume that my specimens are young males since all the measurements are roughly in proportion.

It is perhaps worth drawing attention to and stressing the fact that on the structure of the head it would be impossible to distinguish this species from many others of the genus and that I am sure that because of the obviously poor condition of his specimens (see Ditlevsen's figure 37) Ditlevsen overlooked the third row of denticles. I have stressed elsewhere that the structure of the male reproductive organs, spicules and gubernaculum, are very useful in delimiting species within this genus (Inglis, 1962). Nevertheless I am prepared to accept the point made by Wieser and Hopper (1967) that I was over enthusiastic since, obviously, other features (which had been stressed before) are of some value, just as the male characters (which had not been stressed before) are clearly of great value. But Wiesser and Hopper use, as an example of the weakness of my argument, *E. minutisculae* Chitwood, 1951, which they redescribe. But I find it impossible to accept that the species they redescribe is the same as that described originally by Chitwood in 1951 although it is very like the species described by Timm (1952) under that name. On the other hand it looks considerably more like the specimen described by Chitwood as *E. americana* in 1936.

It is inconceivable to me that Chitwood, even at his worst (which is usually better than most bests) could have drawn the massive square gubernaculum of *E. minutisculae* in mistake for the slim structure described by Wieser and Hopper and by Timm. I further cannot agree that the differences between the gubernacula of the two species as illustrated by Chitwood are slight, always accepting that such a judgement is very much a matter of opinion. On the other hand if the slight differences, which run to a totally different outline, could be due to errors in observation it is equally feasible, and to me much more likely, that the denticles in the buccal cavity were misinterpreted. No matter which answer we accept there is an error in the descriptions somewhere, as Wieser and Hopper imply.

Family **ONCHOLAIMIDAE**

Prooncholaimus mawsonae sp. nov.

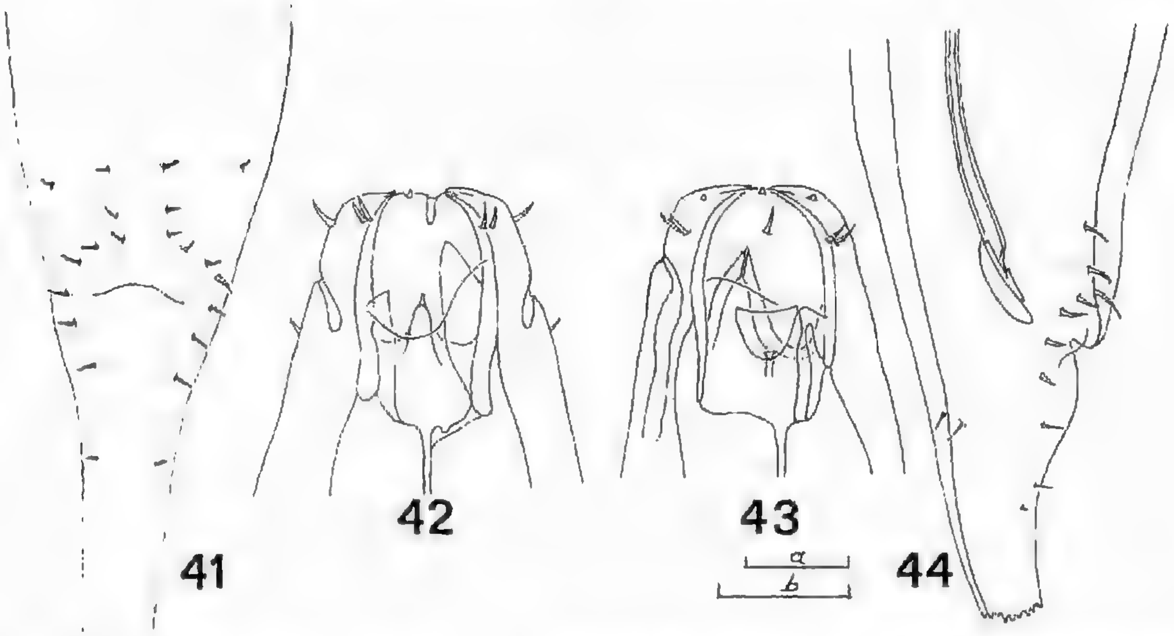
FIGS. 32, 41-43

Locality. Collected from the water filters of the sea-water aquarium in the Zoological Department, University of Western Australia.

Measurements (mm). *Males*: Body length: 2·54; 2·85; 3·44. Body breadth: 0·068; 0·066; 0·079. Oesophagus length: 0·43; 0·44; 0·47. Length of cephalic setae: 0·004; 0·005; 0·004. Buccal cavity, length/breadth: 0·034/0·017; 0·038/0·017; 0·036/0·019. Distance from anterior end of excretory pore/nerve ring: 0·011/0·22; 0·010/0·23; 0·012/0·23. Spicule length: 0·085; 0·096; 0·083. Gubernaculum length: 0·017; 0·015; 0·012. Tail length: 0·13; 0·14; 0·14. Cloacal diameter: 0·029; 0·030; 0·030. *Females.* Body length: 3·25; 3·50; 3·51. Body breadth: 0·086; 0·089; 0·089. Oesophagus length: 0·44; 0·46; 0·48. Length of cephalic setae: 0·005; 0·006; 0·006. Buccal cavity, length/breadth: 0·043/0·019; 0·042/0·019; 0·043/0·018. Distance from the anterior end of excretory pore/nerve ring: 0·012/0·22; 0·021/0·23; 0·023/0·23. Tail length: 0·15; 0·18; 0·17. Anal diameter: 0·035; 0·040; 0·039. Distance of vulva from anterior end of body: 2·44; 2·54; 2·73. Size of eggs: 0·066 × 0·066 and 0·059 × 0·067.

This species is typical of the genus with slightly subequal cephalic setae, and a large buccal cavity in which the left ventro-lateral onchium is larger than the other two which are equal. The usual bubble-like cells are present but variable, particularly in the males where they were almost not present in some specimens.

The tail is long and slim in both sexes and the posterior lip of the cloacal opening in the male is not cut back relative to the anterior lip. The cloacal opening is usually surrounded by a series of six pairs of setae. The spicules are



Figs. 41-44. *Prooncholaimus mawsonae*. Fig. 41.—Male cloacal region ventral view. Fig. 42.—Head, ventral view. Fig. 43.—Head, lateral view. Fig. 44.—Male cloacal region, lateral view. (Scale a = 0·02 mm in Figs. 41, 44; b = 0·02 in Figs. 42, 43.)

typical with barbed posterior ends in which the barb is not set-off from the shaft of the spicules by a distinct "handle" (Fig. 44). The gubernaculum is a rounded mass.

The female reproductive system is single with a reflexed ovary.

Discussion. The form of the spicule which has no distinctly set-off barb eliminates *P. banyulensis* Inglis, 1962 and *P. hastatus* Wieser and Hopper, 1967 from consideration and leaves *P. eberthi* (Filipjev, 1918), *P. ornatus* Kreis, 1932, *P. uransas* Chitwood, 1951 and *P. megastoma* (Eberth, 1863). Wieser and Hopper (1967) treat *P. mediterraneus* Schuurmans Stekhoven, 1943 and *P. megastoma* var. *neapolitanus* Micoletzky, 1924 as synonyms of *P. megastoma*. With this I agree, also with their treatment of three species named by Kreis (1932) as *species inquirendae*.

The present species differs from *P. ornatus* and *P. aransas* in the barbed spicules, and differs from *P. eberthi* in the sharply pointed posterior end to the barb of the spicule (blunt in Filipjev's illustration, Plate 4, Fig. 27d) and the short gubernaculum (long and slim in Filipjev's Fig.). In addition to the slight difference in the shape of the posterior end of the spicule this species differs from *P. banyulensis* in the greater number of peri-cloacal setae, the shorter cephalic setae (0·004-5 against 0·007), the poorly developed "balloonings", and the relatively shorter spicules.

This leaves *P. megastoma* to be considered, a species reported by Mawson (1957) from South Australia. The original description of this species is poor but if we accept that *P. mediterraneus* is the same species, the Western Australian species differs from it in the hooked posterior end to the spicule as well as the length of the spicules which, from Schuurmans Stekhoven's (1950) figure of the male tail (Fig. 28D), must be about 0·26 mm long. Here they are only 0·083-0·096 mm long, although the total body lengths are comparable.

It is difficult to be sure about any of this because the barb on the spicules is not pronounced and could have been overlooked. Until there is further information this species must be considered different from *P. megastoma* and also from the species recorded under the same name by Mawson (1957).

Acknowledgments

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A NEW SPECIES OF MICROHYLID FROG OF THE GENUS *SPHENOPHRYNE* FROM MILNE *BAY*, PAPUA

BY M. J. TYLER AND J. I. MENZIES

Summary

A new species of terrestrial, forest-dwelling, microhylid frog, *Sphenophryne dentata* is described. It is unique amongst Papuan members of this family in having well developed maxillary and premaxillary teeth, and numerous, prominent folds on the skin of the dorsum. The mating call is analysed and described, and is noteworthy in lasting for nearly ninety seconds. Ecological differences between this species and twelve other species found in the same forest are briefly discussed.

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Introduction

Nineteen species of microhylid frogs have been found at the south-eastern extremity of Papua and from islands adjacent to this portion of the mainland. Parker (1934) reported seven species, Zweifel (1956) a further ten, and Zweifel (1963) two more. Of the total, eight species are currently known solely from this area. Milne Bay is located at the extreme eastern end of Papua. Collections made there by one of us (J.I.M.) in 1969 and 1970 included twenty-two specimens of an undescribed species of the microhylid genus *Sphenophryne*.

In our description of this species we have followed very closely the methods, descriptive format, and terminology adopted by Zweifel (1967). The abbreviations used in the text are as follows: S-V = length from snout to vent; TL = tibia length; HW = head width; E = eye diameter; IN = internarial span; E-N = eye to naris distance; SN = snout length; T = tympanum diameter.

Mating calls were recorded in the field on an E.M.I. type L.4 tape recorder, and analysed on a Kay Electric Company Sonagraph.

For the terms used in describing the sonagrams see Irby-Davis (1964).

The type series has been deposited in the collections of the Department of Biology, University of Papua and New Guinea (abbreviated in the text to U.P.N.G.) and the South Australian Museum (S.A.M.).

Sphenophryne dentata new species

Holotype: S.A.M. No. R.12063 collected near Alotau, Milne Bay, Territory of Papua on 11 November 1970, by J. I. Menzies.

Paratypes: U.P.N.G. No. 1727, S.A.M. No. R.11828, collected at the type locality on 8 October 1969; U.P.N.G. Nos. 2625-2629, 2640-2646, S.A.M. Nos. R.11819-11827, collected at the type locality during the period 6-12 November 1970.

Diagnosis: This is a terrestrial species, and the combination of characters that is unique to it is as follows: body size: moderate (snout to vent length up to 37.2 mm); maxillae and premaxillae dentigerous, fingers and toes with small discs, skin of dorsal surface of body bearing numerous prominent tubercles and raised folds.

Description of Holotype (fig. 1): The holotype is a gravid, adult female with the following measurements: S-V, 37.2 mm; TL, 18.4 mm; HW, 16.6 mm; E, 4.8 mm; E-N, 3.7 mm; IN, 4.0 mm; SN, 6.2 mm; T, 2.9 mm; disc of third finger, 0.9 mm; penultimate phalanx of third finger, 0.7 mm; disc of fourth toe, 1.4 mm; penultimate phalanx of fourth toe, 0.7 mm. The maxillary bones are eleutherognathine and bear, as do the premaxillaries, small teeth. The post-choanal portion of the vomer bears a transverse ridge on which there are numerous, minute odontoids. There are two transverse pre-pharyngeal ridges: a diffuse glandular one, preceding a more highly developed posterior ridge terminating in triangular serrations. The tongue is extremely broad, approximately one-half free and has two posterior flaps

The pectoral girdle is similar to that of *S. cornuta* described and illustrated by Parker (1934).

The snout is blunt and very slightly rounded when viewed from above and in profile. The

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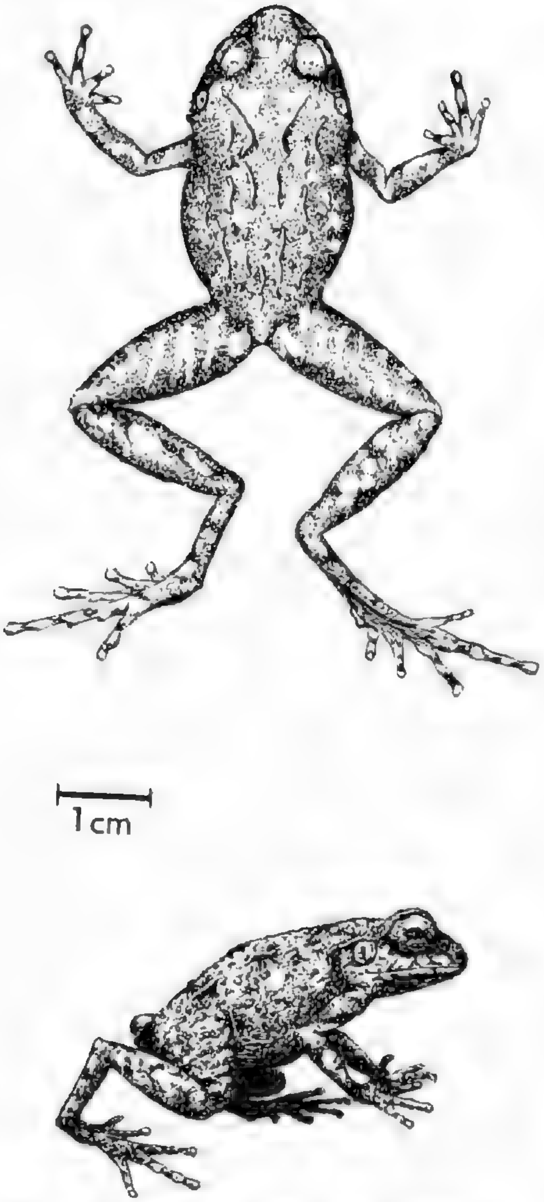

Fig. 1. *Sphenophryne dentata* new species.

head is as broad as the body, and its width is slightly less than one-half of the snout to vent length (HW/S-V = 0.45).

The eyes are large and prominent with a horizontal pupil and the interorbital distance is only slightly greater than the width of an upper eyelid. The snout is approximately one and one-third times the length of the eye (SN/E = 1.29). The loreal region is sloping and slightly concave, and the canthus rostralis slightly rounded but not prominent. The nostrils are directed laterally, and the distance from eye to naris is slightly less than the internarial-span (E-N/IN = 0.92). The tympanum is distinct.

The fingers and toes bear small terminal discs on which there are marginal grooves. The discs of the toes are much larger than those of the fingers; the ratio of the width of the disc of the third finger to that of the fourth toe is 0.64. The relative difference in development of finger and toe discs is reflected by the ratios of disc width to the width of the penultimate phalanx. Those of the above digits are 1.29 and 2.0 respectively. Fingers and toes in decreasing orders of length 3>4>2>1 and 4>3>5>2>1 respectively. Subarticular tubercles are poorly developed beneath the fingers but well developed beneath the toes. There is an elongate and prominent inner metatarsal tubercle and a circular and poorly developed outer metatarsal tubercle.

The skin of the dorsal surface of the head and body is extremely irregular, bearing numerous prominent tubercles and sharply defined skin folds. The skin folds follow the longitudinal axis of the body except for those immediately behind the head which form the letter **W**. There is a prominent supratympanic fold. The ventral surfaces are smooth and the flanks slightly tubercular.

In preservative the ground colouration of the dorsal surface of the body and limbs is dark brown. Upon the dorsum there are a few, irregularly shaped, small patches now fading from orange to grey. A pair of these patches are located within the **W** mark on the back, and others on each side of the coccyx and on other portions of the back and flanks. The posterior surfaces of the femora bear pale, narrow transverse bands. The mandibular border is brown and the remainder of the ventral surface of the body lacks pigment.

Variation: The twenty-one paratypes include adults and juveniles. Several of the adult females are gravid, the smallest having a snout to vent length of 34.7 mm and the largest 37 mm. The means and ranges of the characters recorded are as follows: TL/S-V = 0.50 (0.47-0.54); HW/S-V = 0.43 (0.41-0.45); SN/E = 1.20 (1.07-1.29); E-N/IN = 0.91 (0.80-1.00).

All paratypes share with the holotype a dark brown dorsal ground colouration. The lighter markings described above vary in their distribution and are absent in several specimens.

In life the colouration of the dorsal surface varies from sandy brown to reddish brown, stippled or mottled with darker and lighter brown, and with occasional orange patches of an irregular distribution. The scapular W-mark is occasionally reddish. The backs of the thighs are usually grey, and finely stippled with white, but sometimes pinkish. The ventral surface is white, with sparse grey mottling on the sides of the throat. The groins and lower sides of the hind limbs are reddish, sometimes bright red. There is a light diagonal stripe through the tympanic membrane and the iris is a greenish gold.

Comparison with Other Species

Sphenophryne dentata differs from all Papuan microhylids in possessing well developed teeth, and bears a striking resemblance to members of the ranid genus *Platymantis*. This is, however, only a superficial resemblance because the pectoral girdle is typically that of *Sphenophryne* and further lacks the bony omosternal elements that characterise Papuan ranids. Similarly the Musculus cutaneous pectoris which is present in all Papuan ranid genera is lacking in this species, as in all other microhylids examined (Tyler 1971a, 1971b). Additional features supporting the familial disposition of the species are the procoelous condition of the vertebrae, dilation of the sacral diapophyses and the presence of prepharyngeal, palatal folds.

The presence of teeth and of numerous skin folds are unique to this species and render it one of the most distinctive members of the genus. Of the fourteen species currently recognised, three Australian species (*S. fryi*, *S. pluvialis*, and *S. robusta*) and five Papuan species (*S. brevicrus*, *S. brevipes*, *S. crassa*, *S. mehelyi* and *S. polysticta*) are small robust animals not exceeding 30 mm in length.

Some of the salient distinguishing characters of the remaining species are as follows: *S. palmipes*, sympatric with *S. dentata*, is mainly aquatic and is readily distinguished by the presence of extensive webbing between the toes (absent in *S. dentata*). *Sphenophryne cornuta* possesses vestigeal teeth but exhibits a large conical tubercle on each upper eyelid, and in life may be bright red on the ventral surface; *S. hooglandi* has a prominent snout, smooth skin and a different colouration. *Sphenophryne macrorhyncha*, also mainly an aquatic species, has slight webbing between the toes, and the nostrils are equidistant between the eye and tip of the snout; *S. rhododactyla* has a dark ventral surface with lighter markings, the finger discs are larger than the toe discs, and the maximum recorded snout to vent length is 60 mm. *Sphenophryne schlaginhaufeni* possesses skin folds on the scapular region but lacks the other folds and rugosities of *S. dentata*. It is readily distinguished from *S. dentata* by the shape of the snout (angular and strongly projecting in profile, with a very sharp canthus rostralis) and by its possession of a black loreal mask.

Ecological Note

All the specimens were collected on the forest floor of hillsides above the town of Alotau, Milne Bay District of Papua. These hillsides are steep and are dissected into numerous ridges and gullies by small streams running down to Milne Bay. The forest is well developed and remains largely untouched other than in the immediate vicinity of the town. The rainfall of the region is high (annual mean approximately 3,000 mm; 120 inches) but a season in which there is slightly less rainfall than in the remainder of the year usually commences in November and lasts until March or April.

In October 1969 few males were heard calling and only two were collected. However, in November 1970 large numbers were heard and found all over the forest floor. Because many of the adult females collected on the latter occasion were gravid, it appears that the breeding season corresponds to the 'dry' season at Milne Bay.

All the specimens in the type series were collected at altitudes between 60 and 150 metres (200-500 ft) above sea level. The maximum altitude at which the species occurs there is unknown, but the mountains in the region do not extend much above 1000 metres (approximately 3000 ft). The species occurs at slightly higher elevations on Mt Dayman, approximately 100 Km north-east of the type locality. A specimen taken at 1550 metres (American Museum of Natural History No 56734) and tentatively referred to *S. schlaginhaufeni* by Zweifel (1956) has been examined by one of us (J.I.M.), and is considered to be a juvenile *S. dentata*.

Twelve other species of frogs, including nine microhylids were collected in the same forest as *S. dentata*, but ecological differences appear to separate most of them. *Sphenophryne palmipes* is aquatic: *Litoria genimaculata* (formerly *Hyla genimaculata*) and *Oreophryne biroi* are arboreal; a species of *Rana* is only found at the streamsides; *Cophixalus verrucosus*, *C. ateles*, and an *Oreophryne*

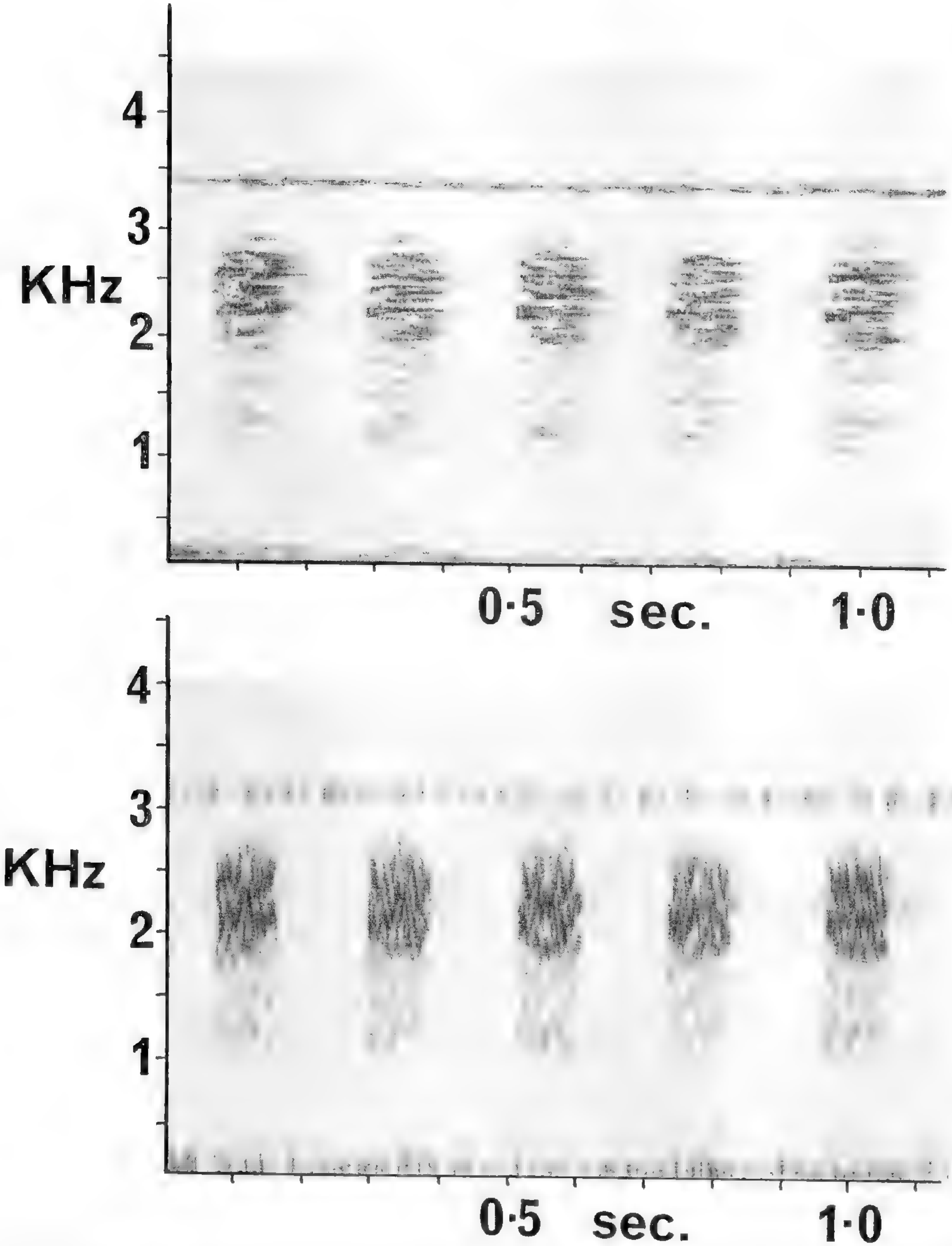

Fig. 2. *Sphenophryne dentata*. Sonagrams made from the middle of the call. (a) narrow filter. (b) wide filter. The continuous trace above 3 KHz is insect noise.

species hide in leaf litter on the forest floor during the day, but ascend low vegetation at night. *Asterophrys doriae* has been collected in subterranean burrows; *Platymantis papuensis* favours the forest floor but at this locality is usually found lower down the hillsides. *Metopostira ocellata*, *Cophixalus oxyrhinus* and *Asterophrys rufescens* are the only species which appear to occupy exactly the same habitat as *S. dentata*.

Voice

The call of the male consists of a very long succession of identical components, at first in acceleration then at a steady rate, finally in deceleration. It lasts for nearly ninety seconds and includes approximately 300 motifs, each of 0.1 second duration and including twelve figures. There is no clearly defined frequency intensity maximum: several bands between 2 and 3 KHz appear of equal importance. Sonograms of a small portion of the middle of the call are shown in Figure 2.

The acoustic impression is rather like the rapid bark of a dog and the call can be heard at a distance of several hundred metres.

Acknowledgements

We wish to express our thinks to Mr Colin Jennings, formerly of Alotau High School, for much assistance in the field, and to Dr Richard G. Zweifel (American Museum of Natural History) and Dr W. G. Inglis (South Australian Museum) for helpful comments on the manuscript.

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THE DENUDATION CHRONOLOGY OF THE FLEURIEU PENINSULA, SOUTH AUSTRALIA

BY E. J. BROCK

Summary

Some aspects of the geomorphology of the Fleurieu Peninsula are examined from an evolutionary standpoint. Convex and concave breaks of slope serve to delineate physiographic regions defined on the Peninsula.

Summit planate remnants, capped by laterite, have been mapped. These are the dissected remnants of a peneplain, named the Parawa Peneplain, to which a Mesozoic age is assigned. Various forms of laterite are described, and the question of their origin and age crucial to a reconstruction of the evolution of the Peninsula, is examined. A Mesozoic to Early Tertiary age is assigned to the high level laterite. Other lower level laterites are interpreted as low-slope cappings formed after the high level ones.

The morphology of Tunkalilla Creek and the associated dissected terrain is examined and erosional chronologies of the Creek are proposed. A chronology based on a three-phased uplift of the Peninsula in Eocene (?), Late Miocene, and Plio-Pleistocene times is preferred.

Evidence of high sea levels attributed to Tertiary tectonism is cited for 201-207, 183-192, 119-125, and 58-64 m ASL. Lower levels at 40-44 and 8 m ASL are related to glacioeustasism of the Pleistocene.

Ideas based on the model of Kennedy, and to some extent of Davis and Penck, appear most appropriate for the construction of the evolution of the region.

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Introduction

Several general theories of landscape evolution have been proposed and it is the purpose of this paper to examine the Fleurieu Peninsula with particular reference to the cyclic models of Davis (1954) and Penck (1953) and the noncyclic model of Kennedy (1962) for whom the issue revolves around the relative rates of uplift, erosion, and denudation.

Topographic and Geologic Setting

Fleurieu Peninsula, the most southerly part of the Mt. Lofty Range Province[1], rises to 375 m above sea level[2], and covers an area of approximately 518 square kilometers. It is flanked by Gulf St. Vincent, Backstairs Passage, and the Southern Ocean. To the north lies a valley depression, Inman Valley, which trends ESE-WNW from Encounter Bay to Yankalilla Bay. Within the study area streams radiate from the lateritic backbone of the upland. In their lower reaches they are cut in either the metasediments of Cambrian, Proterozoic, and Archaean ages which form the basement rock of the Peninsula and upon which the laterite profile has developed, or in unconsolidated sands, clays, and compact sandstones of Permian age which lie unconformably on the older rocks.

The Province has been subjected to at least three phases of orogeny. Little is known concerning the first in Archaean time. The second in the early Palaeozoic was characterized by intense folding of the sediments of the Adelaide geosyncline. Low angle shears and thrusts developed either in place of or accompanying the folds. The third, in Tertiary time, was characterized by block faulting along lines of weakness inherited from the Palaeozoic phase (Sprigg 1942; Glaessner 1953; Campana 1954; Webb 1958).

During the Tertiary the Peninsula acted as a tectonic unit. Uplift began in the early Tertiary and continues to the present day (Kerr Grant 1955; Sutton & White 1968). The tectonics involved three major phases of uplift of the Mt. Lofty Ranges (Webb 1958); the first in Early Tertiary (Eocene ?) time, the second in the Late Miocene bringing sedimentation to a close in the Myponga and Hindmarsh Valleys, and the third in Late Pliocene or Early Pleistocene time. Campana

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[1] The term "Province" is used as defined by Linton (1951), and refers to a region throughout which there has been uniformity of structural evolution.

[2] All heights are referred to the Port Adelaide Datum, designated ASL in the text.

and Wilson (1953) note that Oligo-Miocene limestone crops out in the Myponga and Hindmarsh Valleys at some 210 m below the level of the nearby lateritic plateau, and attribute this difference to pre Oligo-Miocene upward movements; these caused the exhumation of Permian glacial valleys and basins. Campana and Wilson (1955) further conclude that the cumulative effect of the Tertiary tectonics was an uplift of the "pre-Tertiary peneplain" of some 460 m in the Myponga region, half of which is attributed to the pre Miocene phase.

The southern part of the Peninsula upon which the enquiry is focused has been divided into a number of morphological regions (Brock, M. A. thesis, University of Adelaide, 1964). In summary, the centrally located Parawa High Plain and Ridge & Vale Section are surrounded by the South Coast Valley Region, Cape Jervis Lowland, Mt. Rapid Hill Country, Finnis Vale Region, and the Inman Valley Lowland (see Fig. 1).

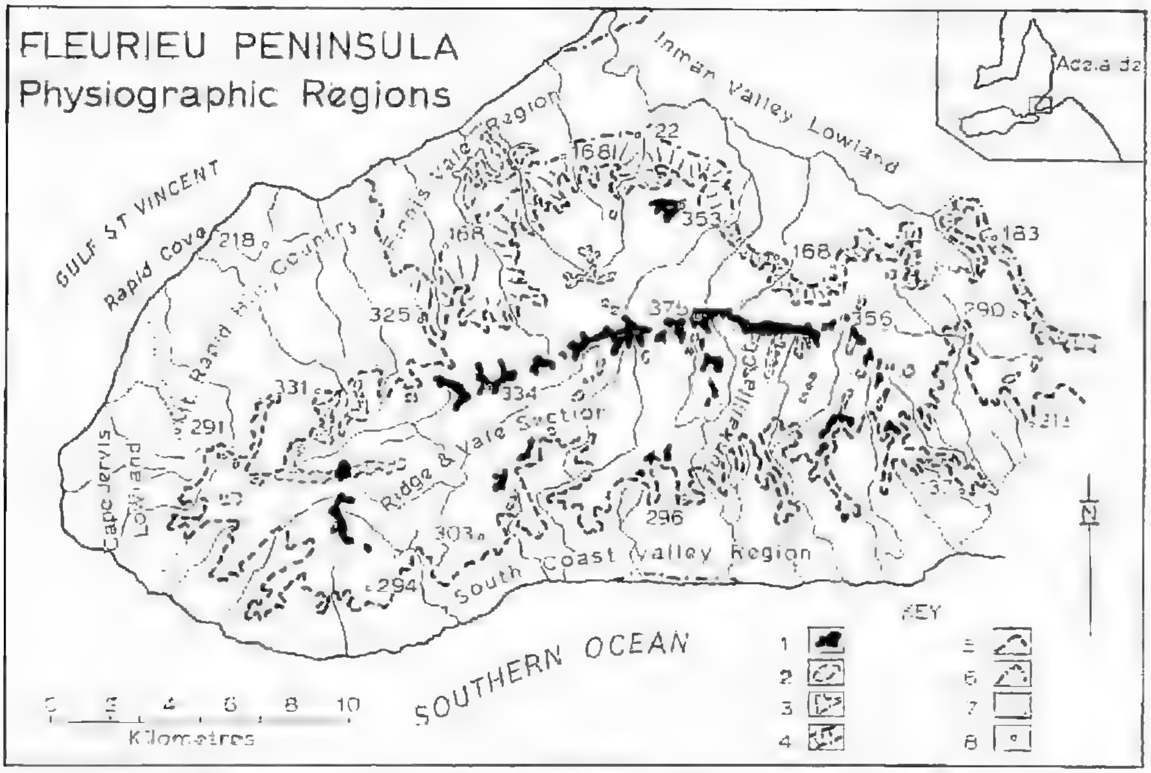


Fig. 1. Explanation of key. 1: Parawa High Plain, remnant of the Parawa Peneplain. 2: Etch surface capped by truncated laterite. 3: Surface of partial peneplanation graded to 61 m ASL base level. 4: Bedrock scarp. 5: Convex break of slope. 6: Concave break of slope. 7: Regional boundary along ridge crest. 8: Spot height, metres ASL.

Geomorphology of Typical Regions and Features

The Parawa High Plain

The Parawa High Plain occurs as isolated remnants on an E-W ridge, and on spurs branching from this spine. In plan, most lateral extensions and isolated outliers are located south of the spine, and in section they are parts of a dissected dome. Each remnant is of low relief (Fig. 2) and is capped by a laterite profile (Stephens 1946). Following Prescott and Pendleton (1952), the term "laterite" is used to refer to the ferricrete developed within the laterite profile typical of southern Australia and originally described by Walther (1915).

The plain remnants are commonly bounded by bluffs formed on the laterite (the "breakaways" of Jutson 1934), particularly where headwater streams are actively undercutting them. Elsewhere they merge into a lower surface not capped by laterite, on lateral spurs by way of concave break of slope. However, on this surface lateritic gravels in places overlie mottled yellow clays, while elsewhere ironstone occurs as an amorphous mass containing fragments of weathered bedrock, or as weathered bedrock cemented by iron oxides. Both of these varieties of ironstone were formed by the secondary deposition of iron hydroxides accompanying or following the dismantling of the High Plain laterite (see D'Hoore 1954).

It is likely that this topographically lower surface has been formed by the stripping of the High Plain laterite profile because it is generally contiguous with the latter and its soil profile is indeed that of a truncated laterite (Stephens 1946; Mulcahy 1960). As such it is a type of etch surface, and is the morphological equivalent of the Balkuling Surface of Western Australia (Mulcahy & Hingston 1961, who called it a pediment), and the Maranboy Surface of the Daly River Basin (Wright 1963); genetically it belongs to the Ridge & Vale Section.

The pisolitic laterite of the High Plain resemble in appearance the West Australian varieties described by Walther (1915) and Mulcahy (1960), and the "Eleanor Sands" of Kangaroo Island (Northcote 1946). Dissection encourages lateral movement of surface and subsurface waters. Whether or not further accumulation of iron oxides takes place appears to depend in part on the amount of relief (D'Hoore 1954). Where slopes are gentle and lateral movement of water is slow, then accumulation forms low-slope cappings. However, strong dissection encourages rapid movement of surface and subsurface water, and accumulation of iron oxides is not favoured. This condition may account for the low incidence of lateritic detritus in the Ridge and Vale Section.

Two varieties of ironstone occur on the glacigene sands of the Coolawang Creek headwater basin. First, on gentle slopes it occurs as a ferruginous sandstone, a "low-slope capping" (D'Hoore 1954; the "seepage laterite" of Alexander & Cady 1962) formed after the initiation of dissection of the High Plain. Second, a vesicular and poorly laminated form surmounts an isolated summit planate surface (MR 6412, 6093, Torrens Vale, sheet 6526-1, Australia 1:50,000) occurring between 275 and 290 m ASL, and has been mapped as a Parawa High Plain remnant. The laminated form is attributed to the structure of the host sediments.

The age of the Parawa High Plain rests on the age of the laterite developed upon it. Campana & Wilson (1953) consider, without citing direct evidence, that weathering culminating in the formation of the laterite on the Fleurieu Peninsula is of Pliocene to Recent age and that it is still active.

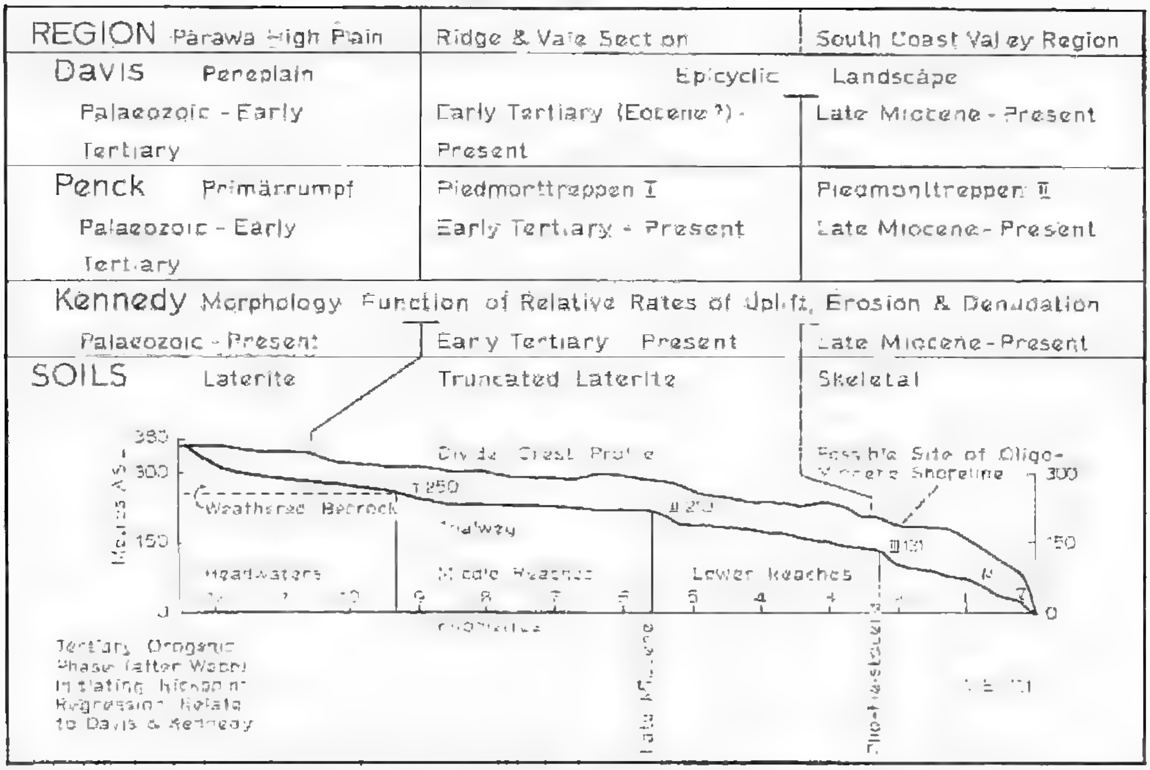
Horwitz (1960) has deduced that two phases of lateritization are evidenced in the Southern Mt. Lofty Ranges. The first suggested phase occurred in pre-Miocene, possibly Eocene time. Horwitz cited the occurrence of glazed pisolites which occur in the base of the Oligo-Miocene limestone near Strathalbyn and which were presumably derived from a preexisting lateritized surface.

The second phase occurred in the Pliocene accompanying peneplanation. Horwitz's evidence for this is twofold. Lower Miocene limestone intersected in a bore near Cloverdale in the Upper Hindmarsh Valley is overlain "By extrapolation by over 500 feet (152 m) of brown ferruginous sands, cross bedded and mottled . . . which are capped by a crust of limonite cemented gravels" (Thomson & Horwitz 1961, The geology of the Milang Sheet, p. 10 Mines Dept., S. Aust; unpublished). The latter occur on an isolated hill. In addition, the high plateau laterite (the equivalent of the Parawa High Plain laterite) is elsewhere continuous with the limonite cemented gravels (in the Upper Hindmarsh Valley) which overlie the Tertiary sediments. This provides evidence that the lateritization of the high plateau occurred in post Lower Miocene time, assuming that the lower level laterite on the sands of the Hindmarsh Valley was indeed formed at the same time as the high plateau laterite. However, similar occurrences of laterite found as iron oxide cemented sands on low angle slopes and at elevations lower than the High Plain laterite (see above) have been interpreted as low-slope cappings formed after the latter. The supposed contemporaneity of the high and lower level laterites is thus called into question.

Tunkalilla Creek

The Tunkalilla Creek drainage basin and its associated landform assemblages, which constitute the Ridge and Vale Section and South Coast Valley Region, typifies all the streams draining south to the Southern Ocean, and its erosional chronology may be taken as characteristic of areas marginal to the Parawa High Plain.

In the headwater embayments below the High Plain, peat marshes commonly occur



REGION	Parawa High Plain	Ridge & Vale Section	South Coast Valley Region
Davis	Peneplain Palaeozoic - Early Tertiary	Epicyclic Landscape Early Tertiary (Eocene?) - Present	Late Miocene - Present
Penck	Primärrumpf Palaeozoic - Early Tertiary	Piedmonttreppen I Early Tertiary - Present	Piedmonttreppen II Late Miocene - Present
Kennedy	Morphology Function of Relative Rates of Uplift, Erosion & Denudation Palaeozoic - Present	Early Tertiary - Present	Late Miocene - Present
SOILS	Laterite	Truncated Laterite	Skeletal

Fig. 4. Tabular summary of geomorphic history, Fleurieu Peninsula, according to the concepts of Davis, Penck & Kennedy.

where the water table is at or near the surface. Downstream, the valley has an open V-shaped transverse profile (Fig. 3), and the stream channel is weakly incised in sands and clays of weathered bedrock and slope wash debris.

The middle reaches of the stream are separated from the headwaters by a nickpoint (I on Fig. 4) on unweathered bedrock. Downstream from the nickpoint the valley floor widens, the stream gradient is gentle with an average fall of 5.9 m per kilometre, and the relief amplitude is of the order of 76 to 92 m (see Fig. 4). In these reaches the stream course is adjusted to the strike of the bedrock.

The lower reaches of the stream are separated from the middle reaches by another nickpoint (II on Fig. 4) accompanied by marked basal slope steepening. Below the nickpoint the stream is confined between steep rectilinear valley sides, the channel gradient steepens with an average fall of 39 m per kilometre, while the relief amplitude attains a maximum of about 100 m. The steep valley side facets grade into the broad summit convexity of the interfluves by way of a convex break of slope, which is genetically associated with the nickpoint II to which it can be traced. Three additional nickpoints occur (III, IV, & V in Fig. 4), below the last of which the graded channel is cut into the surface of a fill terrace underlain by grey, silty alluvium containing abundant charcoal.

The occurrence of several breaks of channel slope (nickpoints) is a characteristic feature of the streams draining to the Southern Ocean. Lewis (1945) cites four factors for the de-

Fig. 2. Parawa High Plain in foreground. Etch surface in Ridge and Vale Section in middle distance. View northwest from 35° 34′S, 138° 22′E.

Fig. 3. Headwater reaches of Tunkalilla Creek. View south.

Fig. 5. Marine abraded boulders at cliff-top site (MR 6148-6224, Cape Jervis, Sheet 6526-IV, Australia 1:50,000) at between 61 and 67 m ASL. Boulders derived from Permian till.

Fig. 6. Surface of partial peneplanation in Finniss Vale Region (see Fig. 1) in middle distance, graded to 61 m general base level. Quartzite ridge in foreground. View landward of site of Fig. 6.

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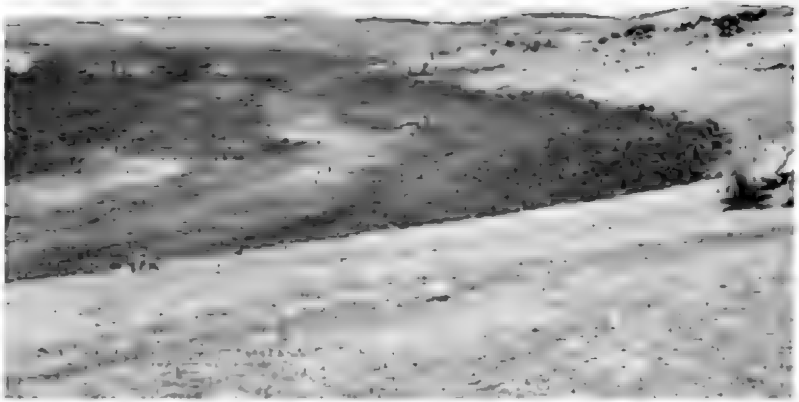

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velopment of nickpoints, namely, rejuvenation; the presence of rock bars; the confluence of streams; and a change in the transport-erosion relations resulting from a change in the nature of the bed material. To these may be added the influence of climatic change, and intermittent shoreline retrogradation (Cotton 1940).

Rejuvenation caused by the relative lowering of the general base level by uplift is considered to be the greatest single factor in the development of the nickpoints in the study region. Geological evidence adduced above demonstrates that the Peninsula, acting as a single unit, has been subjected to uplift since early Tertiary time, at least into the Quaternary, and possibly to the present (Kerr Grant 1955). The valleys commonly display basal slope steepening at and down stream from the nickpoints, a feature most marked in association with nickpoints II, and III, and in the absence of alluvial deposits and paired terraces the best evidence of rejuvenation (Baulig 1940). Below the level of nickpoint II the streams have irregular grades associated with steep valley walls and stranded high level slip-off slope terraces. Those nickpoints thought to be caused by rock bars and increase of discharge at the confluence of a tributary with the trunk stream have been disregarded.

Of the other factors cited above, the influence of shoreline retrogradation deserves consideration. That the south coast is retreating is indicated by the presence of coastal hanging valleys, the development of a narrow marine abrasion platform, and the occurrence of a small stack formed of dune limestone on Tunkalilla Beach, lying some 15 m seaward of the retreating low cliff line cut in alluvium.

The significance of shoreline movement as a causative factor is difficult to appraise since the rate and magnitude of uplift together with the rate of stream incision also must be taken into account. However, rapid intermittent advances of the sea of considerable magnitude, beyond that for which evidence exists, would be necessary to account for the observed succession of nickpoints. Therefore it is concluded that uplift is the primary factor with shoreline movement playing a relatively insignificant role.

Even if they did occur (Castany & Ottmann 1957; Twidale 1968) the Pleistocene high sea levels (Zeuner 1950) are not considered relevant to the question for the following reasons. The Fleurieu Peninsula was uplifted at least 230 m (the level of outcrop of Oligo-Miocene marine limestone near Myponga), and possibly some 460 m (the figure for the net vertical displacement during the Tertiary uplift in the Myponga area given by Campana & Wilson 1953), prior to the onset of the Pleistocene glaciation. Hence vertical movements are held

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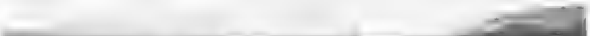

Fig. 7. Beach shingle buried by colluvial debris and resting on marine abrasion platform related to 8 m ASL general base level. Coastal site at Rapid Cove (MR 6116-6137, Cape Jervis, Sheet 6526-IV, Australia 1:50,000).

Fig. 8. Marine abrasion platform on aeolianite related to 8 m ASL base level. Cape Jervis (MR 5996-6089, Cape Jervis, Sheet 6526-IV, Australia 1:50,000). View northwest.

responsible for the base level lowering which initiated most of the nickpoints, with the effects of glacioeustatic oscillations and shoreline movements being superimposed but assuming minor roles.

Brock (thesis) documents other evidence, both morphological and depositional, for stands of the sea higher than at present (see Figs. 5-8). Respecting their ages, no more can be said of the levels cited at 201-207, 183-192, 119-125, and 58-64 m ASL than that they are post Permian because marine abraded boulders that occur at these levels have been derived from Permian glacigenes. These high levels are attributed to Tertiary tectonism. Levels at 40-44 and 8 m ASL post date the deposition of aeolianite in which they are cut near Cape Jervis. Accepting that the aeolianite is of Pleistocene age (Crocker 1946; Sprigg 1952; Bauer 1961) then it is reasonable to suppose that these lower levels are related to the glacioeustasism of the Pleistocene or Holocene. Brock assigns a lower Recent age to the 8 m level.

Crocker, Sprigg, and Bauer suggest that the aeolianite deposition occurred during the Pleistocene in periods of glacioeustatic lowering of the sea and consequent exposure of the continental shelf, which then became the source region of the aeolianite deposits.

Erosional Chronologies of Tunkalilla Creek

The morphology of Tunkalilla Creek is open to at least two interpretations based on the presumption of phased, intermittent, uplift of the Peninsula.

Arguing from morphological evidence only, a four-phased uplift is indicated assuming that nickpoints I, II, and III all originated by rejuvenation. Accordingly, the incision of the headwater segment began with phase 1, the middle reaches with phase 2, and the two segments between nickpoints II and III, and between III and present sea level, with phases 3 and 4 respectively.

Alternatively, accepting that the Tertiary uplift was three-phased, and assuming that nickpoints II and III are the principal erosion heads, and explaining nickpoint I in lithological terms, occurring as it does on essentially unweathered bedrock at the base of the deep soil mantle, then the following hypothesis is feasible.

Phase 1 in pre Oligo-Miocene time initiates the incision of Tunkalilla Creek. Incision continues in Oligo-Miocene time when marine limestone is deposited in the Myponga Basin. Tunkalilla Creek may have been grading to a shoreline near the site of coastal benches at 187 m ASL (see Fig. 4). Nickpoint II is initiated by the late Miocene uplift which brought sedimentation to a close in the Myponga Basin. Phase 3, of proposed Plio-Pleistocene age later initiates nickpoint III.

Denudation Chronology: Evolution of the Region

Viewed from the perspective of a Davisian model of landscape evolution the evidence above may be interpreted in the following way.

The Parawa Peneplain, of which the Parawa High Plain is the dissected remnant, was the end-product of an earlier cycle of erosion which began in the Palaeozoic. The actual age of the Peneplain is probably Mesozoic, since, as noted above, some of its remnants cut across Permian glacigenes. A reconstruction based on the High Plain remnants produces a surface which has the features of an ideal peneplain; a surface of low relief of broad convexity, mantled by a deeply weathered zone, and featuring a monadnock, Mt. Arthur, formed on a resistant band of ferruginous quartzite.

The commencement of the Tertiary uplift initiated a new cycle that continues to the present. The southeast tilt of the uplifted surface is in harmony with the southeast tilt of the fault blocks further north in the Mt. Lofty Ranges, and of the peneplain surface of Kangaroo Island (Bauer 1961). Accepting a three-phased uplift, this cycle has been interrupted by two later phases (Late Miocene and Plio-Pleistocene) producing a multicyclic and epicyclic landscape (see Fig. 9). Nickpoints II and III were initiated by these latter two phases. An alternative interpretation based on a four-phased uplift adduced from morphological evidence as outlined above is not favoured because it is not supported by geological evidence. In addition, providing that the rate of headward erosion is greater than that of nickpoint I regression, the headwater reaches will be lengthened, and nickpoint I lying as it does at the base of the mantle of deeply weathered bedrock, can be explained in lithological terms rather than by invoking rejuvenation.

Accordingly, therefore, nickpoints II and III separate Tunkalilla Creek into segments which are progressively younger downstream. Applying the Davisian concept of stage, the middle and headwater reaches of the stream's

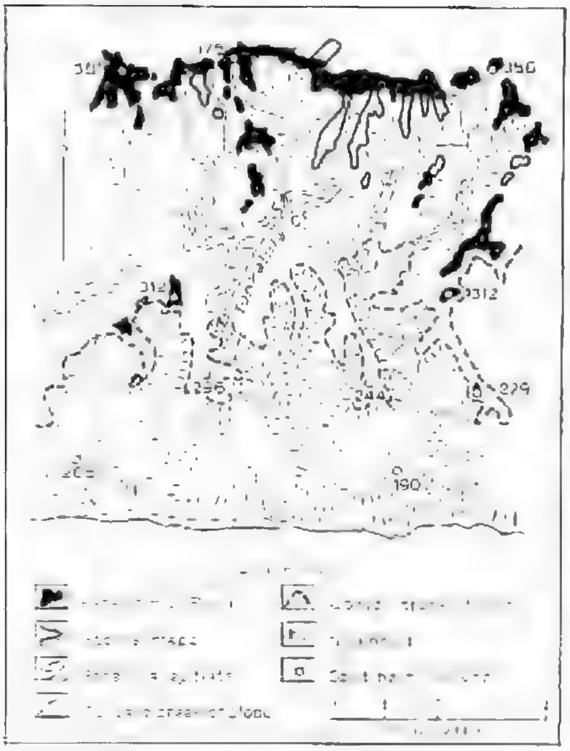

Fig. 9. Tunkalilla Creek and environs. Map based on Torrens Vale Sheet, Australia 1:50,000, and aerial photograph analysis.

channel are mature, and the lower reaches youthful. On the other hand, the terrain of the Ridge and Vale Section and South Coast Valley Region is youthful in that valley sides have not merged to produce a condition of all slopes.

An alternative interpretation based on the model of Penck (1953) rests on the assumption that uplifting of a fault block can be equated with Penck's "structurally expanding dome". Accepting this equation, the pre-existing surface of which the Parawa High Plain remnants are the present vestiges, is a *primärrumpf*. Subsequently, the region experiencing accelerated uplift (*aufsteigende entwicklung*), two sequences of *piedmonttreppen* have developed. These are now represented by the interfluve surfaces of the Ridge and Vale Section and South Coast Valley Region.

Within the framework of this model, nickpoints develop along the stream channels which separate valley forms that are progressively more mature (in Davisian terms) upstream, a condition that does exist in Tunkalilla Creek.

The principal objection to this interpretation lies not so much in the lack of evidence to support it, nor in the need to overstrain the evidence to fit the model, as in the problems inherent in the model itself particularly with reference to the mode of development of nickpoints (see Thornbury 1954). As Thornbury pointed out, Penck used geomorphological analysis as a tool for the interpretation of diastrophic history. Viewed as such the evidence in the study area is indicative of accelerated uplift, a notion that gains a modicum of support from the fact that the difference in elevation between nickpoints II and III is 79 m, while that between III and the present sea level is 131 m. In addition, channel gradients become, in general, progressively steeper downstream.

Whereas the models proposed by Davis and Penck require that a succession of landform assemblages develop from an initial surface of low relief, Kennedy's ideas, in application to the study area, require no such initial surface. Specifically, the Parawa High Plain need not have existed prior to uplift, and the Plain could have continued to form during uplift and at the same time that peripheral areas suffered rejuvenation by baselevel lowering. Furthermore, only those areas whose streams were in direct contact with the general base level (the lower reaches of Tunkalilla Creek for example) would be directly affected by uplift in so far as stream incision would be controlled, in part, by such movement. Upstream, nickpoints would serve as local base levels, and valley form would be dependent upon the relative rates of stream incision and slope downwasting in those areas, which here would include the Ridge and Vale Section and Parawa High Plain. A comparable interpretation is applied by Twidale (1968) to the lateritized summit surface of the Mt. Lofty Ranges east of Adelaide.

The genesis of the laterite that surmounts the High Plain is critical to an appraisal of the Kennedy hypothesis as it applies to the study area. There is no general agreement as to the details of lateritization (see Reiche 1950). However, many hypotheses involve processes of mobilization and accumulation associated with a fluctuating water table beneath a surface of low relief (D'Hoore 1954; Alexander & Cady 1962). D'Hoore further postulates that both "absolute" and "relative" accumulation form preferentially in the horizontal plane, and that lowering of the erosion base brings absolute accumulation to a halt, although relative accumulation may continue at depth. It seems unlikely, therefore, that a zone of iron enrichment high in the laterite profile, and now capping a planate summit surface, would proceed during active dissection of the landmass initiated by the lowering of the erosion base and consequent lowering of the water table. Clearly, acceptance of the above argument brings with it rejection of a Kennedy-type interpretation of the study area in so far as the summit High Plain surface is concerned.

Conclusion

From the standpoint of the models of Davis and Penck it is necessary to consider the evolution of the study area in two parts; the Parawa High Plain, which must be considered as a remnant of a surface of low relief predating the Tertiary uplift, and the peripheral areas formed by dissection of this former surface during the Tertiary and continuing to the present. On the other hand, from the standpoint of the Kennedy hypothesis no such distinction need be made.

The evidence, however, favours the first case above; the former continuity of the High Plain remnants can scarcely be doubted on pedologic and morphologic grounds; nor can uplift through some 300 m or more be questioned. Together, this evidence points to the existence of a quite extensive surface developed during a period that began in the Palaeozoic and ended in the early Tertiary. It must be supposed that during at least the latter part of this period the landmass was essentially stable to allow for the development of the summit laterite. Whether this surface is called a peneplain, *endrumpf*, or otherwise is a matter of choice depending on what mode of evolution is preferred; but since the reconstructed plain has the features of an ideal peneplain, then it should be so designated.

As to the areas peripheral to the High Plain, of the competing models that of Kennedy seems most appropriate. The model itself contains an inherent flexibility suited to the consideration of complex natural systems, involving as it does the interplay of erosion, denudation and uplift. On the other hand, the evidence adduced above throws no light in a quantitative sense on the relative rates of these factors, with the exception of the lower reaches of Tunkalilla Creek; high relief amplitude, steep rectilinear slopes, and steep channel gradient result from a condition in which uplift has outpaced erosion (stream incision). But above nickpoint III it is not known whether the relief is increasing, is stable, or decreasing because there is no evidence from the study area concerning rates of erosion and denudation upon which relief form depends.

The application of Davisian stage terminology to the area sheds no light on its evolution. Indeed, the fact that a "youthful" terrain in the South Coast Valley Region surrounds an inland "mature" one contradicts the Davisian model. But then it may be argued that the ideal cycle does not apply to the peripheral areas because the region has long been unstable.

At this time, therefore, although the evolution of the Parawa High Plain must be considered somewhat enigmatic, it seems most appropriate to apply the term peneplain to it for descriptive purposes. But a synthesis based on the ideas of Kennedy and Penck coupled with the traditional view of rejuvenation by baselevel lowering provides the best framework of thought from which to view the evolution of the regions peripheral to the High Plain.

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WHALES FROM THE COAST OF SOUTH AUSTRALIA

BY P. F. AITKEN

Summary

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The species are: *Eubalaena glacialis australis, Caperea marginata, Balaenoptera musculus, Balaenoptera physalus, Balaenoptera edeni, Megaptera novaeangliae, Plzy.~eter catodon, Kogia breviceps, Kogia simus, Berardius arnouxi, Ziphius cavirostris, Hyperoodon planifrons, Mesoplodon grayi, Mesoplodon layardi, Pseudorca crassidens, Globicephala melaena melaena, Tursiops truncatus, Delphinus delphis. Orcinus orca* is suspected to occur.

Balaenoptera edeni is recorded for the first time from South Australia and a South Australian specimen of *Ziphius cavirostris* is described for the first time. Previous South Australian records of 5 whale species are shown to have been based on incorrect identifications and the previous record of *Grampus griseus* is considered to be of doubtful validity.

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Introduction

In 1837, shortly after the foundation of South Australia, the first industry of the new colony was commenced when a party from Sydney under Captain Blenkinsop in the "Hind" and a double party from the South Australian Company established rival shore-whaling stations at Encounter Bay. It was not until 1889, however, that Amandus Zietz, then Assistant Director of the Public Museum in Adelaide, published the first list of whales from the South Australian coast. Zietz's list comprised 7 species and in subsequent years this number has risen gradually to 17 through contributions from Waite (1919 and 1922), Wood Jones (1925), Hale (1931, 1945, 1959 and 1962b), Handley (1966) and Aitken (1970).

A recent examination of whale remains in the collections of the South Australian Museum revealed that 18 species were represented by specimens from the South Australian coast, and that some previous South Australian species records had been based on incorrect identifications.

An annotated list of whales from the South Australian coast is appended below, compiled from skeletal, cast and photographic material stored in the South Australian Museum. The only specimens used have been those which can be identified accurately to species and for which positive locality data is recorded. The Museum also holds a large collection of cetacean jetsam such as odd vertebrae, broken pieces of mandibles, etc., which are most difficult to identify with certainty. Such material has been disregarded together with numerous identifiable specimens for which no locality is known.

The nomenclature used follows that of Hershkovitz (1966) with the exception of the name *Kogia simus*, a species that Hershkovitz did not recognise.

MYSTACOCETI—WHALEBONE WHALES

BALAENIDAE—Right Whales

Eubalaena glacialis australis (Desmoulins, 1822)—the Southern Right Whale.

Southern right whales, or black whales as they were called by early whalers, provided the mainstay for shore-whaling operations in South Australia from 1837 until the mid 1850's, when such ventures became unprofitable through the over-exploitation and subsequent rarity of the whales. In spite of this flourishing early industry in South Australia, not one specimen of a southern right whale, or part thereof, was preserved in the State Museum and, since no authenticated sighting of this whale was made in South Australia during the first half of the present century, the species was presumed to have vanished from the waters around the State. However, on October 9, 1968, photographs were taken of a large whale and calf swimming close inshore at the entrance to Port Lincoln Proper. From these photographs, now lodged with the South Australian Museum, it was possible to identify

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* South Australian Museum, North Terrace, Adelaide, S. Aust. 5000

Trans. R. Soc. S. Aust. Vol. 95, Part 2. 11th August 1971.

these whales as southern right whales by the bonnet, strongly arched mouth and length of the adult (approx. 15 m) and the lack of a dorsal fin on either the adult or the calf.

The whale and calf were not seen again and is was assumed that they had either moved westwards into the Great Australian Bight or commenced a southerly migration towards their summer feeding grounds amongst the antarctic pack ice. Evidence for these assumptions is provided by an early record of the coastal migrations of southern right whales that appeared in a "Report on Whaling in South Australia", published in the "Southern Australian" on January 4, 1842. John Hart, Jacob Hagen and John Barker, the authors of the report, state that: "The general course of the Black Whale in these Seas, as winter approaches, appears to be from the south-east, consequently the southern shore of Van Diemen's Land is first visited by them, which may be about the beginning of April. These move towards Portland Bay; others continue through the winter to arrive and pass forward. Of those which enter Encounter Bay some have probably coasted along from Portland Bay, while others, it would appear, strike the coast there for the first time. In like manner the whole southern coast of this continent is visited by them, some having come along the land, whilst others are more direct from the great Southern Ocean. At Cape Lewin [*sic.*] the great body of whales seem to strike off Southward, for in October and November they are again working towards the south-east, by keeping two or three hundred miles from the land, where they are again pursued by vessels engaged in the 'Off-shore Fishery'. It is a curious fact that some time after their disappearance from the southern bays of Van Diemen's Land they re-appear suddenly, and in large numbers, in the eastern bays of that island, where they remain only three or four weeks . . ."

Caperea marginata (Gray, 1846)—the Pygmy Right Whale.

Seven pygmy right whales have been recorded from the South Australian coast (Hale, 1964) (Table 1). All known strandings have occurred between early spring and mid summer, in bays with shoaling waters where extensive mud flats or sand spits are exposed at low tide.

TABLE 1

Material of Caperea marginata *in the South Australian Museum.*

No.	Date	Sex	Locality	Material
M1593	21.X.1884	♀	Brownlow, Kangaroo I.	Skeleton
M2966	13.IX.1887	♂	Victor Harbour, Encounter Bay (snared in fishing net)	Skeleton
M2967	31.X.1889	♂	Point Marsden, Kangaroo I.	Plaster cast of head
M5753	before 1948	? (juv.)	Port Lincoln Proper	Part Skeleton
M6110	26.XII.1955	♂	Port Lincoln Proper	Skeleton
M6111	about 1950	♀	Coffin Bay	Skeleton
—	16.VIII.1960	♀	Port Lincoln Proper	Photographs

BALAENOPTERIDAE—Rorquals

Balaenoptera musculus (Linnaeus, 1758)—the Blue Whale.

Two blue whales are known to have been stranded on the South Australian coast. The first, at Corvisart Bay, western Eyre Peninsula on September 9, 1918, was an adult female with a total length of 26·61 metres (Waite, 1919). The skeleton was preserved and stored for many years at the South Australian Museum, but as a result of inadequate storage facilities, vandalism and rat damage most of the bones had either disappeared or been broken beyond repair by 1950. All that remains today are a few caudal vertebrae and one mandible (M793). The second example, represented by 2 baleen plates (M3258), was stranded at Kingston in Lacepede Bay during June, 1932.

Balaenoptera physalus (Linnaeus, 1958)—the Finback Whale.

In late July or early August, 1925, a very young male rorqual of total length 7·41 metres was stranded on the extensive mud flats at the head of St. Vincent Gulf. Approximately 6 weeks later on September 16, 1925, the skeleton was collected for preservation in the South Australian Museum (M2179). Waite (1926) described this rorqual as a young blue whale, but a subsequent examination of the specimen has convinced me that it is a juvenile finback whale.

The rostrum of the cranium is triangular when viewed from above, as opposed to the ovate outline typical of *B. musculus* (Allen, 1916). The premaxillae extend backwards to a point mid-way along the sides of the nasals, as opposed to the condition in *B. musculus* and *B. borealis*—the Sei Whale, where the premaxillae terminate at or behind the posterior dorsal margin of the nasals (Allen, 1916). The total number of vertebrae is 61, but according to Waite one or two of the terminal elements may have been lost. This number conforms with that of *B. physalus* (63) (Allen, 1916), but not with *B. borealis* (57) (Andrews, 1916) or *B. edeni*—Bryde's Whale (54-55) (Omura, 1966). According to Waite the number of major baleen plates in each series was about 374, which is within the limits for *B. physalus* (350-400) (Hall and Kelson, 1959), but not for *B. borealis* (320-340) (Hall and Kelson, 1959) or *B. edeni* (250-280) (Olsen, 1913). The colour of the baleen, as described by Waite, was: "horn coloured, darkening to the outer edges, so that, viewed externally, the series appears to be black in its upper half, fading downwards, the lower third of each plate being yellowish-white, which is also the hue of the bristles developed on the whole inner surface of the series". Such a colour pattern is within the range for *B. physalus* baleen (Allen, 1916), but does not compare with the all black baleen and black bristles of *B. musculus* (Gaskin, 1968) or the black baleen with white hair fringes of *B. borealis* (Gaskin, 1968).

Balaenoptera edeni Anderson, 1878—Bryde's Whale.

In 1883, a medium sized rorqual was stranded at Corny Point and its skeleton, lacking only the sternum and tongue bones, was mounted for display in the South Australian Museum (M5584). Zietz (1889) tentatively identified this rorqual as a humpback whale (*Megaptera novaeangliae*), an erroneous conclusion perpetuated by Wood Jones (1925). The presence of well developed acromion and coracoid processes on the scapulae show that the skeleton could not be that of *M. novaeangliae* (True, 1904), but must be that of another balaenopterid rorqual. Complete coalescence of all vertebral epiphyses indicate that the skeleton is that of an adult in which the total length from the anterior tip of the upper jaw to the posterior tip of the last caudal vertebra is 12·56 m and the vertebrae number 54. This combination excludes *B. acutorostrata*—the Minke Whale in which the total length in adults very seldom exceeds 9·15 m (Gaskin, 1968) with 50 vertebrae (Allen, 1916), also *B. musculus* in which the total length in adults exceeds 20 m with 64 vertebrae (Allen, 1916) and *B. physalus* in which the total length in adults exceeds 16 m with 63 vertebrae (Allen, 1916). The skeleton could possibly be that of *B. borealis* in which the total length in adults ranges from 12-15 m (approx.) with 57 vertebrae (Andrews, 1916), but is more likely to be that of *B. edeni* in which the average total length in adults is 13 m (Olsen, 1913) with 54-55 vertebrae (Omura, 1966).

Comparison of the skeleton with descriptions and figures of the skeletal anatomy of *B. edeni* (Omura, 1959 and 1966) and *B. borealis* (Andrews, 1916) shows it to be that of *B. edeni* because: the dorsal surface of the rostrum is relatively straight and flat with the anterior tips of the premaxillae sunk between the maxillae (*B. borealis* has a curved rostrum with mesially elevated premaxillae); the anterior margin of the nasals is bent forward on the outer sides (in *B. borealis* the anterior margin of the nasals is straight); the anterior margin of the nasals falls well behind the anterior borders of the maxillary concavities (in *B. borealis* these two features are at the same level); there are no grooves between the squamosal and articular parts of the temporals (*B. borealis* has deep grooves); the angular shafts of the mandibles extend behind the articular condyles (in *B. borealis* they terminate in front of the condyles); and the spinous processes of the last 6 dorsal and the first 4 lumbar vertebrae are inclined so far to the rear that their anterior tips are behind the posterior vertical planes of their centra (in *B. borealis* the spinous processes are not so backwardly inclined).

The Corny Point skeleton differs from the description of *B. edeni* given by Omura (1959) in that it has a pair of rudimentary fourteenth ribs, 13 chevrons and a vertebral column of 7 cervical, 14 dorsal, 12 lumber and 21 caudal vertebrae. Omura considered *B. edeni* to possess 13 pairs of ribs, 12 chevrons and have a vertebral formula of 7:13:13:21.

Megaptera novaeangliae (Borowski, 1781)—the Humpback Whale.

Humpback whales migrate annually between their summer feeding grounds in the Antarctic and their winter breeding areas in sub-tropical waters. On these migrations many individuals congregate along the eastern and western coasts of Australia swimming northward in autumn and southward in spring, during which seasons they have been commercially exploited by whaling stations in Western Australia and Queensland since the middle of the nineteenth century. It is apparent, however, that their migratory routes seldom pass through the Great Australian Bight (Dawbin, 1966) and, in consequence, stranded humpback whales are rare on the South Australian coast.

Chittleborough (1965) records two sightings of humpback whales swimming off the coast of South Australia, a single individual in 1952 at the head of the Great Australian Bight and a female with new-born calf in St. Vincent Gulf during the winter of 1961.

Only one example is known to have been stranded, however, represented by a scapula and humerus in the South Australian Museum (M5120). All that is known of the history of this specimen is that it was collected prior to November 1943 (date of registration) on the west coast of South Australia.

ODONTOCETI—TOOTHED WHALES

PHYSETERIDAE—Sperm Whales

Physeter catodon Linnaeus, 1758—the Sperm Whale.

Although sperm whales were hunted occasionally by the early bay whalers of South Australia, reports indicate that very few were captured. Newland (1921) in an account of whaling activities at Encounter Bay stated that: "to obtain [sperm whale] in the forties properly equipped vessels were required as the animal resorted to very deep waters when scenting danger". In fact, most sperm whaling around Australia at that time was carried out by pelagic whalers from other countries, particularly North America.

Tremendous numbers of sperm whales were slaughtered by the nineteenth century whalers and the slaughter has continued with increasing efficiency throughout the present century. But in spite of this relentless attack sperm whales are still observed off the coast of South Australia, as reported to me by cray fishermen from the south-east of the State and aerial tuna spotters from Port Lincoln, and material evidence of 3 stranded specimens is preserved in the South Australian Museum (Table 2). Single teeth of this species have been collected also from Kingston, Beachport and Sleaford Bay.

Kogia breviceps (Blainville, 1838)—the Pygmy Sperm Whale.

The first record of a pygmy sperm whale from South Australia was made by Zietz (1889), who stated that:—"A lower jaw of this very small species was recently obtained by Mr. Adcock at Middleton, Encounter Bay, and by him presented to the South Australian Museum. The dental formula is $\frac{0}{13}$ $\frac{0}{13}$". The lower jaw referred to by Zietz has not been located with certainty, since the only *Kogia* jaw of unknown origin in the collections of the South Australian Museum has 14 teeth is each ramus. However, 9 other pygmy sperm whales are known to have been stranded on the South Australian coast (Hale, 1962 and 1963) (Table 3). Hale reported that most of these strandings occurred during calm weather and all have occurred from late autumn to early spring.

TABLE 2

Material of Physeter catodon *in the South Australian Museum.*

No.	Date	Sex	Locality	Material
M5585	XI.1881	?	Point Bolingbroke, Louth Bay	Skeleton
M7194	26.VI.1966	♂	Victor Harbour, Encounter Bay	Skull
—	V.1956	?	Coffin Bay	Photographs

TABLE 3

Material of Kogia breviceps *in the South Australian Museum.*

No.	Date	Sex	Locality	Material
M5009	25.IV.1937	♀	Port Victoria, Spencer Gulf	Cast and skeleton
M5010	25.IV.1937	♀ (juv.)	Port Victoria, Spencer Gulf	Cast and skeleton
M5011	25.IV.1937	♂ (foetus of M5009)	Port Victoria, Spencer Gulf	Spirit
M5197	VIII.1944	?	Sleaford Bay	Part skeleton
M6156	7.VIII.1957	♂	Sleaford Bay	Teeth
M6156	7.VIII.1957	? (juv.)	Sleaford Bay	Skull
M6256	28.VI.1959	♀	Encounter Bay	Skeleton
M6257	28.VI.1959	♀ (juv.)	Encounter Bay	Skeleton
M6266	29.IX.1959	♂	Glenelg, St. Vincent Gulf	Skeleton
M6310	12.IX.1961	♀ (juv.)	Orange, St. Vincent Gulf	Skeleton

Kogia simus (Owen, 1866)—the Dwarf Sperm Whale.

On July 12, 1958, two small whales were stranded at Largs Bay, on the eastern shore of St. Vincent Gulf. One of these whales, a male, was secured for the South Australian Museum and prepared as a skeleton (M6186). The skull of the other whale was smashed and its body was hacked to pieces by souvenir hunters as soon as it reached the beach, but before this, two excellent coloured photographs of the whale were taken whilst it was thrashing about in shallow water, and these photographs also were lodged with the Museum. Hale (1959) described both specimens as *K. breviceps*, but a recent examination of the skeleton from the first whale and the photographs of the second whale indicated, on the evidence supplied by Handley (1966), that both are examples of *K. simus*. The first whale (M6186) may be recognised as *K. simus* from the skull, which has a single pair of maxillary teeth (*K. breviceps* has none); a ventrally plane, short mandibular symphysis, approximately one tenth of the ramus length (in *K. breviceps* this symphysis is ventrally keeled and approximately one quarter of the ramus length); posteriorly cupped, subsymmetrical dorsal cranial fossae (in *K. breviceps* these fossae are not cupped posteriorly and the left fossa is conspicuously longer and narrower than the right fossa); and a dorsal sagittal septum pinched near the vertex (in *K. breviceps* this septum is broadly expanded near the vertex). The second whale may be recognised as *K. simus* from the photographs, both of which depict a high dorsal fin placed near the centre of the back (*K. breviceps* has a low dorsal fin placed some distance behind the centre of the back).

ZIPHIIDAE—Beaked Whales

Berardius arnouxi Duvernoy, 1851—the Large Beaked Whale.

On December 27, 1935, a pregnant female large beaked whale was stranded on a wide, tidal flat south of Port Lorne near the head of St. Vincent Gulf. The skeleton of this whale, minus caudal vertebrae 4-19, was collected for preservation in the South Australian Museum (M5012). Hale (1962b) provided a full description.

Ziphius cavirostris Cuvier, 1823—Cuvier's Beaked Whale.

One cuvier's beaked whale is known to have been stranded on the South Australian coast at Maslins Beach, south of Noarlunga, on the eastern side of St. Vincent Gulf. The whale, a young male, came ashore on a particularly high tide during the night of April 22, 1966. On the following day the carcase was buried by local council employees in a nearby sand quarry, from where it was disinterred by me on April 27, 1966. Flesh measurements were taken and the complete skeleton was flensed for preservation in the South Australian Museum (M8400). Positive identification of the specimen was made by comparing the nasal and pre-maxillary bones at the synvertex of the skull with those figured for *Z. cavirostris* by Moore (1968).

Flesh dimensions are presented in Table 4 and skull measurements in Table 5. Other details of the external and skeletal anatomy appear below.

TABLE 4

Flesh dimensions of Ziphius cavirostris *from Maslins Beach.*

Tip of snout to posterior margin of tail (curvilinear)	6000 mm
Tip of snout to anterior margin of dorsal fin	3790
Basal length of dorsal fin	305
Tip of snout to eye	710
Tip of snout to axilla	1500
Tip of snout to blowhole	664
Tip of snout to angle of mouth	308
Angle of mouth to eye	410
Breadth across tail flukes	1360
Tip of mandible to anus (curvilinear)	3860
Tip of mandible to tip of snout	20
Length of pectoral fin from axilla	430
Greatest breadth of pectoral fin	150
Greatest girth	3200

External characters: purple-black on the dorsal half of the body and around the head, tail and pectoral fins, grading through dark grey-brown on the lower sides to pale grey-brown on the belly. A smoothly curved forehead with no pronounced bulge; 2 conspicuous throat grooves on the posterior third of the lower jaw extending backwards to the level of a point midway between the angle of the mouth and the eye; and no central notch between the tail flukes.

Teeth: two conical, open rooted teeth protruding above the gums, one from the anterior tip of each mandible and approximately 30 vestigial teeth buried in the gum of each mandible.

TABLE 5

Skull Measurements of Ziphius cavirostris *from Maslins Beach.*

Condylo basal length	920 mm
Breadth across post-orbital processes	505
Height from synvertex to inferior border of pterygoids	460
Greatest length of nasals	135
Greatest breadth of nasals.	62
Length of rostrum	510
Breadth of rostrum at base	215
Length of mandible (cal; tip broken)	790
Length of mandibular symphysis (cal.)	155
Height of right tooth	52·3
Greatest diameter of right tooth	12·7
Height of left tooth	53·2
Greatest diameter of left tooth	12·5
Height of typical vestigial tooth	4·7
Greatest diameter of typical vestigial tooth	1·4

Age: Ossification of the cranial sutures, but lack of anchylosis of all vertebral epiphyses other than the fused 1st-4th and 6th-7th cervical vertebrae, suggests a young adult.

Vertebrae, ribs and chevrons: the vertebral column consists of 7 cervical, 10 dorsal, 10 lumbar and 19 caudal vertebrae. Ten ribs are present on each side, but the tenth rib on the left is a demi-rib: half the size of its counterpart on the right. Ten chevrons are present, all joined, the third being the deepest.

Pelvic bones: subequal, the left element being of equal depth but 8 mm shorter than the right element, which has a total length of 89 mm and a greatest depth of 12 mm.

Hyperoodon planifrons Flower, 1882—the Southern Bottlenosed Whale.

On November 22, 1929, an adult male southern bottlenosed whale was stranded near Port Rickaby on the eastern shore of Spencer Gulf. A full description of this whale was provided by Hale (1931) and its complete skeleton is preserved in the South Australian Museum (M2852).

Mesoplodon grayi von Haast, 1876—Gray's Beaked Whale.

The first record of a gray's beaked whale in South Australian waters was that of Waite (1922), based on the right mandible from a specimen stranded at Kingscote, Kangaroo Island in 1910. Since that date, 2 further examples are known to have been stranded on the South Australian coast (Table 6).

TABLE 6

Material of Mesoplodon grayi *in the South Australian Museum.*

No.	Date	Sex	Locality	Material
M 849	IV.1910	?	Kingscote, Kangaroo I.	Right mandible
M3003	II.1931	?	Younghusband Peninsula	Part skeleton and skin of jaw
M7476	14.I.1964	♀	Aldinga, St. Vincent Gulf	Skull

Mesoplodon layardi (Gray, 1865)—the Strap-toothed Whale.

Thirteen strap-toothed whales are known to have been stranded on the South Australian coast. The first of these was recorded by Waite (1922) with a specimen collected in 1919 from Kangaroo Island and three of the remaining examples have been described by Hale (1931). Details of the acquisition of 12 of these whales are summarised in Table 7. The thirteenth example, for which no specimen is available in the South Australian Museum, was recorded by Hale (1931) after he had examined privately owned photographs and teeth from a male strap-toothed whale stranded on Coffin Bay Peninsula in February 1933. All strandings have occurred in mid-summer.

TABLE 7

Material of Mesoplodon layardi *in the South Australian Museum.*

No.	Date	Sex	Locality	Material
M 794	II.1919	♀	Kangaroo Is.	Skeleton
M2853	XII.1929	♀	Port Rickaby, Spencer Gulf	Skull
M2969	3.III.1931	♂	Victor Harbour, Encounter Bay	Skull
M4564	14.I.1934	♀	Streaky Bay	Skull
M5006	12.I.1939		Victor Harbour, Encounter Bay	Skeleton
M5007	12.I.1939	♀	Victor Harbour, Encounter Bay	Skull
M5008	12.I.1939	♀	Victor Harbour, Encounter Bay	Skull
M6269	13.II.1956	♂	Rocky Point, Kangaroo I.	Skeleton
M8401	III.1969	♂	Cape Elizabeth, Spencer Gulf	Part skeleton
	3.II.1931	♀	Victor Harbour, Encounter Bay	Photographs
—	2.II.1939	♀	Wharff's Point, Streaky Bay	Photographs
—	2.II.1939	?	Wharff's Point, Streaky Bay	Photographs

GLOBICEPHALIDAE—Great Dolphins

Pseudorca crassidens (Owen, 1846)—the False Killer Whale

On October 5, 1944, there was a mass stranding of false killer whales on the eastern side of St. Vincent Gulf. The main body of about 200 whales came ashore at Port Prime, but a smaller concentration of about 50 whales landed approximately 2½ kilometres further north and isolated individuals were found over a 30 kilometre front between Port Parham and Port Gawler. Hale (1945) initially identified these whales as pilot whales (*Globicephala melaena*) but corrected his error in a later paper (1959). No examples were secured for the South Australian Museum at the time of the stranding in 1944, but skeletal material can still be found scattered amongst the dunes along the beach near Port Prime and a well preserved cranium with 2 teeth *in situ* was collected recently to provide specimen evidence of the event (M8384)

Globicephala melaena melaena (Traill, 1809)—the Pilot Whale.

Five pilot whales are represented in the collections of the South Australian Museum (Table 8). No other examples are known to have been stranded in South Australia.

TABLE 8

Material of Globicephala melaena melaena *in the South Australian Museum*

No.	Date	Sex	Locality	Material
M1592	before 1922	?	St. Vincent Gulf	Skeleton
M5645	5.IX.1903	♀	Glenelg, St. Vincent Gulf	Skeleton
M5646	5.IX.1903	♂	Glenelg, St. Vincent Gulf	Skeleton
M5647	5.IX.1903	♂	Glenelg, St. Vincent Gulf	Skeleton
M5648	5.IX.1903	♂	Glenelg, St. Vincent Gulf	Skeleton

DELPHINIDAE—Lesser Dolphins

Tursiops truncatus (Montagu, 1821)—the Bottlenosed Dolphin.

The first record of bottlenosed dolphins in South Australian waters was made by Wood Jones (1925) who considered the species to be: "evidently not uncommon around our [South Australian] coast". Wood Jones cited examples of skulls he had examined from Port Lincoln, Port Noarlunga and Cowell. Nevertheless, the first actual record of the species for South Australia was almost certainly that of Zietz (1889) under the name of *Steno rostratus*, because in his description of *S. rostratus* Zietz stated: "This species, as in the case of the Common Dolphin [*Delphinus delphis*], is incorrectly called a porpoise. It is easily distinguished from the porpoise by having a much larger and thicker head, and the snout more tapering, and not so abruptly narrowed: the tail and breast fins are also much broader, and the body narrowed behind. It is not so neatly shaped as *Delphinus delphis*, and the teeth are much stronger and less numerous .... Its presence in the Australian Seas has hitherto not been noted, though it is not uncommon on our [South Australian] coast."

Now, since *S. rostratus* (presently classed as a synonym of *Steno bradanensis* Lesson, 1828) is neatly shaped and does resemble *D. delphis* (Gaskin, 1968) and since Zietz compiled his account from material in the South Australian Museum where no specimens of *Steno* are held in the collection, it is reasonable to assume that Zietz was mistaken in his identification. However, Zietz's description is well suited to another dolphin, which is abundant around the South Australian coast and which is well represented by specimens in the South Australian Museum, namely *Tursiops truncatus*.

Bottlenosed dolphins are abundant throughout the year off South Australia and may frequently be observed swimming close inshore. Few become stranded, however, and when related to their obvious abundance there is a relatively small number of examples preserved in the South Australian Museum (Table 9).

TABLE 9

Material of Tursiops truncatus *in the South Australian Museum.*

No.	Date	Sex	Locality	Material
M1384	before 1922	?	South Australia	Skull
M1597	before 1922	?	South Australia	Cast
M2130	7.V.1925	?	Franklin Harbour	Skull
M2666	V.1929	?	Sellicks Beach, Encounter Bay	Skull
M4819	1935	?	Henley Beach, St. Vincent Gulf	Part skull
M5078	3.III.1941	♂	Port Lincoln Proper	Skeleton
M5609	before 1945	?	Glenelg, St. Vincent Gulf	Part skull
M5795	before 1950	?	Cape Jervis, Investigator Straight	Part skull
M5902	29.XI.1950	?	Woods Well, Lacepede Bay	Skull
M6038	1.V.1955	?	Murray Mouth, Encounter Bay	Skull
M7479	24.II.1966	?	West I., Encounter Bay	Mandible
M8383	VIII.1969	♂	Port Stanvac, Encounter Bay	Skull

Delphinus delphis Linnaeus, 1758—the Common Dolphin.

Common dolphins, first recorded for South Australia by Zietz (1889), are abundant in all seasons throughout the waters around the State. They are sometimes observed close inshore, but appear to be most numerous some distance from land, where they are a familiar sight to fishermen and other seafarers due to their habit of ship pacing. These dolphins seldom become stranded and are not well represented in the collections of the South Australian Museum (Table 10).

DOUBTFUL RECORDS

GLOBICEPHALIDAE—Great Dolphins

Orcinus orca (Linnaeus, 1758)—the Killer Whale.

TABLE 10

Material of Delphinus delphis *in the South Australian Museum.*

No.	Date	Sex	Locality	Material
M1389	before 1922	?	South Australia	Part skull
M2297	9.III.1927	?	Yorke Peninsula	Skull
M3047	XI.1931	?	Younghusband Peninsula	Part skull
M4815	29.X.1936	♂	Brighton, St. Vincent Gulf	Skeleton and cast
M4847	before 1940	? (juv.)	Victor Harbour, Encounter Bay	Skull
M4976	11.X.1892	♀	Port Adelaide, St. Vincent Gulf	Skeleton
M7480	before 1969	? (juv.)	Port Lincoln Proper	Skull

Wood Jones (1925) recorded killer whales for South Australia on the basis of an *Orcinus* skull in the South Australian Museum (M5649). Wood Jones stated that this skull: "probably came from the shores of this [South Australia] State". But, in fact, there is no evidence to support such a view. The skull is labelled 'Old Collection—no data' and could have come from anywhere in Australia or have been purchased from overseas. It is probable, however, that killer whales do occur off the coast of South Australia since the South Australian Museum also possesses a mandible of this species (M5345), from Portland in Victoria, only 80 kilometres east of the South Australian border.

Grampus griseus (Cuvier, 1812)—Risso's Dolphin (formerly—the Grampus).

Zietz (1889) reported that: "A skeleton of a grampus eleven feet long, was found on the beach between Glenelg and Brighton, the skull of which is in the [South Australian] Museum". A careful search of all cetacean material in the South Australian Museum has failed to reveal either this specimen or any skulls of *G. griseus*. Either the skull has been lost or Zietz was mistaken in his identification.

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PACHYTREMA CALCULUS LOOSS, 1907 (TREMATODA: OPISTHORCHIIDAE) FROM AUSTRALIA

BY L. MADELINE ANGEL

Summary

Pachytrema calculus Looss, 1907 is recorded from South Australia from *Larus novaehollandiae* Stephens and *Chlidonias hybrida* Pallas, and from New South Wales from *Larus novaehollandiae*. This is the first record of a species of *Pachytrema* from the Southern Hemisphere. The Australian specimens differ from those described from Europe and Asia in the size of the eggs, the largest eggs from *L. novaehollandiae* measuring 103 by 41 µm, and from *C. hybrida* 93 by 43 µm. However, it is not considered desirable to assign the Australian forms to another species solely on the size of the eggs.

PACHYTREMA CALCULUS LOOSS, 1907 (TREMATODA: OPISTHORCHIIDAE) FROM AUSTRALIA

by L. MADELINE ANGEL*

Summary

Pachytrema calculus Looss, 1907 is recorded from South Australia from *Larus novaehollandiae* Stephens and *Chlidonias hybrida* Pallas, and from New South Wales from *Larus novaehollandiae*. This is the first record of a species of *Pachytrema* from the Southern Hemisphere. The Australian specimens differ from those described from Europe and Asia in the size of the eggs, the largest eggs from *L. novaehollandiae* measuring 103 by 41 μm, and from *C. hybrida* 93 by 43 μm. However, it is not considered desirable to assign the Australian forms to another species solely on the size of the eggs.

Introduction

Pachytrema calculus Looss, 1907 was described from the gall bladder of *Larus ridibundus* and *L. argentatus* in Trieste. Since then it has been recorded by nine authors† from Europe and Asia. Including Looss' records, it has been described from five species of *Larus*, several charadriiform birds and a teal (*Querquedula falcata* (Georgi)). Eight other species of *Pachytrema* have been described, but it seems likely that there is some synonymy among these. Purvis (1937) thought that many of the apparent differences between the species may be due to differences of pressure when the worm is mounted; and that to determine the validity of the species, it would be necessary to study all the specimens by sectioning. Brinkmann (1942) agreed with Purvis that one worker should investigate all species, though he thought that this would be difficult, as *Pachytrema* spp. were "exceedingly rare". MacInnis (1966) discussed the genus and thought it highly probable that four of the eight species (he did not mention *P. skrjabini* Kadenatsii, 1960) were synonymous.

Pachytrema calculus Looss, 1907.

Host. *Larus novaehollandiae* Stephens, 1826 (Silver gull). Location in host—Gall bladder.

Localities. West Island, Encounter Bay, South Australia, 14.vi.1968. (Coll. Mrs. P. M. Thomas). (2 slides).
Sydney district, New South Wales, 14.xii.1957. (Coll. A. J. Bearup), School of Public Health and Tropical Medicine Museum No. 1469. (2 slides).
Bateman's Bay, New South Wales, 28.ii.1963. (Coll. W. H. Ewers). (4 specimens in spirit).

Host. *Chlidonias hybrida* Pallas, 1826 (Marsh tern). Location in host—Gall bladder.

Locality. Tailem Bend, South Australia. Oct. 1948 (Coll. T. H. Johnston).

Measurements of six mounted and one spirit specimen are given in Table 1. The other spirit specimens measured 9·5 by 6·5 mm, 6·4 by 5·0 mm and 6·0 by 5·0 mm.

Pachytrema has been found only twice among many hundreds of birds examined for helminths in this department, including 143 in the Charadriiformes, 79 in the Lariformes (including 40 *Larus novaehollandiae*) and 15 *Querquedula* spp. (the only genus in the Anseriformes in which *P. calculus* has been recorded). By the courtesy of Dr. B. McMillan, of the School of Public Health and Tropical Medicine, Sydney, I have also been able to study two collections from *L. novaehollandiae* from New South Wales. All specimens from the two Australian hosts are assigned to *Pachytrema calculus* Looss.

In the specimens from *Larus novaehollandiae* the measurements of the body and of the organs fall within the range of measurements given by Looss, Yamaguti, Timon-David and

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† Kotlan (1922), Isaichikov (1927), Odhner (1928), Yamaguti (1939), Belopol'skaia (1954), Bykhovskaia (1954), Timon-David (1955), Mamaev (1959) and Macko (1964). I have been able to study the works of Odhner, Yamaguti, Timon-David and Macko. References to the other authors are to be found in the Index Catalogue of Medical and Veterinary Zoology. Trematoda and trematode diseases, Part 6.

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Macko for *P. calculus*. The reproductive system is not clear in some of the specimens (due to the abundance of eggs) and it has not been possible in any to determine whether a receptaculum seminis and Laurer's canal are, or are not, present. MacInnis (1966), describing two specimess of *Pachytrema* (from the Royal Tern, *Thalasseus maximus maximus*) which he attributed to *P. sanguineum* (Linton, 1928), did not observe Laurer's canal and seminal receptacle (even in frontal sections of one specimen) and stated that their absence differentiates *P. sanguineum* from *P. calculus*, in which they are present. However, Looss (1907) said that there was no receptaculum seminis in *P. calculus*, and Brinkmann (1942) agreed with this. Laurer's canal is not always easy to identify, and I would suggest that Odhner (1928, p. 6 (footnote)) and Skrjabin and Petrov (1950, p. 285) were right in making *Minuthorchis sanguineus* Linton, 1928 a synonym of *P. calculus*. If this is so, *Larus atricilla* makes a sixth species of *Larus* in which *P. calculus* is found.

The specimens in the present study appear to differ from *P. calculus* only in the size of the eggs. Looss (1907) gave the average size as 110 × 44 μm. Measurements given by other authors are:—Yamaguti (1939), 99-112 μm by 42-51 μm (in life): Timon-David (1955), 114-116 μm by 52 μm: Macko (1964), 115-120 μm by 46-50 μm. In the species from *Larus novaehollandiae*, the largest eggs in mounted specimens are 103 by 41 μm. Linton (1928) gave the measurements in the living worm as about 110 by 40 μm, and in balsam two uncollapsed eggs measured 88 by 47 μm and 90 by 45 μm. It seems that the eggs in the Australian specimens from *Larus novaehollandiae* are definitely smaller than in European and Asian forms, but it appears undesirable to separate the species from *Pachytrema calculus* on this character only.

The specimens from *Chlidonias hybrida* are smaller than those from *L. novaehollandiae* (Table 1), but the measurements of the organs are very similar in the trematodes from the two hosts; *C. hybrida* is a smaller bird than

TABLE 1

Measurements of Pachytrema calculus *Looss, 1907.*

		LOOSS (1907)	New material						
			Larus novaehollandiae					*Chlidonias hybrida*	
			S. Australia		New South Wales			S. Australia	
			1	2	3	4	5	6	7
Body	l.	5·5 mm	7·0	6·75	7·2	8·0	9·0	3·75	3·9
	w.	4·0	5·0	5·75	4·7	4·7	6·0	3·0	3·4
Oral sucker	l.	280—290	258	282	153	329	247	247	259
	w.	(? l or w)	365	353	388	365	423	294	350
Acetabulum	l.	300	353	341	340	435	456	353	365
	w.	(? l or w)	423	447	447	470	514	435	400
Pharynx	l.	170	174	165	192	198	176	141	174
	w.	160	167	176	174	180	176	176	191
Ovary	l.	—	153	—	—	247	—		—
	w.	—	223	—	259	165	—	—	118
Testis (R)	l.	—	270	—	—	270	—	—	118
	w.	—	176	—	—	188			200
Testis (L)	l.	—	247	282	270	235	—	—	—
	w.	—	141	223	223	188	—		—
Eggs	l.	110	100	103	97	88	105	93	89
	w.	44	41	41	42	44	42	43	39

Specimens 1—4, 6, 7 are balsam mounts; 5 a spirit specimen (measurements of internal structures when examined in glycerine).

Body measurements in mm., all other measurements in μm.

L. novaehollandiae, and the size of its gall bladder could well limit the size of the trematodes. In the two specimens from *C. hybrida* the reproductive system is obscured by the eggs in the uterus; however, in one specimen a testis is clearly visible, and the ovary is visible, though not clearly outlined. There is nothing in these, or in the other organs, to suggest that the species is other than *P. calculus*. In fact, the only difference (other than size of body) between the trematodes from *L. novaehollandiae* and *C. hybrida* is in the size of the eggs, which are slightly smaller in the specimens from *C. hybrida*, the largest egg being 93 by 43 μm.

No life history has yet been described for a species of *Pachytrema*. Food found in the gut of *Larus novaehollandiae* examined in this department includes insect, crustacean, gastropod, and fish remains. Food of *Chlidonias hybrida* includes water insects, shrimps, yabbies (*Cherax destructor*), tiny fish and frogs. The marsh tern frequents lakes and swamps, chiefly of inland regions. The silver gull is commonly found in these areas, as well as on coastal shores. The occurrence of *P. calculus* in the marsh tern thus suggests that the intermediate hosts will be freshwater organisms, at least in Australia. The second intermediate host might be a fish or a crustacean.

Acknowledgements

I wish to thank Dr. B. McMillan, of the School of Public Health and Tropical Medicine (Commonwealth Department of Health and the University of Sydney) for lending me material collected for his School and allowing me to study it.

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THYSANOTOUS FRACTIFLEXUS SP. NOV. (LILIACEAE), ENDEMIC TO KANGAROO ISLAND, SOUTH AUSTRALIA

BY N. H. BRITTAN

Summary

Thysanotus fractiflexus sp. Nov. (Liliaceae), a distinctively zigzag branched perennial herb, endemic to Kangaroo Island, South Australia, is described and illustrated.

THYSANOTUS FRACTIFLEXUS SP. NOV. (LILIACEAE), ENDEMIC TO KANGAROO ISLAND, SOUTH AUSTRALIA

by N. H. Brittan*
Communicated by Hj Eichler

Summary

Thysanotus fractiflexus sp. nov. (Liliaceae), a distinctively zigzag branched perennial herb, endemic to Kangaroo Island, South Australia, is described and illustrated.

Specimens of this distinctive species of *Thysanotus* R.Br., the present known distribution of which shows that it is endemic to Kangaroo Island, have previously in the State Herbarium of South Australia (AD) been referred to *T. dichotomus* (Labill.) R.Br., a Western Australian endemic, although Cleland in ms. (AD, 96021054) has questioned whether it should not be distinguished as a distinct taxon. Its distinctive zigzag branching habit and hirsute ridged stem (which have been found to be retained in cultivation in Perth), taken in conjunction with floral characteristics, justify the erection of a new species. It is most closely related to a new New South Wales species *T. virgatus* Brittan (1971), from which it differs in that the outer perianth parts are 2-2·5 mm wide and 5-nerved, whereas in *T. virgatus* they are 3-4 mm wide and usually 7 (occasionally 6) nerved. The internodes are also longer in *T. virgatus*, and it lacks the zigzag appearance of *T. fractiflexus*.

Thysanotus fractiflexus sp. nov.

Herba perennis, rhizoma horizontale, radices rigidae, haud tuberosae. Folia radicalia, pauca, cito marcescentia. Caules numerosi, rigida, ad 30 cm longi, porcati, porcis dense brevissime hirsutis, fractiflexi, internodiis 8-10 mm longis. Umbellae terminales 2-3 florae. Bracteae extimae, 1-2, herbaceae, 2 mm longae, plerumque hirsutae supra nervos. Bracteae intimae, membranaceae, circa 2·5 mm longae, 1-3 nervatae. Pedicelli 7 mm longi, basin versus articulati. Tepala exteriora, angusti-lanceolata, anguste membranaceo-marginata, 10-11 mm longa, 2-2·5 mm lata, extus 5-nervata; tepala interiora elliptica, circa 5 mm lata, fimbriis 3-3·5 mm longis fimbriata. Stamina 6; antherae tortae, 3 exteriores erectae 4 mm longae, 3 interiores curvatae 6 mm longae; poris terminalibus dehiscentes. Filamenta 2-2·5 mm longa. Ovarium sessile, plusminusve globosum, triloculare, utroque loculo ovulis 2. Stylus terminalis, curvatus, stamina longiora aequans. Capsula cylindrica, ab perianthio persistenti inclusa.

Holotypus: Near the junction of Sect. 500, Hundred of Duncan, and Sect. 97, Hundred of Newland, Kangaroo Island. *N. H. Brittan* 60/15-1, 20.i.1960 (AD 97116005). Fig. 1.

Isotypus: Ibid. 60/15-2 (K).

Perennial with ± horizontal rhizomes ca 8-10 mm dia. with stiff roots without tubers. Radical leaves produced with new shoots, usually absent at flowering time. Stems rigid, terete, striate, up to 30 cm with short stiff hairs on ridges, branching monopodial with short ca 8-10 mm internodes giving a distinctive zigzag appearance, older stems straight with internodes ca 5 cm long; some sterile bracts in upper part of stem. Umbels terminal 2-3-flowered, 1-2 outer bracts similar to stem bracts, usually with hirsute veins, inner bracts ca 2·5 mm long mostly membranous with 1-3 dark veins. Pedicels 7 mm long, articulated near base. Outer tepals 10-11 mm long, narrow-lanceolate, 2-2·5 mm wide, usually with 5 distinct veins on back; inner tepals ± circular including fimbriae, inner entire portion elliptical, 5 mm wide with tapering 3-nerved midrib, fimbriae reaching maximum length of 3·5 mm towards upper portion of tepal. Stamens 6; 3 outer stamens with 4 mm long anthers, straight and twisted; 3 inner stamens with 6 mm long anthers, curved and twisted. Ovary sessile, ± globular, style terminal ± as long as longer anthers. Capsule cylindrical, erect, enclosed within persistent perianth.

Other specimens (all from Kangaroo Island). —Kingscote, *Jackson* 396, 30.x.1964 (AD

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Fig. 1. *Thysanotus fractiflexus* Brittan. Habit of Brittan 60/15-1 (holotype, AD) (× 0·5); on right, flower of Brittan 60/26-2 (AD) (× 1·5).

9669063); nr. Western River homestead, *Eichler* 15355 bis, 10.xi.1958 (AD 96407048); Harriet R.-Vivonne Bay, *Eichler* 18471, 24.xii.1965 (AD 96650163); Breakneck R., *Cleland* s.n., 25.xi.1945 (AD 96021144); Karratta, *Tepper* 74, 13.xii.1886 (AD 96021163); Flinders Chase, *Cleland* s.n., 8.i.1946 (AD 96021060); Ravine des Casoars, *Cleland* s.n., 2.ii.1948 (AD 96021054); Cape Borda rd., *Symon* s.n., Mar.1954 (ADW 10532); Hundred of Duncan, *Cashmore* s.n., 15.xi.1933 (ADW 742); 2 miles (3 km) W. Vivonne Bay, *Brittan* 60/21, 20.i.1960 (UWA); Parndana township, *Brittan* 60/30, 22.i.1960 (UWA); Junct. sects. 80/83, Hundred of Newland, *Brittan* 60/26-1 (K), 60/26-2 (AD 97116019), Fig. 1.

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NEW RECORDS AND TAXA OF MARINE CHLOROPHYTA IN SOUTHERN AUSTRALIA

BY H. B. S. WOMERSLEY

Summary

Distribution and depth records are given for ten species of marine Chlorophyta. Two species of *Ulvaria (U. oxysperma* and *U. shepherdii* sp. nov.) are the first representatives of this genus known from southern Australia; records are given of three little known deep water species of *Caulerpa (C. alternans, C. ellistoniae* and *C. hedleyi);* the ranges of *Callipsygma wilsonii, Avrainvillea clavatiramea* and *Rhipiliopsis peltata* are extended considerably, and a second species of *Rhipiliopsis (R. robusta)* is described; and the subtropical species *Acetabularia calyculus* is recorded from St. Vincent Gulf, South Australia.

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Summary

Distribution and depth records are given for ten species of marine Chlorophyta. Two species of *Ulvaria* (*U. oxysperma* and *U. shepherdii* sp. nov.) are the first representatives of this genus known from southern Australia, records are given of three little known deep water species of *Caulerpa* (*C. alternans*, *C. ellistoniae* and *C. hedleyi*), the ranges of *Callipsygma wilsonii*, *Avrainvillea clavatiramea* and *Rhipiliopsis peltata* are extended considerably, and a second species of *Rhipiliopsis* (*R. robusta*) is described; and the subtropical species *Acetabularia calyculus* is recorded from St. Vincent Gulf, South Australia.

Introduction

Since publication of a critical survey of the Chlorophyta of southern Australia (Womersley 1956), several species have become better known, especially from collections made by SCUBA divers. The more interesting of these records, together with two new species, are described below. Most of the species are from deeper water and rarely if ever are found in the drift.

A further deep water species, *Palmoclathrus stipitatus*, from deep water off Waldegrave Island, Eyre Peninsula, has been described separately (Womersley 1971).

ULVALES

No species of monostromatic ulvacean algae has previously been recorded from southern Australia, although *Monostroma* and allied genera are present on most temperate and cold water coasts. Several species of *Monostroma* have been described from New Zealand by Chapman (1956).

Recognition of the genera of these monostromatic algae depends upon which species is accepted as lectotype of *Monostroma* Thuret. Following Kornmann (1964) and Bliding (1968), *M. bullosum* (Roth) Thuret is here accepted as the lectotype species, rather than *M. oxyspermum* (Kuetz.) Doty which Papenfuss (1960, p. 315) and Gayral (1965, p. 627) regarded as lectotype. Kornmann and Bliding point out that *M. bullosum* agrees better with Thuret's type description of *Monostroma* than does *M. oxycoccum* (Kuetz.) Thuret (=*M. oxyspermum*).

Ulvaria Ruprecht is based on *U. obscura* (Kuetz.) Gayral, and differs from *Monostroma* in having an alternation of isomorphic generations, a uniseriate germling which becomes tubular and opens to a monostromatic sheet, and distinct rhizoids at the base of the thallus. *Ulvaria* includes *U. oxysperma* (Kuetz.) Bliding when *Monostroma* is based on *M. bullosum*.

Ulvaria oxysperma (Kuetz.) Bliding 1968: 585, figs. 31-34.

FIG. 1

U. oxysperma was first recognised in South Australia in Proper Bay, Port Lincoln, during a field trip in August 1967 with Dr. C. den Hartog who was familiar with this species on European coasts. The South Australian plants agree well with Bliding's (1968, p. 585, figs. 31-34) description. They form light to medium green thalli (Fig. 1) up to 8 cm high and as much across, delicate but fairly firm, and with a smooth to convolute margin. The thallus is attached by rhizoids from the basal cells while the upper cells are irregularly polygonal to rounded in shape, 7-15 µm across, with gelatinous walls of variable thickness, and arranged mostly irregularly though sometimes in groups or in linear rows. The thallus thickness is 10-15(—20) µm and each cell contains 1(—2) small pyrenoids.

Most of these measurements are towards the lower end of the ranges given by Bliding.

U. oxysperma (often recorded as *Monostroma*) is a widespread species in the temperate northern Hemisphere and has also been recorded from subtropical regions (e.g. from Hawaii [Gilbert 1965, p. 483]). It is known from the following localities, but is probably widespread in suitable habitats during winter along the southern Australian coast. It is apparently a winter species and occurs at a

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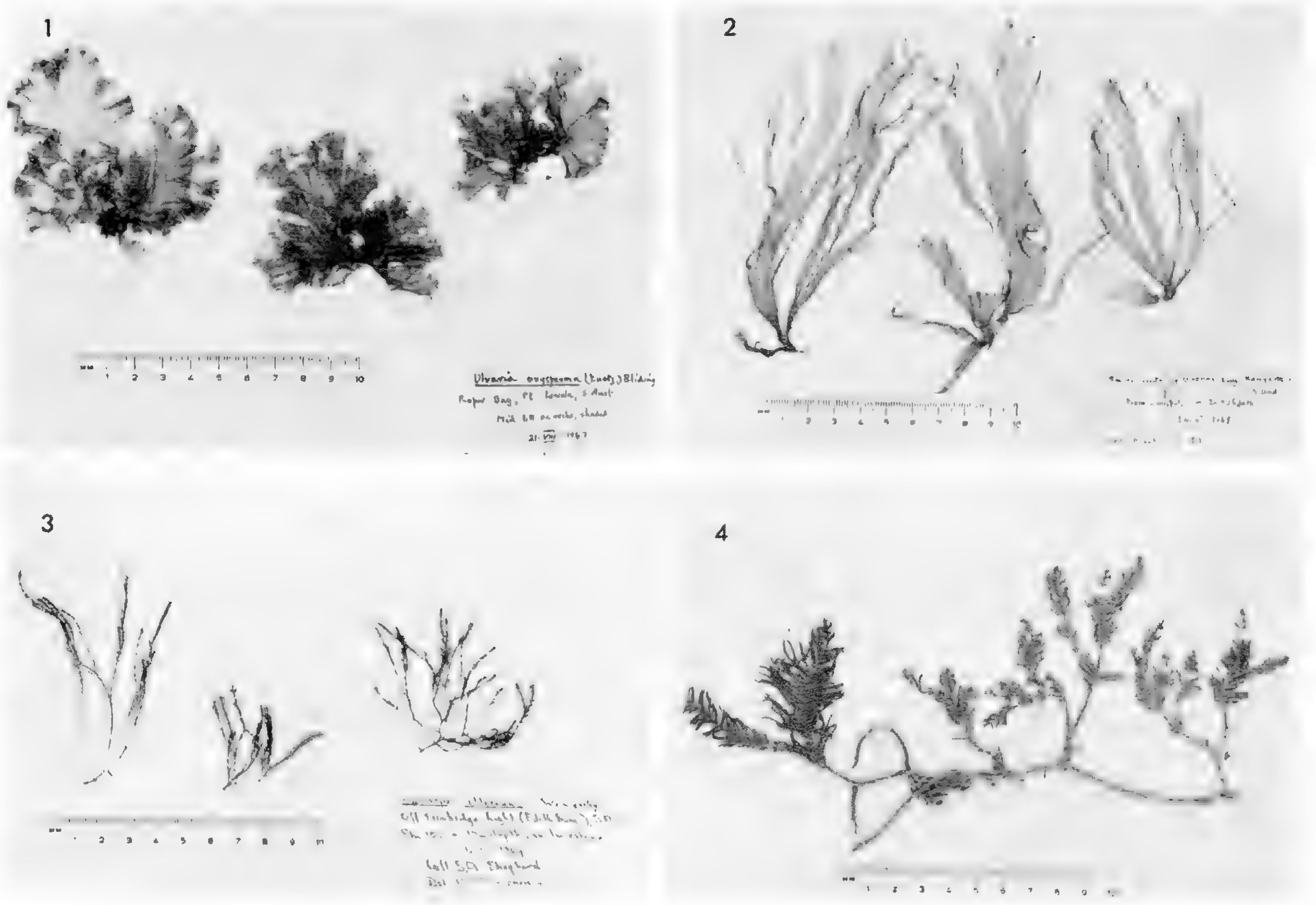


Figs. 1-4. Fig. 1.—*Ulvaria oxysperma.* Proper Bay, Port Lincoln, S. Aust. (ADU, A31812). Fig. 2.—*Ulvaria shepherdii.* Holotype sheet. Fig. 3.—

mid to lower eulittoral level in calm water bays and inlets.

Localities—Kellidie Bay, Coffin Bay, S. Aust., mid eulittoral (*Womersley*, 22.viii.1967; ADU, A31874); Proper Bay, Port Lincoln, S. Aust., mid eulittoral, partly shaded (*Womersley*, 20.viii.1967; ADU, A31812); Goolwa Barrage, S. Aust., mid eulittoral on stone bank, seaward side (*Womersley*, 13.iv.1970; ADU, A35820, *Parsons*, 5.viii.1969; ADU, A35746); Nelson Lagoon, Vic., on rocks (*Beauglehole*, 10.v.1959; ADU, A24674); Louisville, Tas., on *Heterozostera* (*Olsen*, 6.ix.1967; ADU, A31965); Port Arthur, Tas. (*Cribb*, 18.x.1951; ADU, A20434).

Ulvaria shepherdii sp. nov.

FIGS. 2, 5-7

Thallus (Fig. 2) to 12 cm high, deeply lacerate into numerous linear to narrowly cuneate, straight to slightly curved, segments with rounded to truncate ends, 2-15(—20) mm broad, arising from a small, semi-prostrate region attached on the lower side by numerous slender rhizoids (Figs. 6, 7) about 10 µm diam. and about ½ mm long, often with lobed ends. Thallus monostromatic, 50-75 µm thick below, decreasing to 30-40 µm thick above, cells in section slightly to 1½ times as high as broad.

Cells polygonal (Fig. 5), with rounded to narrowly angular ends, tending to form lengthwise rows, with walls 4-5 µm thick; splits in thallus originating by separation of the walls between cells (Fig. 5). Cells 25-50 (—85) µm long by 10-25(—35) µm broad (occasionally larger in some rows or patches), with the chloroplast filling most of the cell and containing usually 3-5 pyrenoids (Fig. 5).

Diagnosis—Thallus ad 12 cm altus, laceratus, segmentis linearibus vel anguste cuneatis 2-15 (—20) mm latis, per rhizoidea affixis. Monostromaticus inferne 50-75 µm crassus, superneque 30-40 µm crassus. Cellulae polygoniae plerumque 25-50(—85) µm longae et 10-25 (—35) µm latae, et chloroplastus cum 3-5 pyrenoidibus.

Type Locality—About 12 km (8 miles) south of Vivonne Bay, Kangaroo Island, S. Aust., from a craypot in 50-70 m depth (*Latz*, 24.xi.1968).

Holotype—ADU, A33006, holotype on left (Fig. 2).

Distribution—Only known from the type and from Pearson Is., S. Aust., on the rough water coast in 22-50 m depth (*Shepherd*, 7 to 12.i.1969; ADU, A33664, A33713, A33735, A33873, A34006, A34024, A34052, A34058, A34107).

U. shepherdii is named after Mr. Scoresby A. Shepherd whose subtidal ecological studies have contributed greatly to our knowledge of southern Australian marine algae.

U. shepherdii is placed in *Ulvaria* on the presence of distinct rhizoids developed from cells of a monostromatic thallus. The life history and development of the thallus is unknown. It appears most closely related to *Monostroma alittoralis* Tanaka & Nozawa ex Tanaka (1964, p. 75) from Japan. The latter is one of the few deep water species (from 60 m) of this group of algae and should probably also be referred to *Ulvaria*. It is similar in cell arrangement and rhizoids to *U. shepherdii* but differs markedly in form.

CAULERPALES

Caulerpa alternans Womersley 1956: 364.

FIG. 3

This species was previously known only from the type locality (Port Phillip Heads, Vic.) and from "St. Vincent's Gulf, S. Aust., dredged in 20 fathoms" (ADU, A1562).

On 4 February 1969 is was collected by Mr. S. A. Shepherd near Troubridge Light (ADU, A33416) and Tapley Shoal (ADU, A33751) in the south west part of St. Vincent Gulf, in 17 and 13 m respectively, growing on a sandy bottom in an area subject to fairly strong tidal currents. The previous St. Vincent Gulf collection very likely comes from this area also, and the species appears to be confined to deeper water.

C. alternans is a slender species (Fig. 3) up to 8 cm high, with stolon and axes about ½ mm broad, the axes simple or with a few branches and bearing usually two rows of alternating, simple, slender linear ramuli up to 3 mm long and 200-300 µm broad, with a pointed apex. Occasional axes bear ramuli in 3 rows or irregularly for part of their length.

Caulerpa ellistoniae Womersley 1955: 387, fig. 2.

Previously known only from the type collection, *C. ellistoniae* is now recorded from the following localities: Rottnest Is., W. Aust., 10 km south-west 62 m deep on rubble (*Wilson*, Feb.1960; ADU, A24584); Pearson Is., S. Aust., 36 m deep on rough-water coast (*Shepherd*, 10.i.1969; ADU, A35153); Elliston, S. Aust., 7 m deep (*Shepherd*, 21.x.1970; ADU, A37537); 12 km S. of Vivonne Bay, Kangaroo Is., S. Aust., in 50-70 m from craypots (*Latz*, 24.xi.1968; ADU, A32992).

C. ellistoniae appears to be confined to deep water on rough water coasts, but with a wide distribution from Rottnest Island in Western Australia to Kangaroo Island in South Australia.

Caulerpa hedleyi W.v. Bosse. Womersley 1956: 367.

FIGS. 4, 8, 14

C. hedleyi was previously known only from the type specimen dredged in 15 m (8 fath.) off Kangaroo Island. It has now been collected from the following localities—Pearson Is., S. Aust., 22-30 m deep on sheltered coast (*Shepherd*, 8.i.1969; ADU, A33741 and 9.i.1969; ADU, A33998, A34054); St. Francis Is., Isles of St. Francis, S. Aust., 55 m deep (*Shepherd*, 9.i.1971; ADU, A38069); Egg Is., Isles of St. Francis, 32-38 m deep (*Shepherd*, 11.i.1971; ADU, A38084).

C. hedleyi appears to be restricted to deep water, off either rough water or partly sheltered coasts, but at depths where water movement is only slight and light intensity fairly low. *C. hedleyi*, *C. ellistoniae* and *C. alternans* are the only southern Australian species of *Caulerpa* known to be confined to deep water, though some other species penetrate from shallower into deeper water.

C. hedleyi is a distinctive species. The axes reach 10 cm in height from a long stolon (Fig. 4) and bear closely arranged distichous laterals (Fig. 14) which are densely covered with dichotomous ramuli with acute ends (Fig. 8). The lower axes are usually denuded of laterals but covered with ramuli.

Avrainvillea clavatiramea Gepp & Gepp. Womersley 1956: 372.

FIG. 10

This is the only species of the tropical-subtropical genus *Avrainvillea* known from southern Australia, and previously recorded only from the type locality, Corio Bay, Port Phillip, Victoria.

A. clavatiramea is now known from Eucla, W. Aust., drift (*Parsons*, 5.xi.1968; ADU, A33962); Waldegrave Is., Eyre Pen., S. Aust., 22 m deep (*Shepherd*, 23.x.1970; ADU, A37363) and Investigator Strait, S. Aust., 27 m deep, Lat. 35°13′S, Long. 137°31′E (*Watson*, 9.i.1971; ADU, A38441). It thus appears to be a deep water species, rarely found in the drift.

A. clavatiramea reaches a height of 25 cm (Fig. 10), with long, terete stipes (to 13 cm), then expanding fairly evenly to a broadly flabellate lamina up to 10 cm long and 10 cm across at its flattened to convex apex. In old plants up to 10 stipes with blades may arise from an old matted holdfast (Fig. 10).

Callipsygma wilsonii J.Agardh. Womersley 1956: 372.

FIG. 11

Callipsygma was known only from the type specimen from Port Phillip Heads, Vic. until recorded by Cribb (1958, p. 207) from Cape Barren Is., Tasmania (*Olsen*, 14.x.1950).

C. wilsonii is now known from numerous specimens in ADU, with records from Vivonne Bay, Kangaroo Island and from Port Elliot, S. Aust, to Sorrento, Vic, and King Is., Bass Strait (MELU—S. C. Ducker, *pers. comm.*). It appears to be a plant of deeper water on rough coasts, though it is common in 1-2 m depth in a heavily shaded cave at Nora Creina, south of Robe, S. Aust.

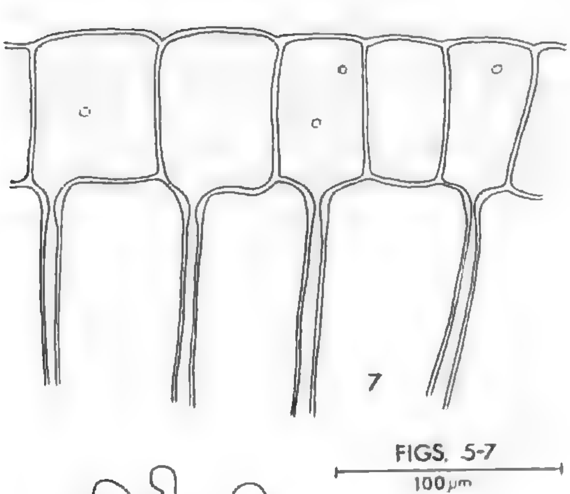
The thallus (Fig. 11) reaches 35 cm in height in old plants, with numerous branches, flabellate above and denuded below where the lower stipe may be 1-2 cm thick and the holdfast up to 3 cm across.

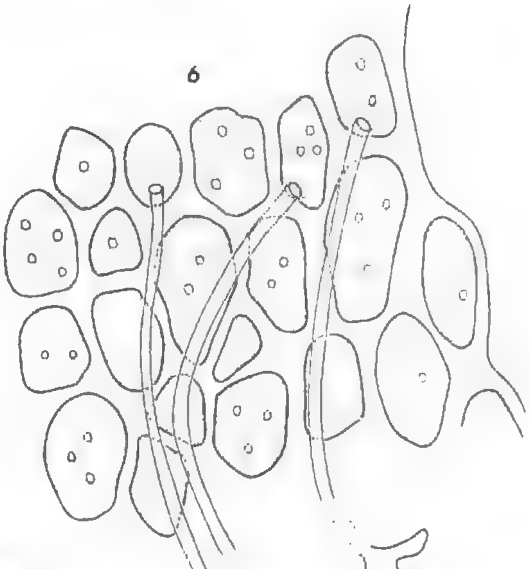
Rhipiliopsis peltata (J.Agardh) Gepp & Gepp. Womersley 1956: 376.

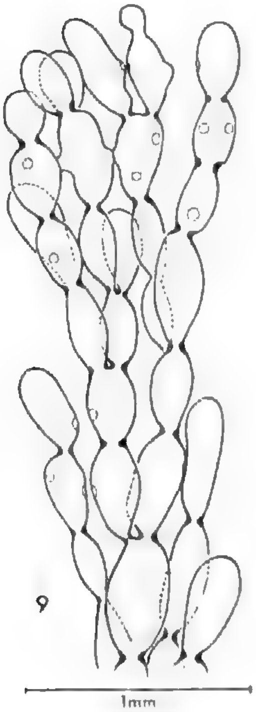
FIG. 12

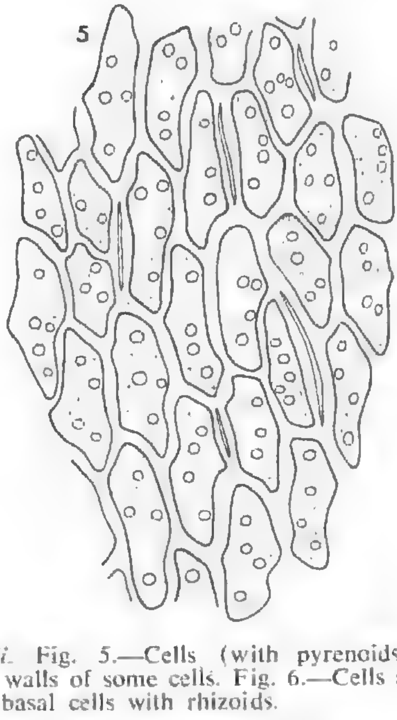
R. peltata was previously recorded from Port Phillip Heads, Vic. and Pennington Bay, Kangaroo Is., S. Aust. and is now known as far west as Waldegrave Is. (near Elliston), Eyre Pen., S. Aust., 22 m deep (*Shepherd*, 23.x.1970; ADU, A37368). It is often common in shaded pools and at just subtidal levels on rough water coasts, and is probably to be found in such habitats anywhere between Port Phillip Heads and Waldegrave Island or further west.

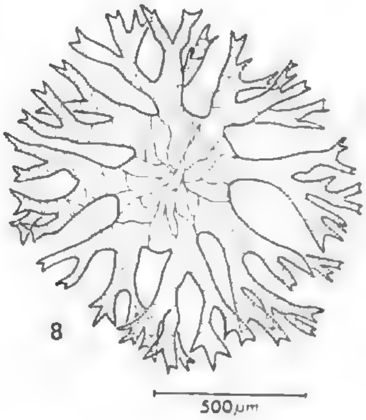
The thallus is distinctive, reaching 4 cm in height and 3(—4) cm across, the flat lamina being borne on a slender stipe up to 1 cm long (Fig. 12).











Figs. 5-7, *Ulvaria shepherdii*. Fig. 5.—Cells (with pyrenoids) in median part of thallus; splits developing between walls of some cells. Fig. 6.—Cells and rhizoids at base of thallus. Fig. 7. —Cross section of basal cells with rhizoids.

Fig. 8, *Caulerpa hedleyi*. Cross section of lateral with ramuli.

Fig. 9, *Rhipiliopsis robusta*. Filaments of lamina showing lateral attachments.

Rhipiliopsis robusta sp. nov.

FIGS. 9, 13

Thallus (Fig. 13) to 9 cm high, dark green, not calcified; holdfast to 1 cm across, stipe to 4 cm long and 2-3 mm diam., lamina to 4 cm high and 3½ cm across, undivided but often lacerate or slightly lobed, about 1 mm and several filaments thick, with a faintly zoned appearance, spongy but moderately dense and firm; surface of lamina without cortical development but the ends of some filaments lying at the surface. Filaments (Fig. 9) of lamina robust, mostly 150-200 µm diam., dichotomously branched, markedly moniliform with ovoid segments 1½-2 times as long as broad (apical segments 2-3(—4)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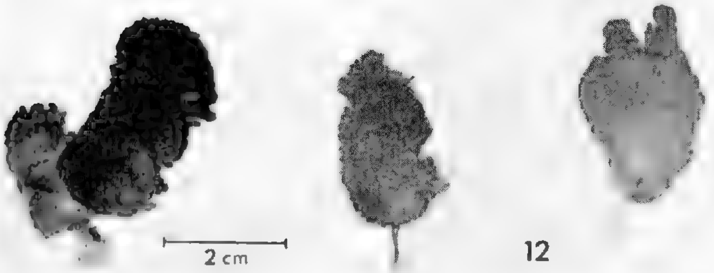
11



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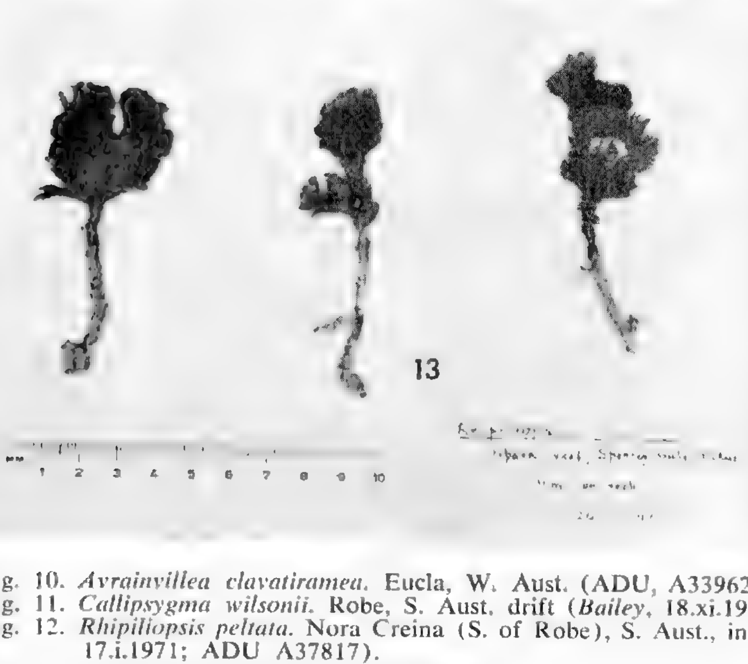
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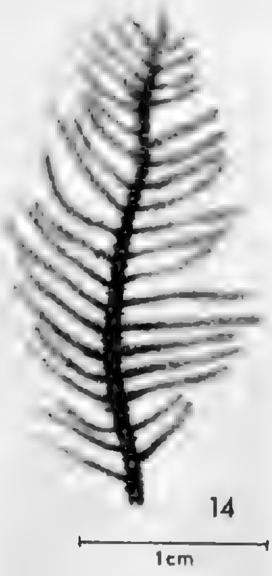

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Fig. 10. *Avrainvillea clavatiramea.* Eucla, W. Aust. (ADU, A33962).
Fig. 11. *Callipsygma wilsonii.* Robe, S. Aust. drift (*Bailey*, 18.xi.1967; ADU, A32028).
Fig. 12. *Rhipiliopsis peltata.* Nora Creina (S. of Robe), S. Aust., in heavily shaded pool (*Womersley*, 17.i.1971; ADU A37817).
Fig. 13. *Rhipiliopsis robusta.* Holotype sheet.
Fig. 14. *Caulerpa hedleyi.* Axis with laterals and ramuli (A33741).

times as long as broad), with thickened wall plugs ingrowing from the periphery of the constrictions; filaments attached laterally by circular areas (Fig. 9) without projections from the filaments. Chloroplasts round to ovoid, 2-3 μm long, without pyrenoids; amyloplasts ovoid, 3-5 μm long.

Diagnosis—Thallus ad 9 cm altus, atro-viridis non calcareus; basali disco ad 1 cm lato, stipite ad 4 cm longo et 2-3 cm diam., lamina ad 4 cm alta et 3½ cm lata, indivisa vel lacerata circa 1 mm crassa. Filamentis robustis, 150-200 μm diam., dichotomis, moniliformibus et segmentis 1½ vel duplo longioribus quam latis, ad constrictiones incrassatis; filamenta lateribus per poros circulares conjuncta. Chloroplasti rotundi vel ovoidei 2-3 μm longi sine pyrenoidibus; amyloplasti ovoidei et 3-5 μm longi.

Type Locality—Tipara Reef, Spencer Gulf, S. Aust., 11 m deep on rock (*Shepherd*, 24.ii.1971).

Holotype sheet—ADU, A38130, holotype on left (Fig. 13).

Distribution—Only known from the type locality and from Pearson Is., S. Aust., 30 m deep on rough water coast (*Shepherd*, 10.i.1969; ADU, A34049).

R. robusta appears to prefer moderate water movement in fairly deep water. The two known localities are distant and other records are to be expected from SCUBA collections in similar habitats.

Rhipiliopsis robusta agrees well with the type species (*R. peltata*) in form and structure, and has similar lateral unions between the filaments by means of circular perforations. This latter character was used by Gepp & Gepp (1911, p. 46) to distinguish *Rhipiliopsis* from *Avrainvillea*. *R. robusta* differs from *R. peltata* in size and in its much broader and more strongly moniliform filaments, these being only 18-25 μm broad in the latter. The only other species of *Rhipiliopsis* described appears to be *R. aegyptiaca* Nasr (1939, p. 53, figs. 3, 4) from the Red Sea, but this species is described as being monostromatic and is doubtfully a species of *Rhipiliopsis*.

DASYCLADALES

Acetabularia calyculus Quoy & Gaimard 1824: 621, pl. 90, figs. 6, 7. J.Agardh 1887: 171.

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Fig. 15. *Acetabularia calyculus*. Living specimen from Tapley Shoal (Edithburgh), S. Aust. (corresponding to ADU, A33400).

Boergesen 1913: 75, figs. 61-65. De Toni 1889: 418. Harvey 1863: pl. 249. May 1938: 213. Nasr 1947: 40, figs. 10-11. Solms-Laubach 1895: 26, pl. 3, figs. 6-8, 10.

FIG. 15

Acetabularia calyculus is a widespread subtropical species, known previously in Australia from Fremantle northwards on the west coast and from about Newcastle northwards on the east coast. The type locality is Shark Bay, Western Australia. The original illustration of Quoy & Gaimard shows a fairly typical plant with a distinct cup of united rays, and as noted by Boergesen (1913, p. 77), Solms-Laubach's (1895, p. 26) reference of *A. calyculus* to a group with separate rays is not correct. After decalcification however, the rays readily separate.

A. calyculus is now known from the following records in South Australia: Tapley Shoal, off Edithburg, S. Aust., 13-15 m deep in strong current (*Shepherd*, 5.ii.1969; ADU, A33400—Fig. 15); Glenelg, S. Aust., in 20 m depth, 4½ km offshore (*Shepherd*, 15.ii.1969; ADU, A33450). In both cases, the alga was growing on dead shells on a sandy bottom, usually in current channels in *Posidonia* beds; current slight to strong. It appears to be confined to deeper water, and is recorded mainly from deep water elsewhere in the world.

The occurrence of a further subtropical species in southern Australia is noteworthy, since a small group of such species is now known from the Gulf region of South Australia. Other species include *Hormophysa triquetra* (L.) Kuetzing and *Sargassum decurrens* (R.Br.) C.Agardh. The Gulf waters are warmer in summer than the rougher more southern waters, and it is possible that these may be "relict species" from a period of warmer conditions along southern Australia.

Acknowledgements

Gratitude is expressed to Mr. Scoresby Shepherd, whose SCUBA diving resulted in many of the records in this paper, and to the Australian Research Grants Committee for technical assistance.

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VOL. 95, PART 3 15th OCTOBER, 1971

TRANSACTIONS OF THE

ROYAL SOCIETY OF SOUTH AUSTRALIA

INCORPORATED

CONTENTS

PEARSON ISLAND EXPEDITION, 1969

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PEARSON ISLAND EXPEDITION 1969. – 1. NARRATIVE

BY S. A. SHEPHERD AND I. M. THOMAS

Summary

The Pearson Islands, which are in the Investigator Group in the eastern part of the Great Australian Bight, were first investigated scientifically (apart from brief visits by E. Waite in 1914 and by F. Wood-Jones about 1920) by a party led by Professor F. Wood-Jones in 1923, and the results of that expedition were published in the Transactions of this Society in 1923 and 1924.

PEARSON ISLAND EXPEDITION 1969. — I. NARRATIVE

by S. A. Shepherd[*] and I. M. Thomas[†]

Introduction

The Pearson Islands, which are in the Investigator Group in the eastern part of the Great Australian Bight, were first investigated scientifically (apart from brief visits by E. Waite in 1914 and by F. Wood-Jones about 1920) by a party led by Professor F. Wood-Jones in 1923, and the results of that expedition were published in the Transactions of this Society in 1923 and 1924.

The next expedition occurred in 1960 under the leadership of Professor T. O. Campbell and the botanical results of that expedition were published by Specht (1969).

The 1969 expedition was organised by the present authors under the auspices of the Royal Society of South Australia and the Department of Fisheries and Fauna Conservation. The party included Messrs. I. M. Thomas and L. B. Delroy (Mammals); Dr. M. Smyth (Reptiles); Mr. D. E. Symon (Land Flora); Dr. C. R. Twidale (Geomorphology); Mrs. J. Paton (Birds); Mr. G. F. Gross (Insects); Mr. S. A. Shepherd and Mrs. I. E. Watson (Marine Ecology). Messrs. M. Dredge, H. A. Fairbank, P. Macrow, J. Ottaway and A. Thomas also accompanied the expedition and gave assistance in various ways.

The expedition left Coffin Bay on 5th January, 1969 and spent from 6th to 13th January on Pearson Island, operating from a base camp on the northern slopes above Eastern Cove.

One of the purposes of the expedition was to collect numbers of the Pearson Island Wallaby (*Petrogale penicillata*) and transport them to the mainland with a view to establishing a breeding colony. The Wallaby is common on the main island and daily hunts were held on the higher slopes of East Hill and Hill 781. Twenty-four wallabies were trans-shipped to Flinders Island, some 32 km distant, and from here they were flown to the Department of Fisheries and Fauna Conservation's station at Bool Lagoon. Fifteen more wallabies and some native rats (*Rattus fuscipes*) were brought to Adelaide when the expedition returned on 13th January.

A number of geographic features were named by the 1969 expedition. The two anchorages off Pearson Island were named Anchorage Cove and Eastern Cove respectively, as these are the names by which they are known to local fishermen. The three isles to the south of the main Pearson Island were named Veteran Isles and Dorothee respectively, these being the names given by Baudin in 1801 to islands in the eastern Great Australian Bight, but which were either named earlier by Flinders or cannot be identified. These names were approved by the Nomenclature Committee of the Department of Lands on 14th August, 1969. Maps of the islands showing the named features are given by Twidale (1971) and Shepherd & Womersley (1971) in this volume of the Transactions.

Two groups of islands off the southern coast of Australia are named Pearson Islands. One of these is in the Archipelago of the Recherche off Western Australia, lying 13 km (7 nautical miles) southeast of Mondrain Island. The position of these islands is noted on Flinders' Chart of 1814 but they are not named. The other islands of the same name are in the Investigator Group. These are mentioned and given code letters in Flinders' log (1802-03), a photostat copy of which is held in the S.A. Archives, and the name Pearson's Isles appears on the chart and in the narrative of Flinders' account of his voyage to Terra Australis (1814); however, the source of the name is not given.

In the "Nomenclature of South Australia Data Slips" compiled by the Department of Lands, South Australia, and held by the South Australian Archives, it is noted that the islands were sighted by Flinders on 13th February, 1802, "and subsequently named by him after his brother-in-law". Flinders' sister did marry a Mr. Pearson but not until 1806, which suggests that the name was not given until after Flinders' return to England after his enforced stay on Mauritius. However, no authority is given on the data slips.

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Trans. Roy. Soc. S. Aust. Vol. 95, Part 3, 15th October 1971.

Another suggestion as to the origin of the name is given by Caroline Pilgrim in the September 1949 issue of "Homes and Gardens". Here it says that when the islands were first sighted, Flinders was on deck with one of his officers, Lt. Robert Fowler (after whom Fowlers Bay was named). He asked Fowler to suggest a name for the newly sighted islands and Fowler suggested his mother's maiden name which was Pearson. This version is accepted substantially by Praite & Taylor (1970) but no authority is cited in either case.

Still another suggestion is that the islands were so named to honour Sir Richard Pearson. O'Byrne (1859-62, p. 266) records that "Sir Rich. Pearson Kt. in Sept. 1779, beat off an American Squadron of twice his own force, under the notorious Paul Jones by which achievement a convoy, valued at 600,000 *l.* was saved to the country, and who died Lieut. Governor of Greenwich Hospital in Jan. 1806." There can be little doubt that Flinders would have known of the exploits of Sir Richard Pearson, but there can be no certainty that he is the person who was honoured.

Acknowledgements

In addition to those referred to above, particular thanks are due to Mr. A. M. Olsen, Director of Fisheries and Fauna Conservation, for his enthusiastic encouragement of the Expedition. Our thanks are also due to Mr. Robert Jenkin who supplied some of the information concerning the naming of Pearson Islands. Grants in support of the Expedition were made by the Department of Fisheries and Fauna Conservation and the Royal Society of South Australia.

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PEARSON ISLAND EXPEDITION 1969. – 2. GEOMORPHOLOGY

BY C. R. TWIDALE

Summary

The islands of the Investigator Group (Pearson Islands) are true inselbergs. Their major landforms are expressions of jointing in the granite bedrock. Massive curvilinear sheets of rock dominate lower levels, and boulders, probably derived from the breakdown of the sheets, dominate the upper slopes of the topographic domes. Flared slopes and tafoni are well developed.

Other important landforms are of marine origin. The western shores, which face the Great Australian Bight and the dominant westerlies, are strongly cliffed, but on the more sheltered east-facing coasts sheet structure and boulder strewn slopes are prominent. Here also remnants of aeolianite-old coastal foredune deposits-are preserved. They date from a time of lower sealevel. There is also suggestion in the form of benches and deposits of a stand of the sea higher than the present, though it is not possible to say how much higher.

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Introduction

The German word *inselberg* is usually applied to residual hills and ranges which rise abruptly and dramatically from the surrounding plains. Its use in this continental context is apt but, of course, metaphoric. The Pearson Islands are, however, true "island-mountains", for they rise steeply from the waters of the eastern margin of the Great Australian Bight. This apart, however, the islands are morphologically similar to the granite inselbergs of adjacent northwestern Eyre Peninsula, and of the southwest of Australia (Twidale 1962, 1964, 1968a, 1968b).

The islands (see Figs. 1, 2) which, in Pearson Island itself rise to almost 240 m (800 ft.) above sea level, take the form of domes which are rounded and boulder strewn, especially on the upper slopes. In some few areas of Pearson Island the generally irregular profiles of the hills are broken by smooth gentle slopes associated with deposits of limestone (Fig. 1). With the exception of the southern member of Veteran Isles, and the small unnamed island off the SW coast of south section (Fig. 1), the domes stand high above the waves. But, whether high or low, the domes are asymmetric, the exposed western parts of the structures having suffered marked erosion through wave attack.

OUTLINE IN PLAN

The Investigator Group is geologically part of the granitic Gawler Block. The islands are located close to a major structural line (Fig. 1, inset), believed to be a fault zone, which essentially delineates the west coast of Eyre Peninsula and which is still active (Sutton & White 1968; Doyle, Everington & Sutton 1968). This submarine extension of the Gawler Block is delimited to the north by the Polda Basin, a sedimentary trough some 1500 m in depth, and to the south by the Duntroon Basin (Smith & Kammerling 1969; Wopfner 1969), though the fault zone evidently continues beyond these both to the northwest and to the southeast. For instance earthquake epicentres have been recorded to the southeast beyond the Duntroon Basin (Sutton & White 1968). To the northwest the structural line continues in the junction of the Eucla Basin and Gawler Block, though it is noteworthy that earthquake epicentres have not so far been recorded between the Investigator Group and the coast to the northwest (Sutton & White 1968).

This NW-SE structural trend is also reflected in the outlines of Pearson and other islands of the Investigator Group. In addition, a set of fractures at right angles to this is prominent (Fig. 1). Whether these two sets of fractures are faults, and part of a primary shear pattern, or secondary shears related to the nearby fault zone, or merely major joints the pattern of which is determined by the same stresses which are responsible for the regional tectonic framework, is not known.

DETAILED MORPHOLOGY

The detailed morphology of each of the islands is related principally to joint patterns, of which two may be distinguished.

1. *Sheet structure*: The first and most significant systems of joints comprise numerous flat-lying or gently curvilinear fractures which subdivide the rock into massive sheets (Fig. 3)

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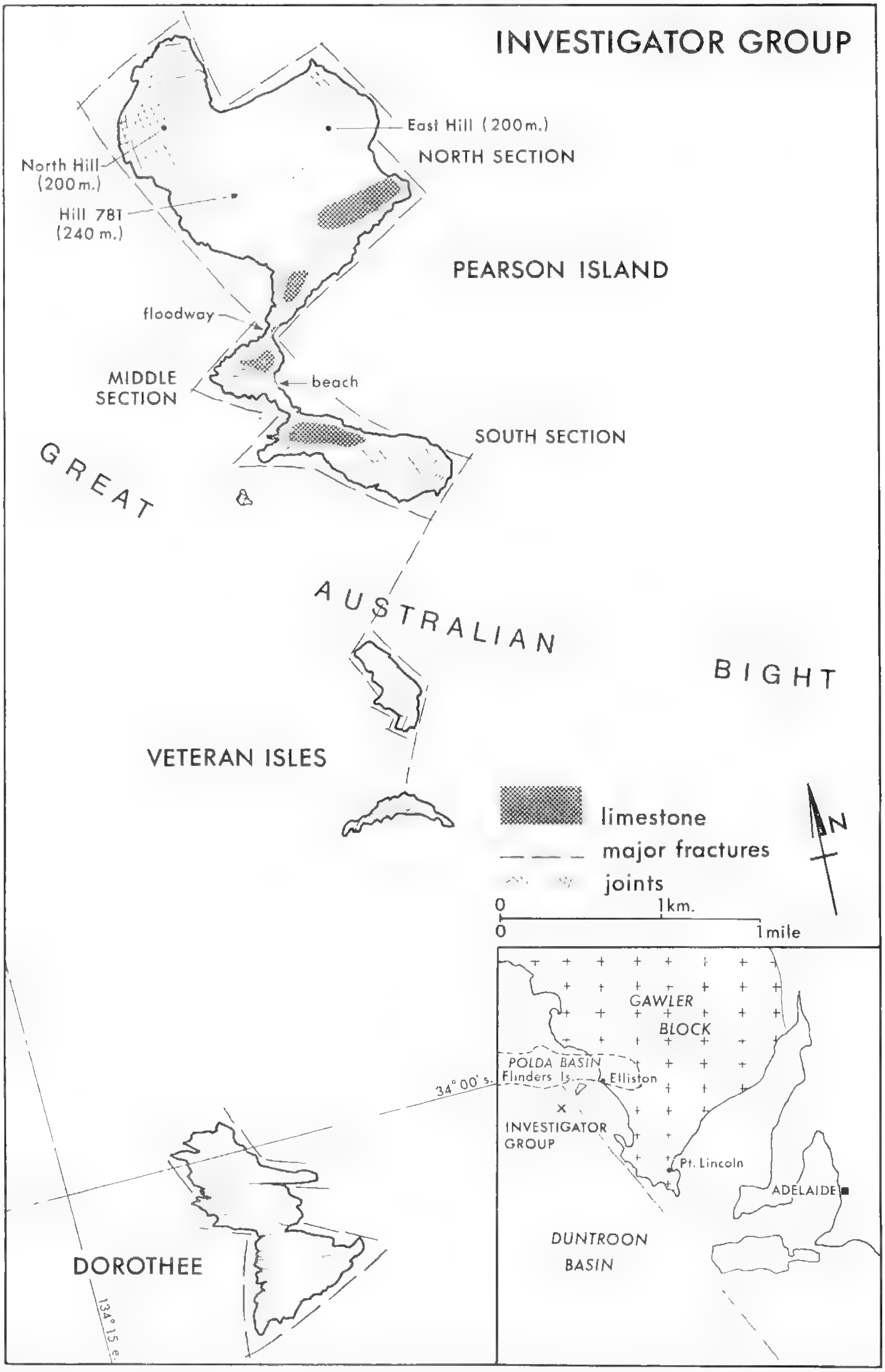

Fig. 1. Pearson Archipelago, showing (inset) location and (main map) suggested major joints, minor joint patterns, and depositional features.

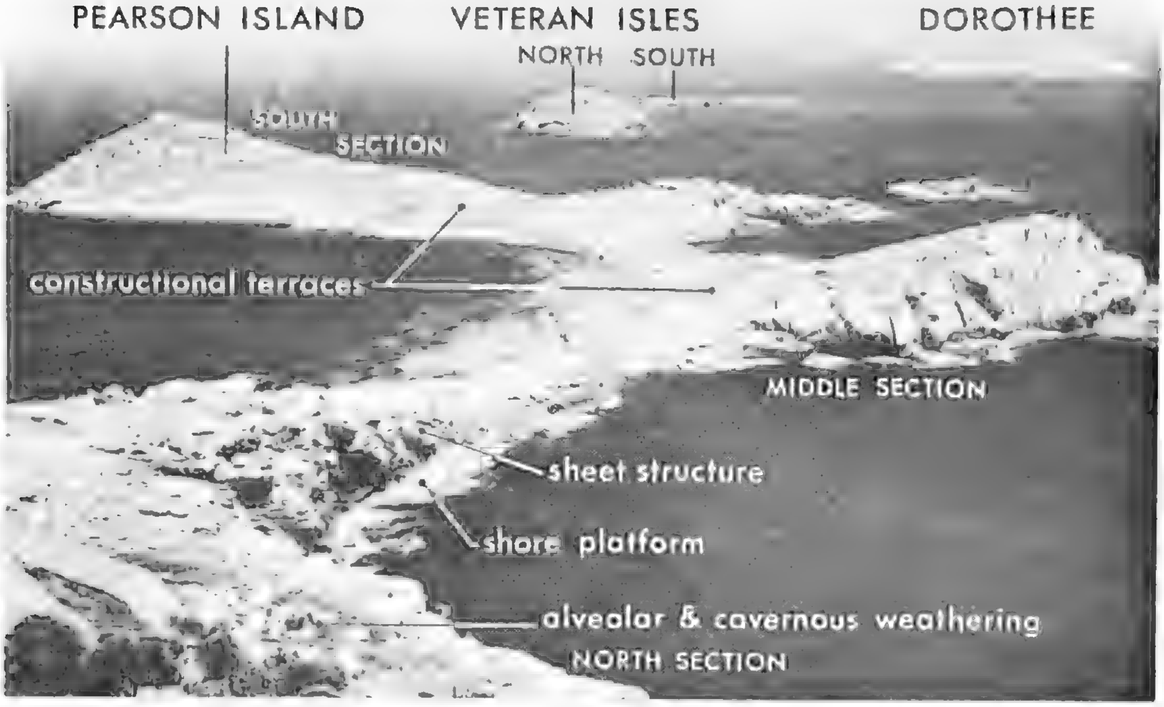

Fig. 2. View of Pearson Archipelago from upper slopes of Hill 781, looking south. (Photo Keith P. Phillips.)

Sheet structures dominate Pearson Island, especially the northern section, and are particularly well exposed in the coastal sections between Hill 781 and middle section, where the structures clearly dip toward the NW-SE trending major fractures postulated earlier.

Sheet structures can be regarded as having developed in one of two ways. Some would maintain that the dome-like character of Pearson and other adjacent islands is due to the joint pattern in the underlying granite (Harris 1888; Merrill 1897; Twidale 1964, 1971), but others would aver that it is the domed form of the residuals which causes the arched fractures to develop (see e.g. Gilbert 1904; Soen 1965). Protagonists of the latter viewpoint, known as the offloading or pressure-release hypothesis, point out that the mere appearance of granite at the land surface argues massive erosion, and hence unloading and release of pressure. They interpret the curvilinear joints associated with sheet structure as tangential fractures deve-

Fig. 3. Hill 781, north section, showing massive sheet structure, bouldery outcrops, and thin and discontinuous debris cover on middle slopes. (Photo C. R. Twidale.)

Fig. 4. Slightly flared slopes and wedges of rock exposed on sheeting plane, headwater region of North Creek. (Photo C. R. Twidale.)

Fig. 6. Cavernous forms (*tafoni*) on underside of flat-lying joints, north end of middle section. (Photo C. R. Twidale.)

Fig. 7. Gently curved sheet structures in granite, with calcareous deposits resting unconformably on them; southeast coast of north section. Note the trickle of water at the unconformity boulders. South section in the distance. (Photo C. R. Twidale.)

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loped parallel to the land surface in response to radial release of stress. In these terms the geometry of the joints is determined by the shape of the land surface.

In respect of the very similar features displayed by the inselbergs of northwestern Eyre Peninsula, it has been suggested that it is structure which is the first developed and which guides the shaping of the land surface (Twidale 1964, 1971). This argument rests on various lines of evidence which indicate that the rocks which form the inselbergs are in compression. Thus, survival of the residuals, and the development of sheet structures, are both regarded as manifestations of the same stresses. Features such as A-tents, though their precise genesis is obscure, surely result from compression and subsequent release of pressure within the rock mass (Jennings & Twidale 1971).

Two of the several features observed elsewhere and regarded as indicating that the sheeting is due to compressive stress occur on Pearson Island. The dip of the sheet structures steepens quite abruptly as they approach major vertical joints (Fig. 3). Also, on the underside of the exposed edges of sheets are displayed wedges which are triangular in cross section and which are believed to be due to differential movement along the fracture planes in response to arching (Fig. 4).

2. *Orthogonal joints:* The second set of joints, of subsidiary importance, comprises three sets of planar fractures disposed more-or-less at right angles to each other, thus effectively subdividing the rock into cubic, quadrangular or rhomboidal blocks. This is the orthogonal joint system. The orientation of the vertical joints varies markedly within the archipelago (Fig. 1). In some areas, as, for example, on the west side of North Hill on Pearson Island, these minor joints run parallel to segments of the major fracture pattern; but elsewhere they are aligned oblique to the framework, and in some localities they are curved in plan, as on the southern extremity of the north section of Pearson Island. These joints have been exploited by weathering and the joint blocks are more or less rounded. There is on the Investigator Group evidence that some of these boulders originated as corestones beneath the land surface (see Twidale 1971, pp. 20-25). On lower slopes some rather irregular masses of cohesive rock are set in gruss but many of the boulders and blocks on the upper slopes could have developed in another way, for not all blocks and boulders on the islands derive from the system of orthogonal joint blocks. On exposure the massive sheets of granite, 2-3 m thick, break down into blocks morphologically identical with those of the orthogonal system. But they can be distinguished from the latter by the inclination of the near vertical joints: they are formed by the development of fractures normal to the gently dipping joint planes which delineate the sheet structure and hence are out of vertical. Such blocks derived from the disintegration of sheet structure are especially common in the coastal areas of the Investigator Group. They are comparable to the grouped blocks related to sheet structure noted on the Everard Ranges of northern South Australia (Twidale 1971, p. 40).

The blocks exposed near the coast, and being quarried out by wave attack, are angular, but those on the middle and upper slopes of the inselbergs, as on East and North Hills, having been long exposed to the elements, are essentially rounded.

But whether derived from sheets or from orthogonal joint blocks, the form of the latter is directly related to the geometry of the joint sets. In particular, turrets are developed, as on East Hill, where the joint blocks are elongated in a vertical sense.

Other minor forms of interest are displayed on the granite bedrock. In several localities flared slopes have developed. Good examples are displayed at an elevation of 200-300 m on Hill 781, in the headwater region of North Creek; on the southeastern lower slopes of middle section, just northwest of the largest beach on the islands (Fig. 5); and on the

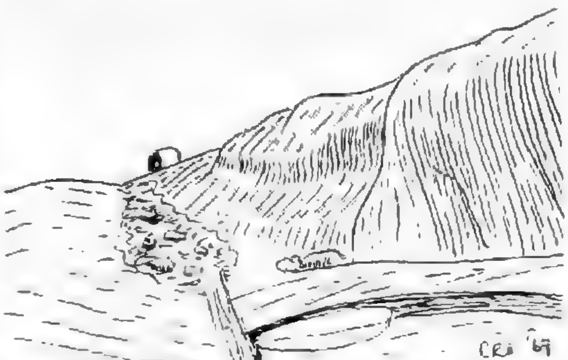

Fig. 5 Field sketch of flared slope marginal to major joint-controlled cleft, middle section.

southeastern slopes of north section. These occur where the bedrock is especially massive, and as a result of strong subsurface weathering by moisture and subsequent exposure of the weathering front (see Twidale 1962). They occur where soil or rock debris, which retains moisture, has previously accumulated but has now been evacuated. On some of the flares and other steep granite slopes, shallow grooves (*Granitrillen*, see Twidale 1971, pp. 89-90) are incipiently developed.

The undersides of the margins of rock sheets and many boulders, particularly those at higher elevations, display *tafoni* or cavernous hollows (Figs. 2, 6). The origin of these features is obscure but probably involves two contributory processes. First, granite which is exposed to the atmosphere is in dry climates less susceptible to weathering than that which is exposed to moisture (Twidale 1962, Wahrhaftig 1965). Moreover, in several climatic environments, though particularly in arid regions, a thin but resistant layer of complex character, rich in oxides of Fe, Mn, Si and Al, forms a resistant encrustation on exposed bedrock surfaces (Hooke, Houng-Yi Yang & Weiblen 1969). This is the so-called desert varnish, or case hardening. On Pearson Island this is present though not well developed. Second, moisture retained along joint planes, or in soil or debris accumulations, causes pronounced disintegration of the lower sides of joint blocks and sheet structure. The hollow so formed expands in ways not yet understood, though flaking and granular disintegration of the rock are involved (see Twidale 1971, pp. 43-44). But the tough outercase is weathered less rapidly and so *tafoni* are formed.

Thus, the major and most common land forms observed on Pearson Island are related to the nature, structure and weathering of the granite bedrock. The other landforms displayed are associated with the oceanic setting of the inselbergs.

COASTAL FEATURES

The coastal landforms of Pearson Island and other members of the Investigator Group are largely determined by the structure of the granite exposed at the shore. On the west-facing coasts, massive erosion has been so pronounced that the lower, inclined sheet structures have been worn away, and the dominant bedding planes exposed in high precipitous cliffs are horizontal (Fig. 6). In sheltered coves and on the east coast however, dipping curvilinear sheets dominate many stretches of the shore (Fig. 7).

Joints are exploited by wave attack, and major joint zones have been eroded to form deep clefts or geos, as for instance on Dorothee (Fig. 1).

Shore platforms in the intertidal zone are few and narrow, and are found on the western shores where major joints are horizontal and exploitable by wave attack. But deep quarrying by big waves is also active here, and such intertidal features are worn back at the expense of the deeper submarine ultimate platform. On the east coast, sheet structure determines the coastal morphology and mitigates against the formation of horizontal or near-horizontal platforms.

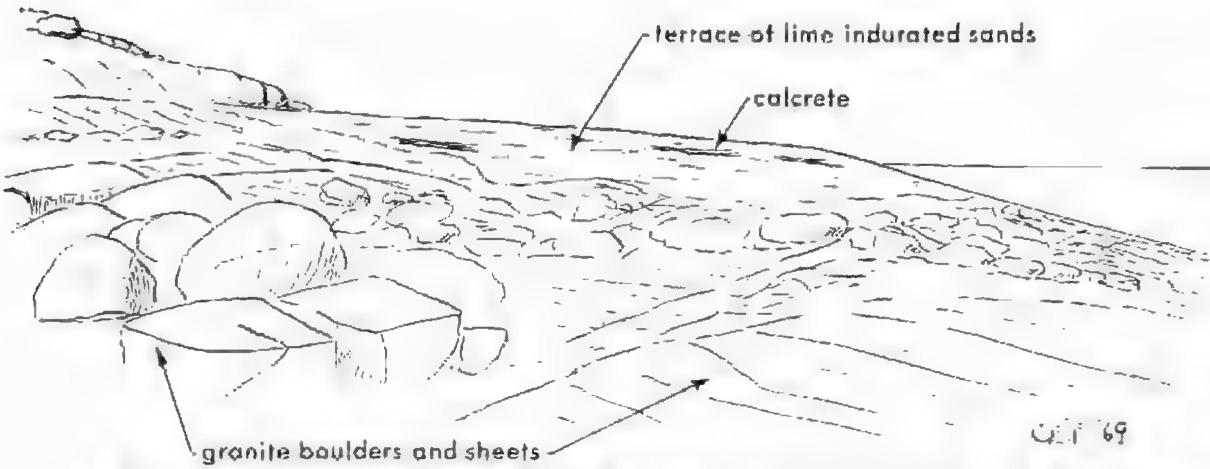

Fig. 8. Field sketch of lime-indurated deposit at southern extremity of north section. Note boulders in granite and rudimentary stratification due to development of layers of calcrete.

Other coastal features on Pearson Island were developed in relation to different stands of the sea. Over considerable areas of the eastern slopes on the island the granite bedrock is covered with limestone (Fig. 1). Cross-bedding indicates its aeolian origin though calcrete is developed at, and indeed forms the upper surface of, the outcrops. The height of the base of the limestone in which granite rubble is common varies from site to site. In addition colluvial deposits, possibly washed downslope during winter rains, merge with the aeolian sediments and tongue up valleys as for instance on middle section. Minor karst features—solution cups, fretting, lapiés—are developed on these limestone outcrops.

Aeolianite is widespread on and behind the coasts of southern Australia. It consists of sand blown from beaches and the emerged sea floor into coastal foredunes. Most of the sand is of quartz but calcareous shell fragments were included and these pounded to lime which subsequently indurated the sands. In several places along the South Australian coast aeolianite extends below sealevel, and according to Sprigg (1965) it has been found at depths of 50 m below sealevel near the mouth of St. Vincent Gulf, indicating a sealevel at least that much lower at the time of its deposition. All the available evidence indicates that aeolianite formed during glacial phases of the Pleistocene, when sealevel was lower than it is at present.

Coastal foredunes must have accumulated all around the lower slopes of Pearson Island, just as they did around and over similar crystalline residuals at the southwestern extremity of Yorke Peninsula. However, remnants of the outcrops of aeolinite are preserved only in east coast situations. It may be that it was formed on the western side of the islands and has been completely eroded by strong wave attack. Alternatively, the emerged seabed between the islands and Eyre Peninsula probably provided a richer source of debris than the area to the west, which, depending on the degree of emergence, probably remained submerged in large measure.

Although the winds of the glacial periods were, to judge from the distribution of aeolianite dunes on the coast of southern Australia as a whole, dominantly westerly, some, smaller, foredunes accumulated in east coast situations under the influence of the occasional easterlies (see e.g. Jennings 1957).

The aeolianite deposits have been truncated so that dune forms are no longer visible. The dunes have been eroded and gently sloping terraces capped by calcrete formed on them (Fig. 7). The outer or lower limit of the terraces stands some 6-9 m above present high tide level. These terraces are not comparable to shore platforms, for they lack the horizontality of such features. They could have been eroded by wash grading to a higher sealevel, though (Fig. 9) because the surface is inclined, the level of the sea to which the aggradation can be related depends with the amount of coastal erosion that has taken place. However, on the sheltered eastern shores, where the deposits are preserved, coastal recession has probably not been marked and the figures cited may be taken as significant.

Fig. 9. Diagram illustrating how coastal recession affects projected elevation of top and base of alluvial deposits and interpretation of former sealevels.

An alternative explanation is that the terraces were originally horizontal platforms eroded by marine agencies (waves plus weathering); that after emergence calcrete formed below the terrace surface coincident with a sloping water table, and that subsequently the loose friable sands above the pedogenic lime have been removed, stabilising the surface at the upper limit of the calcrete. If this is so a slightly higher stand of the sea is indicated (possibly 7-10 m above present), for the upper, rather than the lower, elevation of the terrace remnants is diagnostic.

Comparison with adjacent areas is not rewarding. In view of the regional setting of the Investigator Group, vertical movements of the crust are possible, though in the short time period under consideration they are unlikely to exceed the vertical range of activity of marine processes. This last is the real difficulty. On southwestern Yorke Peninsula the sea is at present active through a vertical range of perhaps 12-13 m, and platforms have developed at various elevations within this range. Even if it is taken that the terraces on Pearson Island are basically of marine origin, there is no means of determining where they stand in relation to high tide, low tide or mean sealevel. If however they are taken as grading to a specific and higher sealevel, then they are evidence of a stand of the sea 6-9 m above present.

Acknowledgements

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PEARSON ISLAND EXPEDITION 1969. – 3. CONTRIBUTIONS TO THE LAND FLORA

BY *D. E. SYMON*

Summary

Further additions to the Fungal, Moss and Angiosperm flora of Pearson Islands are presented, including a first list of plants from Dorothee Island. A brief account is given of the sex ratios of *Casuarina stricta* Ait. Comparisons of photographs taken after an interval of 46 years are made for 8 sites on Pearson Island.

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Introduction

The first expedition to the Pearson Islands was from the 5th to 12th January 1923. During this time a collection of 52 species of vascular plants was made (Osborn 1923). The author noted that it was probably incomplete as far as herbaceous plants are concerned.

The second major collection (Specht 1969) was made by Specht between 10th and 23rd February 1960. Every effort was made to obtain a complete collection of species so that this could be compared with the original 1923 list. He presented a comparison of the two collections in his Appendix I and brought the nomenclature up to date. Specht was able to add 9 species not collected by Osborn but was unable to collect 10 species previously found. These omissions are nearly all annuals such as *Triglochin muelleri, Bulbinopsis semibarbata, Vulpia bromoides,* though it did include a few shrubs (e.g. *Westringia rigida*) or perennials (e.g. *Nicotiana suaveolens*). Specht's visit was slightly later in the year than the first one and this could account for some of these ommissions.

No effort was made during the 1969 expedition to make a third comprehensive collection of all plants on the island. Instead a selective collection was made of any apparent new records and a number of soil scrapes were brought back with the intention of germinating any seeds present. It was hoped that a number of small ephemerals might be grown that would normally have died by January.

Twenty samples of surface soil from varied sites were collected into plastic bags. On return to Adelaide, and after picking out the coarser material the soil was spread on the surface of sterilised soil and lightly covered with peat moss. A second sowing of selected samples was also made by Dr. Hj. Eichler a year later, who obtained all the species found in the first sowing and added at least two more.

All the scrapes produced some plants, with dense germination in several samples. Some species occurred repeatedly in the collections. *Apium prostratum* in 12, *Parietaria debilis* (not previously recorded) in 6, *Plantago varia* in 7, *Vulpia bromoides* in 6, *Agrostis avenacea* in 7, *Hydrocotyle comocarpa* (not previously recorded) in 4, and these species are obviously widespread. It is possible that if the soil samples were given more varied conditions for the germination of the seeds they contain, e.g. flooding or a range of temperatures, that yet more species may be grown, as some annuals known to be present, e.g. *Centrolipsis* spp., *Sonchus* sp. have not been germinated to date.

All specimens of Angiosperms have been deposited in Herbarium ADW.

Additions to the Flora of Pearson Island

Fungi. During the 1969 Expedition the following Fungi were collected. All have been identified by Dr. P. H. B. Talbot and deposited at the Waite Agricultural Research Institute.

Bovista brunnea Berk.
Geastrum fenestriatum (Pers.) Fischer
Geastrum velutinum (Morgan) Fischer
Mycenastrum corium (Guers.) Desv
Fomes sp.

Musci. The following mosses were collected and have all been identified by Mr. L. D. Williams of Meningie; specimens are deposited in the State Herbarium (AD).

Barbula australasiae (Hook. & Grev.) Brid. (*Symon* 183).
Bryum campylothecium Tayl. (*Symon* 170, 174, 177, 180, 184).
Bryum pachytheca C.M. (*Symon* 172, 175).
Campylopus introflexus (Hedw.) Mitt. (*Symon* 170, 173, 179).

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*Waite Agricultural Research Institute, Glen Osmond, S. Aust. 5064.

Trans. Roy. Soc. S. Aust. Vol. 95, Part 3, 15th October 1971.

Fabronia leptura (Tayl.) Broth. (*Symon* 178, 182).

Grimmia laevigata (Brid.) Brid. (*Symon* 181).

Sematophyllum homomallum (Hpe.) Broth. (*Symon* 177).

Tortella calycina (Schwaegr.) Dix. (*Symon* 171.)

Triquetrella papillata (H. J. & W.) Broth. (*Symon* 176).

Angiosperms.

Zosteraceae. *Heterozostera tasmanica* (Martens) Den Hartog, collected by Mrs. J. Watson at North Bay at 26-27 m (85-90 ft.) deep.

Posidoniaceae. *Posidonia australis* Hooker f., collected by Mrs. J. Watson at North Bay at 15 m (50 ft. deep).

Euphorbiaceae. *Beyeria leschenaultii* (DC.) Baill.

Primulaceae. *Samolus repens* (Forst.) Pers.

Gentianaceae. *Erythraea australis* R. Br.

Solanaceae. *Solanum nigrum* L.

Records from germinations from soil.

Urticaceae. *Parietaria debilis* G. Forst.

Caryophyllaceae. *Minuartia* sp. (not yet identified). *Sagina apetala* Ard. *Sagina maritima* Don ex Sm. & Sow. *Spergularia* sp. (not yet identified).

Brassicaceae. *Hymenolobus procumbens* (L.) Nuttall ex Shinz. & Thell.

Apiaceae (Umbelliferae). *Hydrocotyle comocarpa* F. Muell. *Daucus glochidiatus* (Labill.) Fisch. Mey. et Avé-Lall.

Rubiaceae. *Galium murale* (L.) All.

Asteraceae (Compositae). *Brachyscome iberidifolia* Benth. *Cotula vulgaris* Levyns. *Gnaphalium involucratum* Forst. f. *Senecio minimus* var. *picridioides* (Turcz.) Belcher. *Stuartina muelleri* Sond.

Records from Dorothee.

The following plants were collected from the southern island of Dorothee and constitute the first list of plants from that island.

Poaceae (Gramineae). *Agropyron scabrum* (Labill.) Beauv. *Agrostis avenacea* Gmelin. **Distichlis distichophylla* (Labill.) Fassett.

Liliaceae. *Bulbinopsis semibarbata* (R. Br.) Borzi. *Dianella revoluta* R. Br.

Urticaceae. *Parietaria debilis* G. Forst.

Chenopodiaceae. *Atriplex cinerea* Poir. *Atriplex paludosa* R. Br. *Enchylaena tomentosa* R. Br. *Rhagodia baccata* (Labill.) Moq. *Rhagodia crassifolia* R. Br. *Threlkeldia diffusa* R. Br.

Aizoaceae. *Carpobrotus aequilaterus* (Haw.) N. E. Brown. *Disphyma australe* (Ait.) N. E. Brown. *Tetragonia amplexicoma* (Miq.) Hook. f.

Portulacaceae. *Calandrinia calyptrata* Hook. f.

Caryophyllaceae. *Sagina maritima* Don ex Sm. & Sow. *Scleranthus pungens* R. Br. *Spergularia* sp. (not yet identified)

Brassicaceae (Cruciferae). *Hymenolobus procumbens* (L.) Nuttall ex Schinz. & Thell. *Lepidium foliosum* Desv.

Mimosaceae. **Albizzia lophantha* (Willd.) Benth.

Geraniaceae. *Pelargonium littorale* Huegel.

Zygophyllaceae. *Nitraria schoberi* L.

Rutaceae. *Correa reflexa* var. *coriacea* Wilson.

Sapindaceae. *Dodonaea viscosa* Jacq.

Malvaceae. *Lavatera plebeia* var. *tomentosa* Hook. f.

Frankeniaceae. *Frankenia pauciflora* DC.

Apiaceae (Umbelliferae). *Apium prostratum* Labill. ex Vent. *Hydrocotyle comocarpa* F. Muell.

Epacridaceae. *Leucopogon parviflorus* (Andr.) Lindl.

Solanaceae. *Lycium australe* F. Muell. *Nicotiana maritima* Wheeler.

Plantaginaceae. *Plantago varia* R. Br. sens. lat.

Asteraceae (Compositae). *Calocephalus brownii* (Cass.) F. Muell. *Ixiolaena supina* F. Muell. *Olearia axillaris* (DC) F. Muell. ex Benth. *Senecio lautus* Forst. f. ex Willd.

Distichlis distichophylla and *Albizzia lophantha* have not yet been found on Pearson Island and are new records for the group of islands.

The occurrence of *Albizzia* was of particular interest as nowhere is it now common on the mainland and the dense stand here in a ravine like gully may be a reflection of the freedom from grazing that the island still enjoys. Although no quantitative measurements were made, several species were obviously widespread (e.g. *Nicotiana maritima, Ixiolaena supina*), and these too may reflect the freedom from grazing. It is suggested that detailed ecological studies of comparable areas on the two islands (Pearson and Dorothee) would be interesting and may reflect the influence of the wallabies on the vegetation

Sex Ratios of *Casuarina stricta* Ait.

This species of *Casuarina* is dioecious and reproduces mainly if not entirely from seeds: root suckers common in some species of *Casuarina* are rarely seen. It is considered to be sexually normal and not to produce apomictic seeds (B. A. Barlow, personal communication). Sex ratios have not previously been reported. The species is common and well developed on Hill 781 forming a woodland of trees 6-8 m (20-25 feet) high. An example may be seen in Fig. 5 though not taken on Hill 781. The male trees never bear cones though some large galls can be mistaken for cones by the inexperienced observer. The female trees retain many relatively large cones (about 3 x 3 cm) which are readily seen. It was such trees that were counted and it should be noted that a tree without cones would have been counted as male.

A count was made of the cone bearing trees growing along the slope from the shoulder above North Bay to the summit of Hill 781. The method was to inspect all the trees close to a point on the transect.

Site	Trees bearing cones	Trees without cones
1. Near the lowest point on the shoulder	14	13
2. One third up the slope	11	12
3. About halfway up the slope	14	24
4. Towards top of the slope	16	23
5. Just below and about the upper boulder masses, near the summit	21	22
6. Uppermost trees	3	15

The figures show an overall sex ratio of 79 female trees to 109 male trees and they suggest an increase in the number of male trees with increasing height above sea level and exposure to the elements. If exposure is significant in affecting the survival or fertility of the female trees it may account for the rather high count of female trees at site 5 which was at the base of, and to some extent in, the lee of the massive granite outcrop and therefore in a more protected site

Changes in the Vegetation 1923-1969

During the 1923 expedition T. G. B. Osborn took a number of photographs of various parts of Pearson Island and made notes on the vegetation of each site. The negatives, prints and notes have all been preserved. Efforts were made in 1969 to rephotograph as many of these sites as precisely as possible and to examine them for signs of vegetational change in the intervening 46 years. Sixteen sites were rephotographed and a selection of 8 pairs of comparisons is presented here. Reference can be made to Twidale (1971) for a description and map of Pearson Island.

Discussion

Some of the most obvious changes on the Island, occurring in the absence of rabbits, sheep and permanent occupation by man, have been:

1. The great reduction in dead wood and dying trees.
2. Considerable changes in the *Casuarina stricta* trees.
3. The widespread advance of dense *Atriplex* stands at a number of sites.
4. The reduction in bare ground and in annual and short lived species like *Senecio lautus* and *Apium prostratum*.
5. The reduction in medium sized shrubs such as *Olearia*, *Leucopogon*, and *Rhagodia*.

The great increase in *Atriplex* at a number of sites can hardly be due to such biotic factors as the trampling of seals or the effect of penguin rookeries as suggested by Specht (1969). The changes may perhaps be due to slow, long term succession probably triggered by a catastrophe such as fire or drought. Some signs of old fires in the form of charcoal or burnt stumps were visible on the Island. Substantial changes in grazing pressure could occur if the Wallaby population changed very much but as the increase in *Atriplex* in particular has also occurred on south section as well as north section and the former has been free of Wallabies, this seems an unlikely explanation.

After a fire one could expect much bare ground, perhaps scorched and dead trees, followed by subsequent invasions by annuals and short lived shrubs which gradually give place to longer lived shrubs, and the accumulation of dry matter finally precipitating further fire hazards. Such cycles can be seen on the mainland even in relatively arid areas and seem a possible explanation of the very great changes that have occurred on this virgin site. The effects of seasonal or cyclic climatic change or the effects of varying number of wallabies, penguins and seals are not known.

The original negatives and annotated prints by Professor T. G. B. Osborn are deposited in the Botany Department of the University of Adelaide and were kindly made available by Professor Osborn. The 1969 photographs will

Fig. 1. A in 1923, B in 1969. Middle section from the sandy landing place, looking northwest to the summit. The *Atriplex cinerea* in the foreground has obviously become denser and the shrubberies at the base of the granite outcrops have been greatly reduced.

Fig. 2. A in 1923, B in 1969. North Bay on north section, from near the summit of East Hill.

There appears to be a reduction in dead timber, and this was also evident by inspection at other places on the Islands. There has been almost complete removal of the dead and dying *Melaleuca* along the small creek-line in the centre valley. There has been an increase in the *Atriplex paludosa* (pale) and a reduction in *Rhagodia crassifolia* (dark). Compare these also with the next pair of photographs.

Fig. 3. A in 1923, B in 1969. From the slope above North Bay, looking east to the base of East Hill.

The *Melaleuca* to be seen in the earlier photograph has now almost completely disappeared except for a little dead wood. The great reduction in *Rhagodia crassifolia* (dark hummocks) and the filling of open ground by *Atriplex paludosa* is evident. The more erect dark shrubs in the foreground of 3B are *Arthrocnemum halocnemoides*.

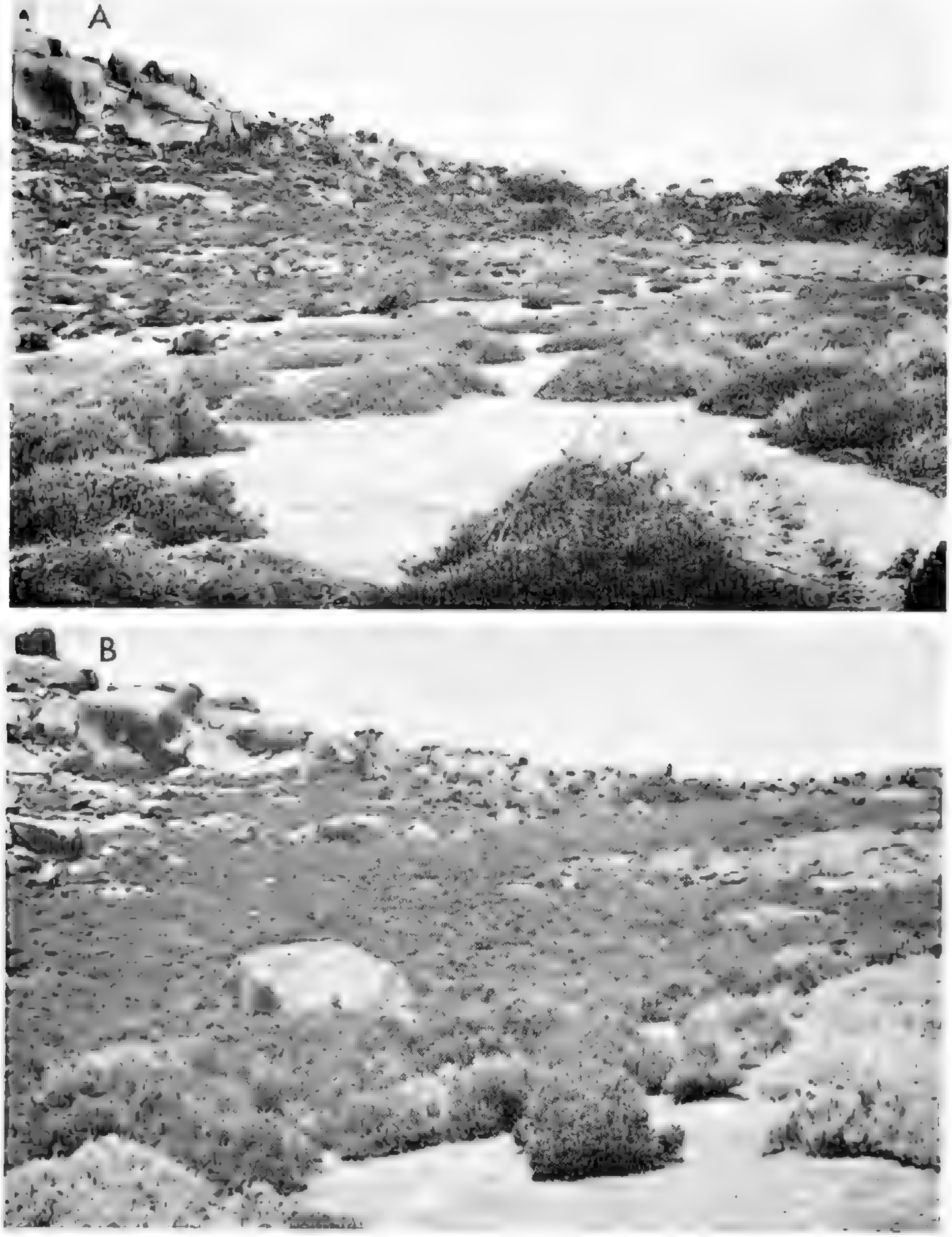

Fig. 4. A in 1923, B in 1969. From the slope above Eastern Cove looking up the slope to the col joining East Hill with Hill 781. Professor T. G. B. Osborn comments that the site has rapid drainage and much bare ground. See also the two previous photographs. Owing to different camera fields, the right hand edge of the 1923 photograph could not be included in the 1969 photograph. Note the almost complete replacement of the sprawling *Rhagodia crassifolia* (dark mounds) by the now dense *Arthrocnemum halocnemoides*, the great reduction of open ground, the increase in *Atriplex paludosa* on the right and the reduction in number of *Casuarina stricta* trees on the skyline.

Fig. 5. A in 1923. B in 1969. North section looking towards the summit of East Hill from the col joining East Hill and Hill 781. The marked reduction in dead wood is evident in the foreground and the middle distance. There has been a loss of the larger shrubs, e.g. the one (*Melaleuca lanceolata?*) growing on the large rounded boulder in the middle distance, though the *Correa rubra*, a little to the right, survives. There has been considerable advance in the *Atriplex paludosa* which is not visible in the earlier photograph and which has largely replaced the *Rhagodia crassifolia* in the foreground. There has been a considerable change in the tree population of *Casuarina stricta* though some individuals can be recognised, e.g. the tree in front of the central split tor, and the tree to the left of the middle tor now leaning and partly hidden in the 1969 photograph).

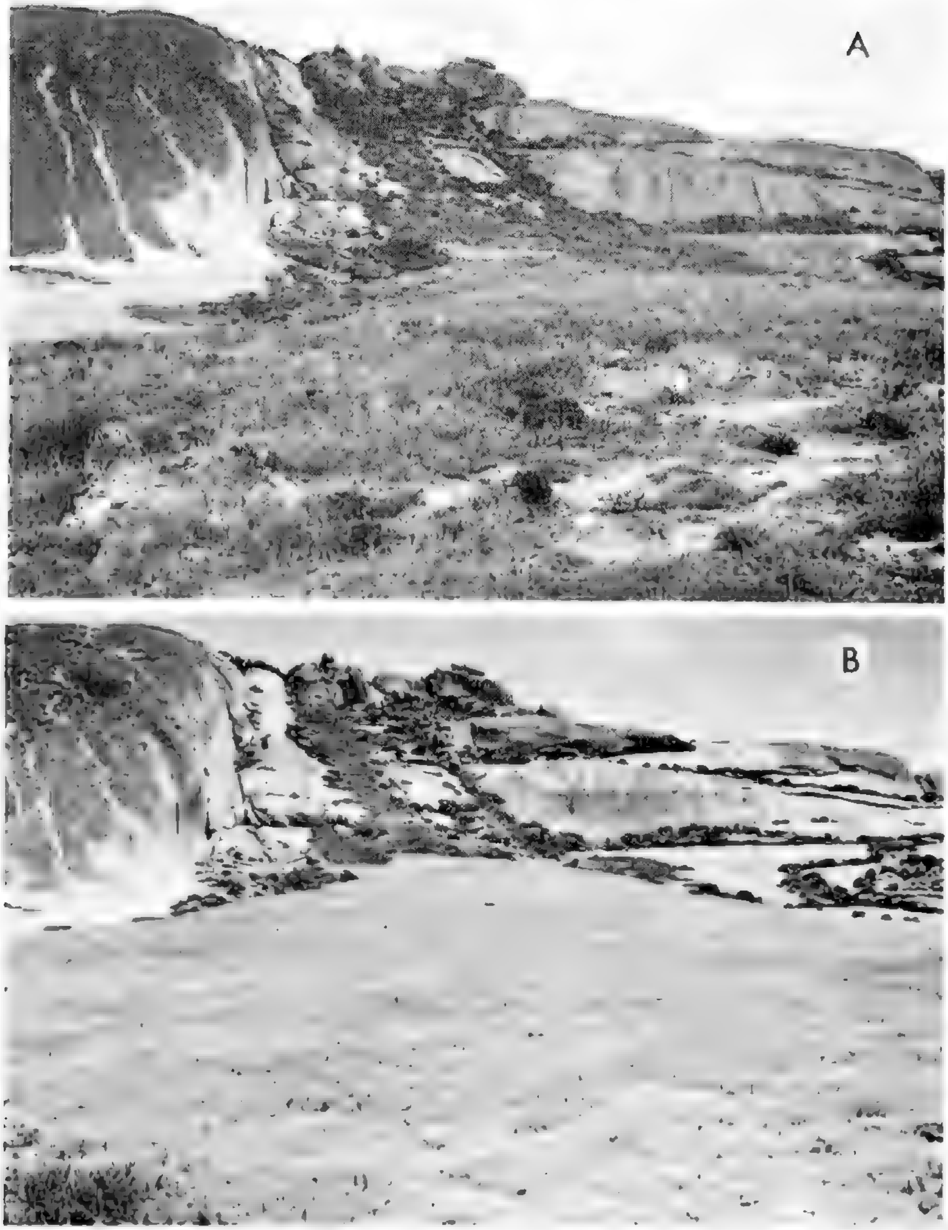

Fig. 6. A in 1923, B in 1969. Middle section, looking northwest to the summit up from the calcarenite plateau. From the foreground Professor T. G. B. Osborn lists *Senecio lautus*, *Apium prostatum*, *Enchylaena tomentosa* and *Lepidium foliosum*, and the bare ground is also evident. These shrubs have been almost completely replaced by dense *Atriplex cinerea*. This was one of the most striking examples of the increase in *Atriplex* on the Island.

Fig. 7. A in 1923, B in 1969. Middle section, northeast edge of the calcarenite plateau looking W to the summit. The changes listed under Fig. 6 are all evident here. In addition, the *Olearia ramulosa* growing at the junction of the calcarenite and the granite has largely disappeared and there has been a general reduction in shrubs. The lichen patterns seen on the main granite masses have possibly increased in the foreground. Where did the large rock present on the middle left skyline in 1969 come from?

Fig. 8. A in 1923, B in 1969. North section, lower slopes of East Hill from the south. The rather open stand of *Atriplex paludosa* in the foreground is now very dense. The *Olearia*, *Leucopogon* and *Correa* shrubs on the slope have been reduced and invaded by *Atriplex*. The *Casuarina* trees on the skyline have been reduced though some (such as the large dense tree to the right in 1923) may persist as a sparse relic in 1969. Almost all the trees at the base of the large low rocks in the centre have gone.

be added to the collection. The availability of these relatively early, well annotated photographs, and the island's freedom from sheep, rabbits and stock make Pearson Island an almost unique site in South Australia for the study of long term natural changes in the flora, and every effort should be made to keep interference by man in the islands to a minimum.

Acknowledgements

I am most grateful for the assistance of the Department of Fisheries and Fauna Conservation and the Council of the Royal Society of South Australia in enabling me to take part in this Expedition. and also to Professor T. G. B. Osborn for letting me have access to his film negatives and original notes from the 1923 Expedition.

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PEARSON ISLAND EXPEDITION 1969. – 4. THE PEARSON ISLAND WALLABY

BY I. M. THOMAS AND L. B. DELROY

Summary

A brief account is given of some aspects of the habits and population structure of the Pearson Island Wallaby, derived from observations made during visits to the islands in 1920, 1960, 1968 and 1969, and also from observations made on groups of captive animals on the mainland of South Australia.

PEARSON ISLAND EXPEDITION 1969. — 4. THE PEARSON ISLAND WALLABY

by I. M. Thomas* and L. B. Delroy†

Summary

A brief account is given of some aspects of the habits and population structure of the Pearson Island Wallaby, derived from observations made during visits to the islands in 1920, 1960, 1968 and 1969, and also from observations made on groups of captive animals on the mainland of South Australia

Introduction

It has been known from the earliest days of colonisation of South Australia that there were wallabies on Pearson Island. This is because, unlike their mainland counterparts, they are not crepuscular in habit but spend a considerable part of the daylight hours out in the open, with individuals often perched on the tops of rocky eminences where they could be observed from passing ships. It is, then, perhaps surprising that it was not until 1922 that they were first described and named. The islands are indeed somewhat inhospitable, as they have no permanent fresh water and are not easy to land on. They are unsuitable for grazing sheep, and, since several other islands off the western shores of South Australia have satisfactory pasture, the Pearson Islands have been left largely undisturbed

Taxonomy

In November, 1920, some specimens were collected by Professor F. Wood Jones. Of these, a pelt and a skull were sent to Mr. Oldfield Thomas at the British Museum. He (Thomas 1922) described them as a new species, *Petrogale pearsoni*. He considered it to be close to *P. hacketti* Thomas, 1905 from Mondrain and Coombe Islands of the Recherche Archipelago and *P. lateralis* Gould, 1842 from the western coastline of Australia, the Northern Territory and the McDonnell Ranges. The specific status of *P. pearsoni* was maintained by Wood Jones (1923 and 1924), by Burrell & Le Soueff (1926), by Troughton (1967) and others.

Marlow (1962) noted three subspecies of *P. lateralis*, namely *P. l. lateralis*, *P. l. hacketti* and *P. l. pearsoni*. In a letter to the senior author he said, "It is obvious that all these three taxa are very closely related and at present, to prevent unnecessary splitting, I felt it necessary to consider both *hacketti* and *pearsoni* as insular subspecies of the mainland *lateralis*." Tate (1948) merged *P. lateralis* with *P. penicillata* Griffith on the grounds of their very close cranial and dental resemblances. He listed *P. p. penicillata* Griffith, *P. p. herberti* Thomas, *P. p. lateralis* Gould and *P. p. hacketti* Thomas. Presumably, lacking material of *pearsoni* for comparison, he did not consider its status, but Sharman (1961) in discussing the chromosomes of a range of marsupials, described those of *P. p. pearsoni* Thomas. Aitken (1970) agrees with this.

Ride (1970), discussing the native mammals of Australia, is not concerned with them below specific level. He distinguishes six species of rock wallabies and in *P. penicillata*—the brush-tailed rock wallabies—includes *hacketti*, *herberti*, *inornata*, *lateralis*, *longmani*, *pearsoni*, and *wilkinsi*. Of these he says, "although recognisably different from each other by colour, probably represent no more than different populations of a single species . . . which occurs widely over much of Australia."

It is clear from this that the detailed relationships of the rock wallabies is badly in need of close study, particularly in the case of the insular forms.

Biology

Wood Jones (1923) noted, in more than one visit to the islands, that the wallabies occurred only on the northernmost of the three sections of Pearson Island. It is possible, at low spring tides, to pass from the north to the middle section dry-shod with a little "rock hopping". One can pass from the middle to the south section dry-shod at any state of the

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tide except possibly in the roughest weather. The 1960 expedition, led by the late Professor T. Draper Campbell, of which the senior author was a member, also noted the absence of wallabies on the middle and south sections and further that there were no traces of skeletal remains nor of occupation of the several caves on the south section by wallabies. It was therefore concluded that the wallabies had never inhabited the middle or south sections or, at least, they had not done so for a very long time. This could not be because the middle and south sections lacked the proper habitat or food for the animals. The wallabies have been observed to feed freely on several plants on the north section, especially *Lepidium foliosum* Desv., *Atriplex cinerea* Poir., *A. paludosa* R. Br., *Rhagodia baccata* (Labill.) Moq., and *Olearia axillaris* (DC) F.v.M. ex Benth. These plants often grow together in the same communities and are plentiful on the middle and south sections (Specht 1969).

On the 1960 expedition, several wallabies were caught on the north section and brought back to the camp on the middle section. Here they were kept in a wire netting enclosure ready for transport to the mainland. The first group comprising four does and one buck escaped and later, one of unknown sex escaped. In May 1968 one of us (L.B.D.) visited the island for three days and estimated that there were between 50 and 150 wallabies on the middle and south sections while on the north section their numbers were in excess of 500. The senior author made an estimate of 500 to 600 on the north section in 1960.

The rough terrain and the tendency of many of the wallabies to disappear into crevices when disturbed, together with the brief times spent on the island by different expeditions, make even reasonable estimates of the population numbers extremely difficult. Wood Jones (1924) talks of "comparatively large numbers in a limited area", referring to the north section. Perhaps the most accurate estimation for the wallaby population of the northern section was made on the 1969 expedition when a figure of about 800 was arrived at.

Table 1 shows the possible increase in numbers on the south section between 1960 and 1968 using the following assumptions: (a) that all six animals were sexually mature and fertile when released; (b) that there were two males and four females; (c) that females start reproducing in their second year; (d) that females produce one young a year; (e) that life expectancy is ten years (the animals released are allotted a mean age of five years); (f) that male and female young are produced in approximately equal numbers. These assumptions are made on what is known of the reproductive capabilities of mainland rock wallabies and from studies of captive groups of the Pearson Island wallaby which have been maintained at the Adelaide Zoo, at the reserve of the Department of Fisheries and Fauna Conservation at Bool Lagoon, South Australia, and by Dr. M. E. Christian, of Adelaide. It can be seen that the original six animals could have increased to 90 between 1960 and 1968. If there were five females and one male, the numbers could have been 112.

TABLE 1

Predicted increase in numbers of wallabies on the middle and south sections of Pearson Island from 1960 to 1968.

	Males	Females	Young produced	Total
1960	2	4	—	6
1961	2	4	4	10
1962	4	6	4	14
1963	6	8	6	20
1964	9	11	8	28
1965	13*	15*	11	39
1966	16	17	15	48
1967	23	25	17	65
1968	32	33	25	90

*It is presumed that the original two males and four females died during this year.

The rough estimates of the numbers on the island indicate that the population of the north section has been relatively stable over the period of observations. This contrasts strongly with the situation on the middle and south section where the numbers increased from six to possibly over a hundred in eight years. This means that the population was increasing at about its maximum possible rate. The abundance of food on all three sections makes it unlikely that food would be a limiting factor in any section. It seems likely then that living space for breeding groups and a strong inclination to territoriality has been the factor of greatest importance in controlling numbers on the north section. On the main island, the wallabies live in groups of up to twenty or thirty centred on a group of boulders, caves or crevices, amongst which they hide when disturbed. They are rarely seen in the tall *Melaleuca* scrub (Specht 1969) and then only singly. They move into low saltbush only to feed. All their resting places are amongst rocks. They differ from the mainland rock wallabies in that they spend more of the daylight hours out in the open. Characteristically, one or more of a group will remain perched on a rocky eminence for an hour or more at a time, as though acting as "look-out" for the group. However, all retire into shaded regions during the greatest heat of the day in the summer months.

Observations on captive groups show that males fight savagely and that groups are dominated by one mature male. There may be, on occasions, a sub-dominant male but no other mature male is tolerated in the group. There may be several immature males but any one of these would, on reaching maturity, have to defeat the dominant male in conflict, be expelled from the group, or be killed. Those expelled from groups, it is believed, live singly or in small, non-breeding groups. They are unhealthy in appearance and often heavily infested with ectoparasites. Animals caught by being chased into nets on the 1969 expedition, were predominantly males and most of these were probably from this section of the social order. Further, males seem to wander more from the groups' territorial centres and so might be more likely to be caught in nets.

Capture and Treatment

In open country, the wallabies are not difficult to catch by running them down, but once they get into rocky terrain, their agility and powers of leaping prevent this. On the 1960 expedition, wooden drop-door traps baited with apple or carrot were used with some success. On the 1969 expedition, chasing the animals into nets was found to be effective. These were of heavy hemp of about 12 cm mesh and about 45 to 140 m length. They were hung fairly loosely so that they acted as trammel nets and animals encountering them became thoroughly enmeshed. They suffered no injuries however, if released promptly. On return to camp, they were injected with 1 ml Cytovet 1000 to obviate the effects of shock. They could be kept conveniently in open-weave sacks or in plywood tea-chests. As long as the animals were kept in darkness, they remained quiescent. They fed quite readily on "Kangaroo pellets" manufactured to supply zoos, etc., but a supplement of green feed was necessary.

There is no permanent fresh water on Pearson Island and pools appearing after rain are highly saline. Hence, the wallabies must gain all their water from vegetation or from dew. In captivity, however, they will lap up water.

Conclusions

It seems that the numbers of wallabies on the north section of the island have remained fairly constant over a long time. The population explosion resulting from their inadvertent introduction to the middle and south sections, coupled with the apparent abundance of food on all sections, suggests strongly that the availability of adequate territorial areas may be an important factor in controlling population size. This, however, fails to explain why they had failed to spread, of their own accord, over the very narrow strip of water at low tide, which separated them from abundant living space on the middle section. A tentative suggestion is that there is little or no drinking water on the island but a great deal of sea water which might be distasteful to them. This might have produced a strong avoidance reaction to water. Observations that the animals in captivity will tend to avoid large bodies of water, may bear this out.

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PEARSON ISLAND EXPEDITION 1969. – 5. REPTILES

BY M. SMYTH

Summary

Six species of lizards but no snakes occur on the Pearson Islands; two of these are recorded from the Pearsons for the first time.

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by M. SMYTH*

Summary

Six species of lizards but no snakes occur on the Pearson Islands; two of these are recorded from the Pearsons for the first time.

Introduction

Six species of reptiles, all lizards, are now known from the Pearson Islands, of which four, collected during the 1923 expedition, were listed by Proctor (1923a). All species known from the Pearsons are listed below, together with notes on their abundance, their occurrence on the various parts of the islands, and the registered numbers of specimens in the South Australian Museum.

Family GEKKONIDAE

Phyllodactylus marmoratus Gray. Very common on all parts of Pearson and on Dorothee. This species occurs on all the larger islands off the west coast of the State. (R10215; 6 specimens.)

Family AGAMIDAE

Amphibolurus sp. This species was listed by Proctor (1923a) as *A. decresii* Duméril and Bibron, the type specimen of which came from Kangaroo Island. Later, Proctor (1923b) described a new species *A. fionni*, but she gave no type locality. The Pearson Island specimens are well fitted by her description of *A. fionni*; they are also very similar to others from the Neptune Islands, St. Francis Island and the isolated granite and quartzite outcrops of central and northern Eyre Peninsula and the West Coast. But it has so far proved difficult to find criteria to distinguish *A. fionni* from *A. decresii*, and until their taxonomy is examined in detail I prefer not to use either name for the Pearson Island specimens.

This species is always associated with rocks, and on the Pearson Islands can be found on both granite and limestone. It is very abundant on the north section of Pearson Island, but much less so on the middle and south sections and on Dorothee. Its greater abundance on north section is correlated with the greater abundance there of a little ant in the genus *Iridomyrmex* on which the lizards, to judge from the contents of their faeces and stomachs, feed almost exclusively. (R10239; 9 lizards.)

Family SCINCIDAE

Morethia lineoocellata (Duméril and Bibron). This active, fast-moving skink was not taken in 1923 or 1960, but it is not uncommon on north section, though very difficult to catch. It was frequently seen foraging among the branches and foliage of bushes as well as on the ground. It was not seen during the short stay on Dorothee. (R10217, 10238.)

Lerista tetradactyla (Lucas and Frost). This is a secretive little skink, usually found partly buried in loose earth under stones or wood. It was not found in 1923, but several specimens were brought back in 1960 and it is in fact common on all parts of Pearson Island and on Dorothee. It occurs on most of the islands off the West Coast and is widespread on the mainland. (R10233-4, 10229.)

Leiolopisma entrecasteauxii (Duméril and Bibron). A single specimen was caught in 1923; at that time it was the only specimen known from outside south-eastern Australia. It was not seen in 1969, despite an intensive search. I have examined the 1923 specimen and agree with Proctor's identification. This species is common in the southeast of South Australia, but there are very few records from further west than that; Condon (1941) records it for Kangaroo Island and there are other specimens in the South Australian Museum from Middle Beach (about 30 miles north of Adelaide) and South Neptune Island.

Hemiergis peronii (Fitzinger). This species is very common under stones, wood, or foliage on the ground on all parts of Pearson and on Dorothee; it also occurs in coastal areas across much of southern Australia and on most if not all the associated offshore islands (Smyth 1968). (R10216, 10230-1.)

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PEARSON ISLAND EXPEDITION 1969. – 6. BIRDS

BY JOAN B. PATON

Summary

An annotated list is given of the twenty-seven species of birds recorded on the Pearson Islands by the expedition of January 1969. A tabulated list of all records of birds from the islands is also given.

PEARSON ISLAND EXPEDITION 1969. — 6. BIRDS

by JOAN B. PATON*

Summary

An annotated list is given of the twenty-seven species of birds recorded on the Pearson Islands by the expedition of January 1969. A tabulated list of all records of birds from the islands is also given.

Introduction

In the only work published hitherto on the birds of the Pearson Islands, Cleland (1923) has pointed out that the main interest lies in the land birds and whether they are indigenous, chance vagrants, or regular migrants. If they are indigenous, it is possible there are significant differences from the corresponding mainland species.

Thirty-three species of birds have now been recorded from the Pearson Islands. This list is not likely to be complete as records are available only for five visits—by E. R. Waite (Sept. 1914), F. Wood Jones (Nov. 1920), J. B. Cleland (Jan. 1923), in Jan. 1960, and the 1969 expedition.

With the exception of the Raven (*Corvus coronoides*) which Cleland (1923) said "occupied a nest", no land birds have been found breeding. This is not surprising because most visits have been short and mainly in the summer at the conclusion of the nesting season of many species.

The geomorphology of the Pearson Islands, including a locality map, is described by Twidale (1971) in this volume of the Transactions.

Annotated Systematic List

Eudyptula minor (Forster). *Little Penguin*

These were seen on all the Pearson Islands. Some were found in burrows near the top of East Hill, more than 150 m above sea-level. There seems no obvious reason why these birds should seek shelter involving such an arduous climb.

On several sloping granite faces on the Islands, there are long, nearly square-sectioned, gutters of varying size (usually about 20-30 cm deep and about 50 cm wide) which clearly carry penguin excreta downhill. The chemical action of the excreta, aided by the wear and tear of many penguins walking up and down them, could be an important factor in the formation of these *granitrillen*. Similar gutters have not yet been recorded from other granitic islands inhabited by penguins.

Pelagodroma marina (Latham). *White-faced Storm-Petrel*

Wings of at least ten of these birds were found in front of small burrows on Dorothee. There was no sign of head, body or legs. These had presumably been eaten by an avian predator such as the Sea-Eagle or by the Pearson Island Rat (*Rattus fuscipes*) if present. Though the burrows could have been nesting holes, they did not appear to be occupied by Storm-Petrels as would be expected in January if the nests were in current use. The examination, however, was superficial.

Phalacrocorax carbo (Linn.). *Black Cormorant*

One pair was seen on several occasions.

Ardea novaehollandiae Latham. *White-faced Heron*

Two birds were seen feeding on wave-washed rocks.

Cereopsis novaehollandiae Latham. *Cape Barren Goose*

Six birds were seen on Dorothee and two, perhaps from the same group, were seen and heard at day-break near the camp-site at Eastern Cove.

Haliaetus leucogaster (Gmelin). *White-breasted Sea-Eagle*

Two birds were seen circling over Dorothee. An unoccupied nest was seen on the highest rocks off the peak on the southern portion of Dorothee, and another one on the southern section of Pearson Island.

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Falco cenchroides Vigors and Horsfield. *Nankeen Kestrel*

Two birds were seen overhead near Hill 781 and two, possibly the same ones, overhead at Dorothee.

Haematopus fuliginosus Gould. *Sooty Oyster-Catcher*

Four adults and possibly two more were seen on Pearson Island and three adults, and a chick still unable to fly, on Dorothee. The adults were unusually timid and called frequently, possibly because they had non-flying chicks.

Arenaria interpres (Linn.). *Turnstone*

Eight birds were seen feeding on wave-washed rocks on the north section of Pearson Island.

Larus novaehollandiae Stephens. *Silver Gull*

Seen in groups of two and three, totalling perhaps a dozen on Pearson Island and a few more on Dorothee.

Larus pacificus Latham. *Pacific Gull*

At least two adults and two immature birds were seen on Pearson Island and two adults, probably another pair, on Dorothee.

Sterna bergii Lichtenstein. *Crested Tern*

Two birds were seen near Pearson Island and there were about a hundred resting on the rocks at the southern tip of Dorothee.

Sterna nereis (Gould). *Fairy Tern*

Two were seen fishing off the eastern bay of the north section of Pearson Island.

Neophema petrophila (Gould). *Rock Parrot*

There were a few small flocks in the vicinity of low bushes of *Atriplex*, *Olearia* and *Rhagodia* on the north section of Pearson Island. They appeared to be eating *Rhagodia* berries and were seen eating *Senecio* petals. There were a few birds on the south section and on Dorothee.

Melopsittacus undulatus (Shaw). *Budgerygah*

Two birds were seen on the north section of Pearson Island. During the spring of 1968, an unusually large number of these nomadic birds of inland Australia were seen in the southern part of South Australia including the vicinity of Adelaide. The presence of two on Pearson Island suggests that at least in the western part of the State some flocks had continued their southerly journey over the sea where the chance of a landfall would be remote and numbers would have perished.

Apus pacificus (Latham). *Fork-tailed Swift*

At least twenty were seen hawking over the north peak of Dorothee on 11th January, 1969 at 11.00 a.m. The weather was fine with a northwesterly wind of about five knots and there was little change in this weather pattern during the day.

Hirundo tahitica Gmelin. *Pacific Swallow*

Next to the Silvereyes, this was probably the most common species on all the islands. Apart from the difficulty of getting anything resembling mud for nest-building, there seems no reason why they should not nest on these islands. Eckert (1971) found swallows' nests on Franklin Island (S.A.) made of fibrous material with no mud apparent, the nest site having been chosen to give natural support from below.

Ephthianura albifrons (Jardine & Selby). *White-fronted Chat*

A few small flocks, each of about six birds, were seen feeding mainly in the area of saltbush. Their numbers seemed small in comparison with the reports of previous expeditions. One immature bird still with conspicuous yellow gape, indicating that the species breeds on the island, was caught and banded.

Ephthianura tricolor Gould. *Crimson Chat*

Five were seen on the northern slope of the north section of Pearson Island on three consecutive days. Some of these birds appeared immature and it is possible that the adults had bred on the island. One adult male was banded.

The spring of 1968 was noteworthy for the presence of Crimson Chats over the whole of the southern portion of the State, including Kangaroo Island. This species is rarely seen south of about latitude 30°S, and as with the Budgerygahs, its presence on Pearson and other islands, together with records of drowned Chats on beaches of St. Vincent Gulf, indicates that this southerly movement was continued in some cases over the sea.

Petroica goodenovii (Vigors and Horsfield). *Red-capped Robin*

These were common amongst the *Casuarina* of the north section of Pearson Island. The birds were mostly uncoloured but one male in full plumage and one partly coloured bird were seen. Two immature birds with conspicuous yellow gapes were banded. The presence of the latter indicates local breeding. This species was not seen on the south section of Pearson Island or on Dorothee, probably due to lack of trees.

Pachycephala pectoralis (Latham). *Golden Whistler*

One uncoloured bird was seen among the *Casuarina* on the northern slopes of the north section of Pearson Island. No calls were heard. These birds are usually easy to detect and some were seen on each of the earlier expeditions. This suggests that the number present on the islands has dwindled.

Zosterops lateralis (Latham). *Grey-backed Silvereye*

This was the most common bird in all areas including Dorothee. They were seen in flocks of about twenty, particularly in open areas of saltbush.

It is known from bird-banding recoveries that Silvereyes migrate from Tasmania to New South Wales and, in South Australia, from Kangaroo Island to Fleurieu Peninsula. Thus movement of these birds between the Pearson Islands and the mainland would not be unexpected.

Twelve birds were banded. These did not have the green back and yellow chin of the so-called Western Silvereye (subspecies *gouldii* Bonaparte) which extends from southern Western Australia along the coastal area eastwards to about Eucla, and did not differ significantly from the variety near Adelaide (subspecies *halmaturina* Campbell).

Meliphaga virescens (Vieillot). *Singing Honeyeater*

Only one bird was seen and no calls were heard. This bird is common on the adjacent mainland but has not yet been recorded from Flinders Island. It is widely distributed over much of South Australia, particularly in coastal areas and on other coastal islands. There seems no reason why it should not breed on Pearson Island as it is known to do so on Franklin Island. (Eckert 1971.)

Passer domesticus (Linn.). *House Sparrow*

Two sparrows were believed to have been seen in 1923 but none in 1960. However by 1969 a flock of about forty had established itself on the eastern point of the north section of Pearson Island, and a few more were on Dorothee. It would be interesting to know if this were the result of a single or several different invasions of the islands. Sparrows are very common on Flinders Island and these might well act as a reservoir for the recolonisation of the Pearson Islands.

Sturnus vulgaris (Linn.). *European Starling*

Starlings were as numerous as Sparrows and they would probably be more difficult to eradicate. About twenty to thirty birds were seen at one time, but they were not in flocks. Many immature birds were present, one of which was banded. Probably they breed on the islands.

Artamus personatus (Gould). *Masked Wood-Swallow*

Only one bird was seen. Two were seen in 1923 and some in 1960. These are sociable birds and it would be expected that they would appear in small flocks rather than singly. They have been seen on Goose Island near Wardang Island in Spencer Gulf so their presence on an island is not unprecedented.

Corvus coronoides Vigor and Horsfield. *Australian Raven*

These were usually in pairs though sometimes as many as six might be seen feeding together on wave-washed debris on the rocks. Four more were seen on Dorothee. An old nest, probably of this species, was seen in a *Casuarina*. The species was distinguished from the Little Raven (*Corvus mellori* Matthews) by its call.

Discussion

Twenty-seven species of birds were seen on this expedition of which eight had not been reported previously. It is of interest to compare these with the birds recorded from Flinders Island, the nearest land 32 km (twenty miles) to the northeast. Flinders Island is an undulating limestone platform which has been cropped and grazed for many years so that there is little of the original flora left. Although it has been occupied by Europeans since 1870, records of birds are available for only three visits. The most comprehensive list is that of Eckert (1970) who recorded fifty-two species of birds of which twenty-six can be considered as land birds, compared with seventeen out of thirty-three for the Pearson Islands.

Two sea birds, namely the Reef Heron (*Egretta sacra*) and the White-faced Storm-Petrel (*Pelagodroma marina*) and four land birds, the Budgerygah (*Melopsittacus undu-

latus), the Fork-tailed Swift (*Apus pacificus*), the Singing Honeyeater (*Meliphaga virescens*) and the Masked Wood-Swallow (*Artamus personatus*) have been found on the Pearson Islands but not on Flinders Island, nor have they been recorded for the South Neptune Islands (Stirling & Shaughnessy 1970) but the Reef Heron, Fork-tailed Swift and Singing Honeyeater have been reported from the Franklin Islands (Eckert 1971). On the other hand, Pipits (*Anthus novaeseelandiae* (Gmelin) —syn. *Anthus australis*) and Spotted Scrub-Wrens (*Sericornis frontalis* [Vigors & Horsfield]), both of which are very common on Flinders Island and have also been recorded for the South Neptune Islands (Stirling & Shaughnessy 1970), have not been seen on the Pearson Islands.

Of the seventeen species of land birds recorded for the Pearson Islands, four are widely distributed over the State. These are the Kestrel (*Falco cenchroides*), the White-fronted Chat (*Ephthianura albifrons*), the Singing Honeyeater (*Meliphaga virescens*) and the House Sparrow (*Passer domesticus*). The Rock Parrot (*Neophema petrophila*) is considered to be moderately sedentary and is found along most of the South Australian coast and off-shore islands where it breeds. It moves freely between these islands and the mainland. A favourite site for nesting is a limestone hole or crevice behind over-hanging *Mesembrianthemum* or *Carpobrotus*, so they would be expected to breed on the Pearson Islands. The remaining twelve land birds are well-known migrants or are known to move long distances from time to time.

It may be concluded that the land birds of the Pearson Islands have all reached the islands during the normal movements of the species. They might just as easily move to Flinders Island or to the mainland, more particularly in the winter months, either by migration or by chance movements. A comprehensive bird-banding programme could give conclusive evidence of such movements. On this expedition, strong winds and the technical difficulties of erecting mistnets on stony ground resulted in only seventeen birds being banded.

The increase in numbers of the two exotic species, the House Sparrow (*Passer domesticus*) and the Starling (*Sturnus vulgaris*) is cause for concern. Some consideration should be given to the eradication of at least the Sparrows from the Pearson Islands.

Acknowledgements

Records from the 1960 visit were prepared by I. M. Thomas and S. J. Edmonds. Grants in support of the Expedition were made by the Department of Fisheries and Fauna Conservation and the Royal Society of South Australia.

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List of birds seen on the Pearson Islands.

	Sept. 1914	Nov. 1920	Jan. 1923	Jan. 1960	Jan. 1969
Eudyptula minor. Little Penguin	x	x	x	x	many
Pelagodroma marina. White-faced Storm-Petrel					10 dead
Phaethon rubricauda. Red-tailed Tropic-Bird			x		
Phalacrocorax carbo. Black Cormorant			x	x	2
Ardea novaehollandiae. White-faced Heron			x		2
Egretta sacra. Reef Heron		x	x		
Cereopsis novaehollandiae. Cape Barren Goose	x	x	x	x	8
Haliaetus leucogaster. White-breasted Sea-Eagle			x		2
Falco cenchroides. Nankeen Kestrel			x		2
Haematopus fuliginosus. Sooty Oyster-catcher	x		x	x	7
Vanellus miles novaehollandiae. Spur-winged Plover			x		
Arenaria interpres. Turnstone					8
Calidris sp. (? ruficollis, ? alba). Red-necked Stint or Sanderling				x	
Larus novaehollandiae. Silver Gull		x	x	x	a few
Larus pacificus. Pacific Gull	x	x (nest)	x	x	6
Sterna bergii. Crested Tern		x	x	x	ca. 100
Sterna nereis. Fairy Tern					2
Neophema petrophila. Rock Parrot	x	x	x	x	many
Melopsittacus undulatus. Budgerygah					2
Chrysococcyx basilis. Horsfield Bronze-Cuckoo			x		
— Owl?			x?		
Apus pacificus. Fork-tailed Swift					ca. 20
Hirundo tahitica. Pacific Swallow			x	x	many
Ephthianura albifrons. White-fronted Chat			x	x	?15-20
Ephthianura tricolor. Crimson Chat					5
Petroica goodenovii. Red-capped Robin			x	x	many
Pachycephala pectoralis. Golden Whistler	x	x	x		1
Zosterops lateralis. Silvereye	x	x	x	x	many
Meliphaga virescens. Singing Honeyeater					1
Passer domesticus. House Sparrow			?2		ca. 40
Sturnus vulgaris. European Starling			?small flock		ca. 50
Artamus personatus. Masked Wood-Swallow			x	x	1
Corvus coronoides. Australian Raven	x	x	x	x	8

PEARSON ISLAND EXPEDITION 1969. – 7. THE SUB-TIDAL ECOLOGY OF BENTHIC ALGAE

BY S. A. SHEPHERD AND H. B. S. WOMERSLEY

Summary

Pearson Island is washed by clear oceanic water and is subject to very strong wave-action from the south and west, the effect of which penetrates to over 70 m depth. The effect of water movement on the distribution and abundance of algae in two sites, one rough-water and one sheltered, is described. In rough-water situations, high light penetration combined with the adequate water movement provide good conditions for growth of algae to depths of 50 m or more. In both localities, upper and mid sublittoral zones are recognised, the mid sublittoral having three belts dominated by various Phaeophyta. In very clear water this zonation of algal communities is dependent largely on differences in water movement resulting from increasing depth. A comparison between the roughwater and sheltered sites shows that nearly all species are affected in their distribution and abundance by differences in water movement. A richer flora of Chlorophyta and Rhodophyta is developed at the rough-water site, whereas the Phaeophyta are more abundant at the sheltered site. Depth records of all species collected are given, together with biomass (wet weight) variations of the commoner species at the collection sites of the Expedition.

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Introduction

Pearson Island (Figs. 1, 2) is situated at Lat. 33°57'S, Long. 134°15'E, on the continental shelf at the eastern end of the Great Australian Bight, about 64 km (40 miles) offshore. The geomorphology of the Island is described by Twidale (1971).

The joint expedition of the Department of Fisheries and Fauna Conservation and the Royal Society of South Australia to Pearson Island, 6-15 January, 1969, gave opportunity to study with the aid of SCUBA the vertical distribution of benthic algae and to make algal collections from the eastern Great Australian Bight, a region which is not well known floristically. This account is restricted to the subtidal algal ecology; the intertidal ecology was observed briefly both on this expedition and on a previous expedition in 1960 (Specht 1969), and was found to agree with the account of Womersley & Edmonds (1958, p. 230) for the zonation on steeply sloping Palaeozoic rock on South Australian coasts. Collections made in 1960 have been incorporated in the species list.

Only two sites at the northern end of the

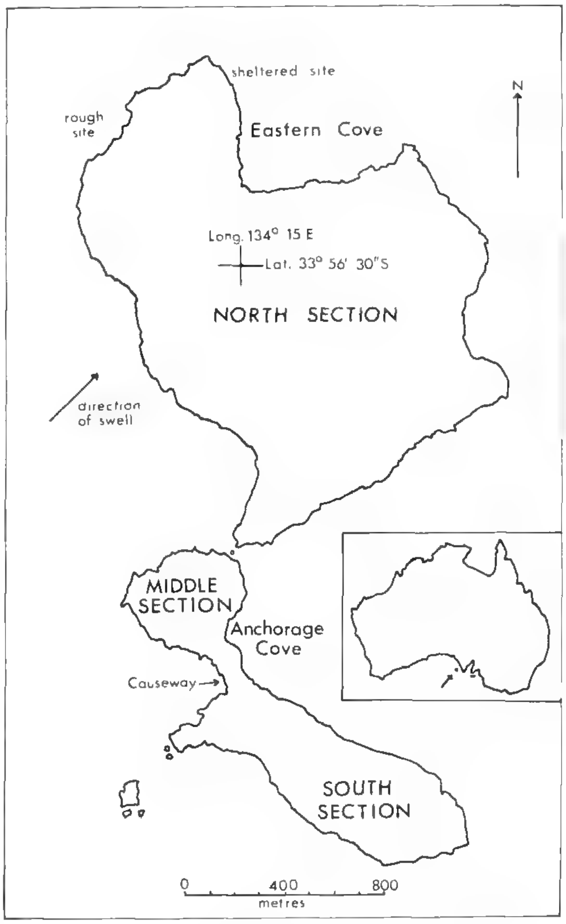

Fig. 1. Map of Pearson Island, showing study sites near the northern end. Inset shows the situation of Pearson Island in the eastern Great Australian Bight.

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Fig. 2. Pearson Island from Hill 781 (north section), looking south. Middle section lies on the right and south section on the upper left. Dorothee is the most distant island. Photo. K. P. Phillips.

island could be studied in detail during the time available. One of these sites is on the very rough windward side of the island where surge is strong, and the other is in a sheltered part of Eastern Cove (Fig. 1). In all, about 14 hours during four days were spent collecting underwater at the two sites.

The underwater topography is similar to the bold granite formation visible above water (Fig. 2) and consists of massive granite blocks separated by rifts, ledges and sometimes caverns. Underwater, the cliffs of the island fall steeply to a sandy bottom at about 38 m depth on the rough-water western side, with a rock and gravel bottom occurring again at 50 m depth, some 400 m offshore. Somewhat further to the west depths exceed 80 m. At the sheltered site studied in Eastern Cove, the steep granite slope meets the sand at about 30 m. Studies were made to a depth of 50 m on the western side and to 30 m in Eastern Cove.

This study extends that of Shepherd & Womersley (1970) at West Island and uses the same terminology.

Methods

The present study was planned in the same manner as that at West Island and similar field methods were used. These included general collections of algae, quantitative samples with a hoop of area 1/10 m^2, and observations (recorded underwater on roughened perspex) upon the vertical range and relative abundance of species. Limited diving time permitted the taking of only 5-7 samples with a hoop at each depth interval; this is probably sufficient to indicate the biomass of commonly occurring species but not that of species of low frequency or patchy distribution. However, species missed in the quantitative samples are probably represented in the general collections, which covered a wide area throughout the depth range.

Biomass figures are based on wet weight of the algae, after removal of surface water. This proved to be the most practicable method under the conditions, and while it is probably less satisfactory than dry weight, it gives a reasonable picture of biomass changes with depth. Limited time, however, prevented an assessment of the variation likely in such sampling, and the figures are to be taken only as examples of the changes of biomass with depth. Experience has shown the usefulness of quantitative techniques as even slight environmental differences affect the frequency of plants as well as the presence or absence of certain species.

Depths are related to approximate low tide level, in the absence of any tidal data from Pearson I. or nearby.

Environmental Factors

1. *Wave action and surge*

Brief observations indicated that the conditions of sea and swell, discussed in detail for West Island (Shepherd & Womersley 1970), are applicable also to Pearson Island with only minor modification. The prevailing south-westerly swell is higher than at West Island by about ½-1 m, and probably ranges from 1-4 m depending on conditions; this estimation is supported by fishermen who are able to judge wave height by the use of a depth recorder. Wave lengths are probably longer than at West Island and of the order of 170 m. Since the surge reaches to a depth of about half the wave length (Sverdrup et al 1942, p. 519), water movement resulting from swell would be expected to penetrate to about 85 m. In fact a ripple pattern in the soft bottom was observed at 70 m, and at 50 m ripples in the course granitic-gravel bottom outside the island were over 1 m from crest to crest and about 30 cm deep, indicating considerable surge at that depth.

Eastern Cove is well sheltered from the prevailing swell and even on days when conditions are moderately rough, wave height inside the Cove is reduced by diffractive effects from about 2.5 m on the rough-water coast to about 0.5 m, and surge is not perceptible below about 10 m. However, both sites studied are subject to stormy conditions from the north to the east but these are of short duration and would have no appreciable effect in the sublittoral below about 15 m.

2. *Temperature, Salinity and Other Chemical Properties*

Data from various oceanographic stations (derived from Hynd & Vaux 1963 and C.S.I.R.O. 1966; 1967a, b, c; 1968) held in the vicinity of Pearson Island since 1963, show that the water temperature ranges from 18-20°C (summer) to 15-17°C (winter) at the surface, with figures of 17-20°C (summer) to 17°C (winter) at 50 m depth. Salinity is generally between 35.7 and 35.9‰ in summer and a winter figure of 36.4‰ is given. Oxygen saturation figures range from 93 to 106% and figures of 0.08 to 0.17 μg atom/litre for inorganic phosphate and 0.3 μg atom/litre for nitrate are given.

3. *Underwater Illumination*

Pearson Island is washed by clear oceanic water and underwater visibility during the study exceeded 40 m. However, at 70 m depth, water transparency was noticeably lower near the bottom due to fine sediments stirred up by the swell. Photometer readings were taken to a depth of 33 m close inshore on the windward side of the island and some distance off-shore. The following figures for light penetration, expressed as a percentage of sub-surface (about 10 cm depth) irradiance were obtained—

13 m depth—37% close inshore
18 m depth—50% close inshore; 27% at 400 m offshore
25 m depth—50% close inshore; 25% at 400 m offshore
33 m depth—35% close inshore; 15% at 400 m offshore

The inshore readings were probably affected by turbulent white water which reduces light penetration near the sea surface (Jerlov 1968, p. 74), thus giving a relatively low reading at 13 m depth, and to a high-reflecting sandy bottom which increases light at depth (25 and 33 m depths). From photometric measurements made in the Great Australian Bight from H.M.A.S. Diamantina in November 1969 (Carpenter, pers. comm.), the water about Pearson Island would be classified as Type IA oceanic water of Jerlov (1951).

The Algal Ecology

This account describes only the communities on upward facing or slightly sloping surfaces although collections were made from vertical faces and shaded places and are included in the "Species List".

Light penetration is high, and algae dominate both horizontal and vertical faces and the fauna is not conspicuous except in shaded places such as caves.

Only a few grazing animals were observed and of these the giant turban *Dinassovica jourdani* (Kiener), which occurs occasionally at depths below about 20 m in rough-water localities and browses on red algae, is probably the most important.

A brief description of the algal communities recognised at the two sites follows.

ROUGH-WATER COAST (Fig. 3)

1. *Upper Sublittoral Zone* [0-7 (-8) m deep]

Even in calm weather, with low swell, surge is too severe to study much of this zone at close quarters by diving. The following description is based on observations made from the shore and from a boat, and from algal collections at a depth of 7-8 m.

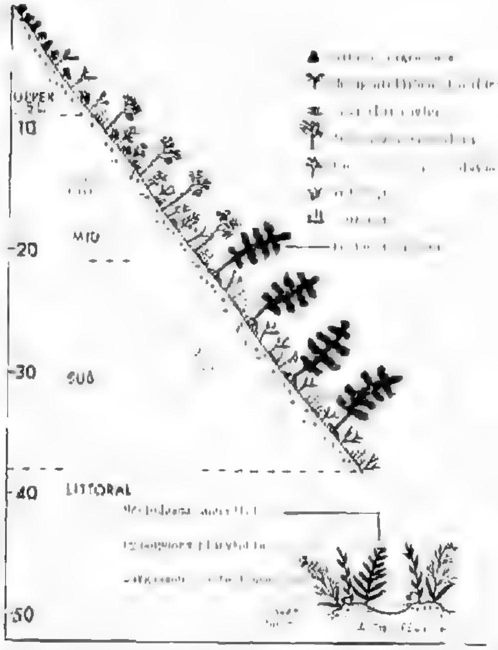

Fig. 3. A vegetation profile at the rough-water site. Sandy floor between 36 and 50 m depth causes a discontinuity in the distribution of algae, as shown in Figs. 5-8 also.

The barnacle *Balanus nigrescens* Lamarck, indicative of extreme wave-beaten conditions, is well developed in and just below the lower eulittoral zone, while a little lower down a coralline algal mat (mainly *Corallina cuvieri*) is co-dominant with the barnacle. Much of this *Balanus*-coralline alga community is momentarily emergent in the suck-back between waves at low tide, and is similar to the lower eulittoral and sublittoral fringe community described by Womersley & Edmonds (1958, p. 232) for Point Sinclair and elsewhere. Collections of Specht in 1960 show that the characteristic sublittoral-fringe alga, *Cystophora intermedia*, occurs on Pearson Island although it was not seen at the two study sites.

The coralline alga community continues into the sublittoral to a depth of about 7-8 m, where the common species are *Corallina cuvieri* and *Metagoniolithon charoides*, together with a few stunted plants of *Acrocarpia paniculata*.

2. *Mid Sublittoral Zone* [8-50+ m deep]

Two horizontal belts dominated by brown algae are conspicuous between 8 and 36 m depth while a third distinctive community of brown algae occurs at about 50 m depth (Fig. 3).

(1) *Acrocarpia paniculata* dominates the vegetation between 8 and 20 (-25) m. In shallower parts of this belt, the vegetation is low and stunted and clearly affected by the violent surge; here the understorey species are mainly coralline algae (Fig. 3) and the brown alga *Pachydictyon paniculatum*. Below about 15 m depth red algae such as *Plocamium angustum*, *P. mertensii* and *P. preissianum*, *Austrophyllis alcicornis* and *Delisea pulchra* become common.

(2) From about 20 m down, the vegetation is three-layered. *Ecklonia radiata* (a spinous form—see discussion), is the dominant species of the upper storey, while the red algae referred to above comprise a fairly sparse understorey. The prostrate species *Peyssonelia novaehollandiae* and *Sonderophycus australis* cover much of the rock surface.

Except for *Caulerpa scalpelliformis*, which is abundant between 10 and 15 m, green algae are sparse at depths less than about 20 m. Below that depth communities of *Caulerpa flexilis*, *C. longifolia* and *C. cliftonii* are common (Figs. 3, 5).

A shade community of red algae occurs only at depths below about 20 m, on cave walls and vertical faces. The component species of this community also occur on horizontal surfaces under the canopy of *Ecklonia* in deeper water to 36 m depth. The red alga *Sarcomenia delesserioides*, conspicuous because of its bright purple iridescence, occurs in shade between 30 and 36 m.

The presence of some sediment on the rock near the sandy bottom at 38 m, coupled with the occurrence at this depth of several species usually indicative of reduced water movement (such as *Caulerpa geminata*, *Lobophora variegata*, *Sargassum spinuligerum* and *Osmundaria prolifera*), suggests that water movement is probably less near the base of the cliff at 36-38 m than in open water at 50 m where these species are absent.

(3) At about 400 m off-shore, where the depth is about 50 m, an abundant growth of

algae occurs on a travertine limestone substrate. Common brown algae are *Myriodesma quercifolium*, *Scytothalia dorycarpa*, *Cystophora platylobium* and *Sargassum bracteolosum*. Some 25 species of red algae are recorded from here, of which *Pterocladia lucida*, *Dasyclonium incisum*, *Metamastophora flabellata* and *Plocamium preissianum* are the most common. Some species occurring here (e.g. *Scytothalia dorycarpa*, *Sargassum bracteolosum* and *Plocamium preissianum*) require considerable water movement and provide further evidence of the deep penetration of the swell.

SHELTERED COAST (Fig. 4)

1. *Upper Sublittoral Zone* [0-2 (-3) m deep]

The rock face is covered by a short algal turf in which *Zonaria sinclairii*, *Caulerpa brownii* and *Pterocladia capillacea* are prominent, the last named species often forming a pure community on somewhat shaded steep faces. This zone was not studied in detail and probably a wider range of species occurs.

2. *Mid Sublittoral Zone* [(2-) 3-29 m deep]

Three horizontal belts may be distinguished in this zone although their boundaries are often blurred (Fig. 4).

(1) The uppermost belt from 3 to 10 (-12) m deep is dominated by the fucoid algae *Acrocarpia paniculata* and *Cystophora moniliformis*, with *C. subfarcinata* and *C. brownii* fairly common in patches. Smaller species are sparse but include *Pachydictyon paniculatum*, *Zonaria spiralis*, *Z. sinclairii* and *Austrophyllis alcicornis*.

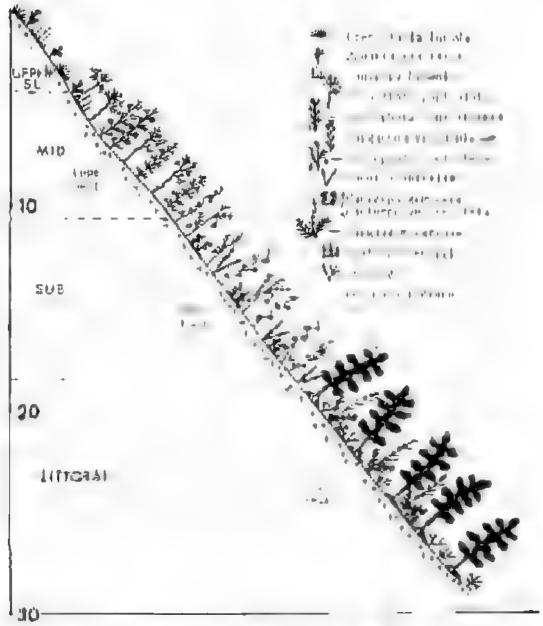

Fig. 4. A vegetation profile at the sheltered site (Eastern Cove).

(2) From about 10 (-12) to 16 (-18) m deep, *Cystophora monilifera* and *Sargassum verruculosum* become dominant; other common species of this belt are *Codium duthiae*, *Glossophora nigricans*, *Dilophus fastigiatus*, *Bellotia eriophorum*, *Colpomenia peregrina* and *Polysiphonia nigrita* (as an epiphyte). Communities of *Caulerpa geminata* and of *C. vesiculifera* also occur in this depth range.

(3) The lowermost belt from 16 (-18) to 29 m deep is dominated by *Ecklonia radiata*. Other species of common occurrence are *Sargassum varians* and *Bellotia eriophorum*, and the red algae *Plocamium mertensii*, *Thamnoclonium dichotomum* and *Delisea hypneoides*. *Plocamium angustum* and *Kallymenia cribrosa* are common on steep faces. The only common green alga in this belt is *Caulerpa hedleyi*.

The rock is buried in sand at a depth of about 29-30 m and communities of the seagrasses *Heterozostera tasmanica* and *Posidonia australis* are common on the sandy bottom.

Discussion

It is well known that in the clear waters of the Mediterranean and the tropical Atlantic, algae grow to much greater depths than in turbid coastal waters (Feldmann 1937, Taylor 1961) due to the high transmittance of light. The present study shows that in clear waters off the South Australian coast, such as at Pearson Island, a rich algal flora grows to 50 m depth and probably deeper.

At West Island it has been shown (Shepherd & Womersley 1970) that water movement as well as light are critical factors determining the depth ranges of algae. As the effect of water movement at depth on algal distribution has been little studied, a comparison of the algal changes with depth at the rough and sheltered sites on Pearson Island is of interest.

At first impression, there seemed to be a marked difference in the algae at the two sites. In general the results confirmed this view and showed that the differences are of two kinds. Firstly, the species composition of the vegetation varies. As shown in Table 1, only one third of the total number of species recorded were found at both sites. Secondly, the conspicuous species show pronounced variation in density according to the degree of roughness and depth (Figs. 5, 6, and 7). As a result, distinctive communities occur at different depths, and vertical zonation patterns are apparent.

Zonation

At West Island (Shepherd & Womersley 1970), three basic zones in the sublittoral were recognised—a narrow upper sublittoral surf zone (to about 5 m depth) consisting of a short red algal turf, a mid sublittoral zone dominated by large brown algae extending to about 20 m depth, and a lower sublittoral zone of red algae. The vertical extent of these zones was found to be correlated with light and water movement.

At Pearson I. the upper and mid zones are of greater vertical extent than at West I. The upper sublittoral is about 8 m wide at the rough-water site, decreasing to about 2 or 3 m wide at the sheltered site. The mid sublittoral zone is also extended downwards but to a much more remarkable degree, going to at least 50 m depth at the rough-water site. Within this zone distinct belts are apparent, each of which is dominated by one or two species of brown algae. One result of this magnified zone appears to be that certain species, which might otherwise remain subordinate, achieve dominance at a depth where conditions for them are optimal. Bergquist (1960) also describes three zones in the sublittoral for communities of the Northland coast, New Zealand; these bear some similarity to the zones described in this paper, but the lower two zones as recognised in New Zealand probably correspond to belts of the mid sublittoral at Pearson Island.

A lower sublittoral zone, as described for West Island, does not occur on horizontal surfaces at the study sites, due no doubt to the relatively high light intensities even at 50 m depth. However, a red algae community is present on shaded overhangs etc., below about 20 m, and this suggests that a lower sublittoral zone might be expected on horizontal surfaces at greater depths than could be reached during the expedition.

The Pearson Island study thus supports observations made at West Island showing the importance of both water movement and light upon the vertical extent of algal zones, water movement being most important in the upper sublittoral zone whereas both factors are important in the mid sublittoral.

Species range and biomass

The vertical range and site distribution of all species collected is given in the "Algal Species List", and Table 1 summarises their site distribution. While more Chlorophyta and Rhodophyta are confined to the rough-water site than the sheltered site, the reverse is true for the Phaeophyta. A higher proportion of the total is restricted to the rough-water site than the sheltered site, with only one third of the total common to both sites.

TABLE 1

Number of Species of Chlorophyta, Phaeophyta and Rhodophyta collected at the Rough-water and Sheltered sites respectively.

	Chlorophyta	Phaeophyta	Rhodophyta	Total	As % of Total
Species from the rough water site only	8	8	49	65	40%
Species from the sheltered site only	5	18	20	43	27%
Species occurring at both sites	8	14	30	52	33%
Total	21	40	99	160	

The vertical distribution of biomass of some of the commoner species of Chlorophyta (*Caulerpa* only), Phaeophyta and Rhodophyta is given in Figs. 5-7 respectively, and their total biomass is given in Fig. 8. Practically all of the species in Figs. 5-7 show marked differ-

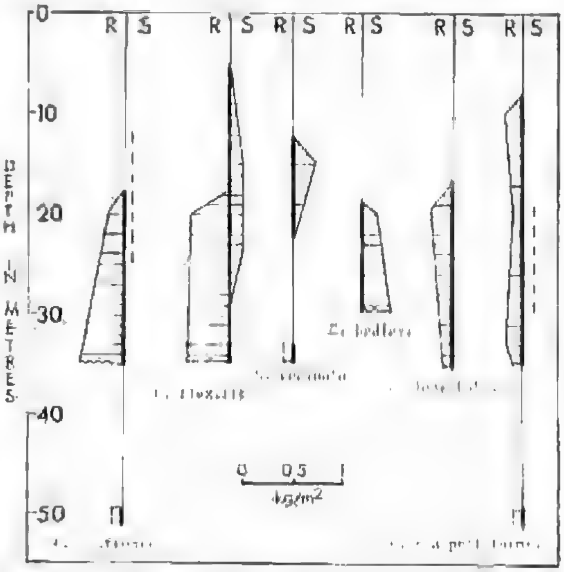

Fig. 5. Depth distribution (by wet weight) of species of *Caulerpa* (Chlorophyta) at the rough-water (R) and sheltered (S) sites.

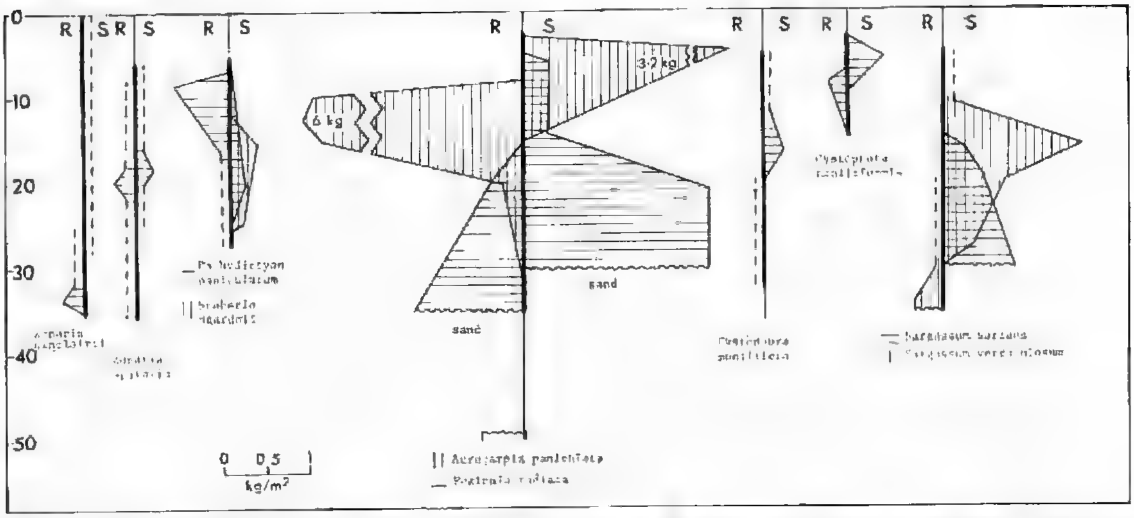

Fig. 6. Depth distribution (by wet weight) of various Phaeophyta at the rough-water (R) and sheltered (S) sites.

ences in abundance between the two sites, with some of them being rare or absent from one or other site. The depression and/or extension of distribution of some species in the rough-water site is evident, and this tendency is shown by many other of the common species indicated in the Species List.

While it is possible that factors such as grazing or competition between species may be involved in some cases, it seems reasonable to interpret the data in terms of the effect of the principal environmental factors, light and water movement. It is unlikely that light attenuation would vary much at the two sites, and since water movement is likely to be the major ecological factor differing significantly, the differences in distribution and biomass of most species can be related (as at West Island) principally to this factor of water movement.

While most species are commonest under moderate water movement, there are smaller groups, some occurring only under strong, and others under slight, water movement conditions. Species occurring under the strongest surge (i.e. near low tide level) are—*Caulerpa brownii, Pachydictyon paniculatum, Acrocarpia paniculata, Cystophora intermedia, Corallina cuvieri, Metagoniolithon*

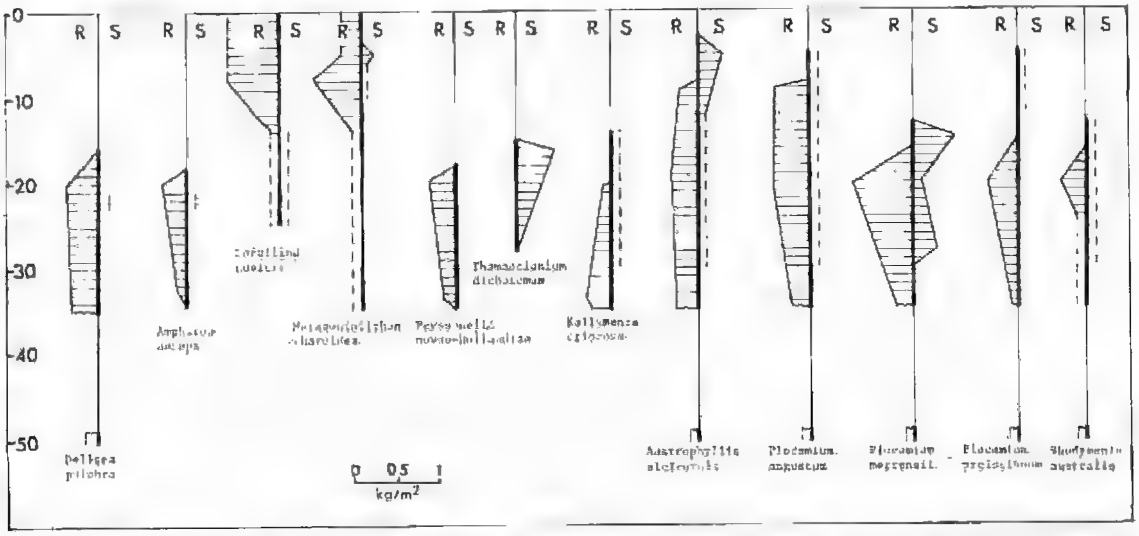

Fig. 7. Depth distribution (by wet weight) of common Rhodophyta at the rough-water (R) and sheltered (S) sites.

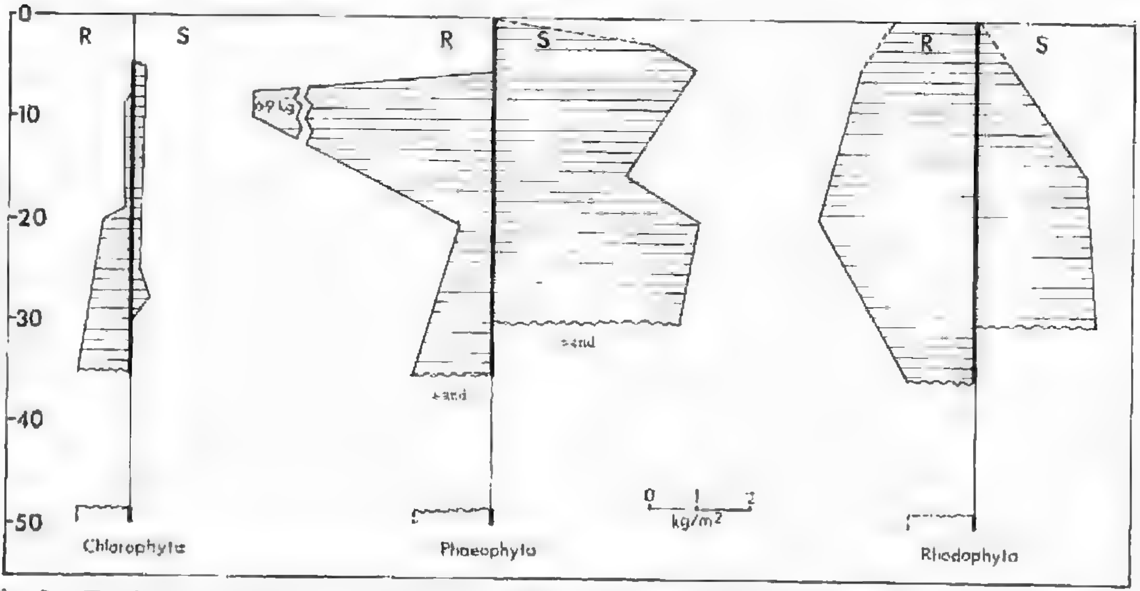

Fig. 8. Total wet weight of Chlorophyta, Phaeophyta and Rhodophyta at the rough-water and sheltered sites.

charoides and *Pterocladia capillacea* (the last named species occuring only in shade). Species requiring least water movement, and hence found only in sheltered localities or at deeper levels, are—*Caulerpa geminata, C. hedleyi, C. vesiculifera, Bellotia eriophorum, Cystophora monilifera, Scaberia agardhii, Sargassum varians, S. verruculosum, Thamnoclonium dichotomum, Kallymenia cribrosa* and *Rhodophyllis membranacea*. Lastly there are a few species which seem indifferent to water movement since they grow equally well in strong or slight water movement. These species are *Zonaria spiralis, Austrophyllis alcicornis* and *Plocamium angustum*.

It is not suggested that the occurrence of the above groups of species is not also dependent on light intensity. Probably in most cases the occurrence of a species is determined by both the degree of water movement and light intensity, but in the above cases the degree of water movement appears to be of greatest significance. Some species, however, are found only in low light conditions with moderate water movement (e.g. *Peyssonelia novaehollandiae* and *Sonderophycus australis*), while others grow only in high light conditions and slight to moderate water movement (e.g. *Colpomenia peregrina, Cystophora brownii* and *C. subfarcinata*).

In general, the preferences shown by algae at Pearson Island are similar to those of the same species at West Island, with a few exceptions. *Ecklonia radiata* appears to be less tolerant of rough water conditions at Pearson Island than at West Island. However, populations of this species comprise two ecological forms in southern Australia, apparently with somewhat different water roughness preferences. The West Island form has relatively smooth fronds with few or no surface spines, while that at Pearson Island has somewhat rugose fronds with the surface covered with spines which are often curved. The latter has been known as *E. exasperata* (Turn.) J. Agardh, but was regarded by Womersley (1967, p. 238) as an "age, ecological or morphological variant" of the species. Further subtidal studies may show that this densely spinous form is worth recognising as a subspecific taxon.

Several floristic differences exist between West Island and Pearson Island, and are shown by a comparison of the species at the two islands.

During three years, with visits throughout each year, 132 species were recorded from West Island, while a few days' collecting in January 1969 at Pearson Island gave 160 species. The Pearson Island flora is richer in Chlorophyta (21 compared to 9 species), and in Phaeophyta (40 compared to 30), while the Rhodophyta are similar in number (99 compared to 93). Further collecting at Pearson Island would be expected to increase the number of Rhodophyta in particular. For the ecologically important species also, there is greater species diversity at Pearson Island, and this is especially so in the Rhodophyta.

Notable species present at Pearson Island and not found at West Island include:

- Chlorophyta—*Ulvaria shepherdii, Caulerpa cliftonii, Caulerpa ellistoniae, C. hedleyi, Chlorodesmis baculifera, Avrainvillea clavatiramea* and *Rhipiliopsis robusta*. All these species are noteworthy as being (except for *Caulerpa cliftonii*) strictly confined to deep water (Womersley 1971).
- Phaeophyta—*Myriodesma quercifolium, Sargassum tristichum* and *S. varians.*
- Rhodophyta—*Galaxaura spathulata, Austrophyllis alcicornis, Kallymenia cribrogloea, K. spinosa, Thamnophyllis lacerata, Hennedya crispa, Bindera splachnoides, Leptosomia cliftonii, Wrangelia nitella* and *Heterosiphonia crassipes.*

The abundance of Chlorophyta both in species and biomass at depth is a conspicuous feature at Pearson Island and is probably an effect of the extreme water clarity permitting deep penetration of blue light (Levring 1968) together with other suitable ecological factors. Other regions of the world with notably clear waters, such as the Mediterranean (Larkum, Drew and Crossett 1967) and Caribbean (Taylor 1961), show the presence of green algae at depth in contrast to colder waters where green algae rarely penetrate into deep water.

Algal Species List

Unless other collectors are named, all collections were made by S. A. Shepherd and depths are given in metres following 'R' and 'S', denoting the rough-water and sheltered localities at the northern end of Pearson Island. A small collection was also made at Dorothee, the most southerly of the Pearson Isles, in sheltered conditions. The collections of R. L. Specht (17.ii.1960), B. B. Carrodus (18.ii.1960) and S. J. Edmonds (16.ii.1960) were made on the 1960 Expedition, mainly on the coast between the north and middle, and middle and south, sections. The 1960 collections were mainly intertidal or from the upper sublittoral (abbreviated to USL).

Identifications are by H. B. S. Womersley, except for Ceramiaceae (Crouanieae, Antithamnieae and Heterothamneae) by E. M. Wollaston, Delesseriaceae by E. A. Mitchell and Dasyaceae by M. J. Parsons.

In most cases depths are given as a range indicating that the species was collected at the limits stated and usually at intermediate depths. While it is likely that most species occur throughout the ranges given, unsuitable microhabitats may prevent this. On the rough water coast the deepest collection from 50 m is shown separately, since sandy bottom occurred from 38 to 50 m. The time limitations of the expedition and of SCUBA diving inevitably mean that further studies would both increase the number of species recorded and broaden their depth ranges in some cases.

An asterisk indicates the commoner species, many of which are referred to in the text.

CHLOROPHYTA

ULVALES

Ulva lactuca L.? Dorothee, 1-6. Pools between South and Middle Sect., *Specht.*
Ulvaria shepherdii Womersley. R, 20-35, 50.

CLADOPHORALES

Cladophora valonioides Sonder. S, 5-25.

SIPHONOCLADALES

Apjohnia laetevirens Harvey. R, 8-33; S, 5-16.
Struvea plumosa Sonder. Between South and Middle Sect. USL, *Carrodus.*

CAULERPALES—Caulerpaceae

Caulerpa brownii (C. Ag.) Endlicher. S, 0-16 Between South and Middle Sect., USL. *Specht.*
**C. cliftonii* Harvey. R, (18-) 20-36, 50; S. 13-25.
C. ellistoniae Womersley. R, 36.
**C. flexilis* Lamouroux. R, (18-) 20-35; S, 6-28.
* var. *muelleri* (Sond.) Womersley. R. 8-26 S, 13-25. Between South and Middle Sect., USL, *Specht.*
**C. geminata* Harvey. R, 35; S, (12-) 15-20 (-25).
**C. hedleyi* W. v. Bosse. S, (19-) 22-28 (-30).
**C. longifolia* C. Ag. f. *crispata* (Harv.) Womersley. R, (18-) 20-35.
**C. obscura* Sonder. R, 20-35; S, 5-23.
C. papillosa J. Agardh. S, 5-12.
**C. scalpelliformis* (R. Br.) C. Agardh. R, 8-35, 50; S, 20-30.
C. simpliciuscula (Turner) J. Agardh. R, 15-35; S, 30.
**C. vesiculifera* Harvey. S, (6-) 15-22 (-25).

Udoteaceae

Chlorodesmis baculifera (J. Agardh) Ducker. R, 30-36
Avrainvillea clavatiramea Gepp & Gepp. Middle Sect., 20; *Carrodus.*
Rhipiliopsis robusta Womersley. R, 30.

CODIALES

**Codium duthieae* Silva. R, 20-25; S, (12-) 20-25.
C. galeatum J. Agardh. R, 30-32
C. harveyi Silva. R, 36.
C. mamillosum Harvey. R, 35.
C. spongiosum Harvey. Between South and Middle Sect., pools. *Specht*

PHAEOPHYTA

SPHACELARIALES

Sphacelaria novae-caledoniae Sauvageau. S, 20-25. A single specimen, growing on rock, but agreeing with southern Australian specimens previously referred to this species but epiphytic on *Myriodesma harveyanum*.

DICTYOTALES—Dictyoteae

Dictyota alternifida J. Agardh. R, 20-25.

D. furcellata (C. Ag.) J. Agardh. S, 15-25.

Dilophus angustus J. Agardh. S. 13-23.

**Dil. fastigiatus* Sonder. R, 20-30; S, 15-18 (-28).

Dil. robustus (J. Ag.) Womersley. R, 20-36, 50.

**Pachydictyon paniculatum* J. Agardh. R, 7-15 (-27); S, 6-25. Between South and Middle Sect., USL, *Specht*.

**Glossophora nigricans* (J. Ag.) Womersley. R, 20-36, 50; S, 5-23. Dorothee, 1-6.

Lobospira bicuspidata Areschoug. R, 22; S, 5-25.

Zonarieae

Chlanidophora microphylla (Harv.) J. Agardh. R, 30-35. Between South and Middle Sect., USL, *Specht*.

Dictyopteris muelleri (Sond.) Reinbold. S, 20-25.

Distromium flabellatum Womersley. R, 36; S, 12-23.

D. multifidum Womersley. S, 12-30.

Lobophora variegata (Lamx.) Womersley. R, 36.

Padina sp. S, 20-25. (A single specimen of a bistratose species, sterile).

**Zonaria sinclairii* Hooker & Harvey. R, (15-) 32-35; S, 0-28.

**Z. spiralis* J. Agardh. R, (8-) 18-22 (-36); S, (6-) 16-20 (-25).

CHORDARIALES—Chordariaceae

Polycerea nigrescens (Harv. ex Kuetz.) Kylin. S, 14 on *Posidonia*. Middle Sect., 20, *Carrodus*.

Spermatochnaceae

Nemacystis sp. S, 20-25. A single specimen, sterile but otherwise agreeing well with the genus and probably close to *N. novae-zelandiae* Kylin.

Splachnidiaceae

Splachnidium rugosum (L.) Greville. Between South and Middle Sect., mid eulittoral, *Specht*.

Notheiaceae

Notheia anomala Harvey & Bailey. On *Hormosira*, between South and Middle Sect., lower eulittoral, *Specht*.

SPOROCHNALES

**Bellotia eriophorum* Harvey. R, 22; S, 14-20 (-30).

Nereia australis (Harv.) Harvey. Middle Sect., 20, *Carrodus*.

Sporochnus radiciformis (Turn.) C. Agardh. R, 22; S, 14-30. Middle Sect., 20, *Carrodus*.

DICTYOSIPHONALES

Asperococcus bullosus Lamouroux. S, 14. Middle Sect., 20, on *Posidonia*, *Carrodus*.

**Colpomenia peregrina* (Sauv.) Hamel. S, 6-16, Dorothee, 1-6.

Hydroclathrus clathratus (C. Ag.) Howe. S, 13-25.

LAMINARIALES

**Ecklonia radiata* (C. Ag.) J. Agardh. R, (15-) 20-35, 50; S, (5-) 6-30, Dorothee, 1-6. Between South and Middle Sect., USL, *Specht*.

FUCALES—Hormosiraceae

Hormosira banksii (Turn.) Decaisne. Between South and Middle Sect., lower eulittoral, *Specht*.

Seirococcaceae

**Scytothalia dorycarpa* (Turn.) Greville. R, 34-35, 50.

Cystoseiraceae

**Acrocarpia paniculata* (Turn.) Areschoug. R, 8-20 (-32); S, 3-12 (-15). Dorothee, 1-6, Between South and Middle Sect., USL, Specht.

**Cystophora brownii* (Turn.) J. Agardh. S, (6-) 8-10.

C. intermedia J. Agardh. Between South and Middle Sect., sublittoral fringe, *Specht*.

**C. monilifera* J. Agardh. R, 20-32; S, (5-) 12-18 (-20).

**C. moniliformis* (Esper) Womersley & Nizamuddin. R, 7-10 (-15); S, 3-10. Dorothee, 1-6. Between North and Middle Sect., USL, *Edmonds*.

C. platylobium (Mert.) J. Agardh. R, 50.

**C. subfarcinata* (Mert.) J. Agardh. S, 3-10. Between North and Middle Sect., USL, *Edmonds*.

Myriodesma integrifolium Harvey. S, 15.

**M. quercifolium* (Bory) J. Agardh. R, 30-35, 50.

**Scaberia agardhii* Greville. S, 12-26.

Sargassaceae

Sargassum decipiens (R. Br.) J. Agardh. S, (5-) 10-16.

**S. varians* Sonder. S, (15-) 20-30.

**S. verruculosum* (Mert.) J. Agardh. R, (20-) 30-35; S, (5-) 12-28 (-30). Middle Sect., drift, *Specht*.

S. bracteolosum J. Agardh. R, 50.

S. lacerifolium (Turn.) C. Ag. Between South and Middle Sect., USL, *Specht*.

S. tristichum Grev. & C. Ag. ex Sonder. Between South and Middle Sect., USL, *Specht*.

**S. spinuligerum* Sonder. R, 35; S, 15-30.

RHODOPHYTA

NEMALIALES—Helminthocladiaceae

Liagora harveyiana Zeh. Between South and Middle Sect., USL, *Specht*.

Nemalion helminthoides (Velley) Batters. Between South and Middle Sect., mid eulittoral, *Specht*.

Bonnemaisoniaceae

**Delisea hypneoides* Harvey. R, 20-25; S, 14-30.

**D. pulchra* (Grev.) Montagne. R, (16-) 20-35, 50; S, 22.

Chaetangiaceae

Galaxaura spathulata Kjellman. R, 35.

Pseudoscinaia australis Setchell. R, 22; S, 16-28.

GELIDIALES—*Gelidium australe* J. Agardh. Between South and Middle Sect., USL, *Carrodus*.

Pterocladia capillacea (Gmel.) Bornet & Thuret. S, 0-3. Dorothee, 1-6. Between South and Middle Sect., USL, _Specht._
*_P. lucida_ (R. Br.) J. Agardh. R, 20-35, 50; S, 5-22. Dorothee, 1-6.

CRYPTONEMIALES—Dumontiaceae
Dudresnaya australis J. Agardh. S, 15.
Rhizophyllidaceae
Rhodopeltis australis Harvey. R, 50.
Squamariaceae
*_Peyssonelia novae-hollandiae_ (Kuetz) Harvey. R, (18-) 20-35.
*_Sonderophycus australis_ (Sond.) Denizot. R, 20-35.
Corallinaceae
*_Amphiroa anceps_ (Lamk.) Decaisne. R, (18-) 20-35; S, 22.
Cheilosporum elegans (H. & H.) Areschoug. R, 22.
*_Corallina cuvieri_ Lamouroux. R, 0-8 (-25); S, 13-25, on _Cystophora monilifera._
Jania fastigiata Harvey. Between South and Middle Sect., USL, _Specht._
Jania sp. R, 15; S, 20-25 (a slender species).
*_Metagoniolithon charoides_ (Lamx.) W. v. Bosse. R, 0-15 (-35); S, 4-10.
*_Metamastophora flabellata_ (Sond.) Setchell. R, 30-35, 50; S, 5-12.

Identification of a few species of crustose Corallinaceae collected must await monographic study of this group.

Cryptonemiaceae
Carpopeltis phyllophora (H. & H.) Schmitz. R, 20-32.
*_Thamnoclonium dichotomum_ (J. Ag.) J. Agardh. S, 15-28.
Kallymeniaceae
*_Austrophyllis alcicornis_ (J. Ag.) Womersley & Norris. R, 8-35, 50; S, (3-) 5-12 (-30)
Callophyllis coccinea Harvey. R, 8-32; S, 5.
C. lambertii (Turn.) Greville. R, 35.
Cirrulicarpus australis Womersley & Norris. R, 50.
Glaphyrymenia pustulosa J. Ag. R, 33.
Kallymenia cribrogloea Womersley & Norris. R, 30.
*_K. cribrosa_ Harvey. R, 20-35; S, 14-30.
K. spinosa Womersley & Norris. R, 22-33.
Polycoelia laciniata J. Agardh. R, 30-35, 50.
Thamnophyllis lacerata Womersley & Norris. R, 30.

GIGARTINALES—Plocamiaceae
*_Plocamium angustum_ (J. Ag.) Hooker & Harvey. R, 8-35, 50; S, 5-30.
P. cartilagineum (L.) Dixon. S, 22.
*_P. mertensii_ (Greville) Harvey. R, (16-) 18-35, 50; S, (13-) 15-30. Off North Sect., sublittoral, _Specht._
*_P. preissianum_ Sonder. R, (15-) 20-35, 50; S, 5-12.
Phacelocarpaceae
*_Phacelocarpus labillardieri_ (Mert.) J. Agardh. R, 20-25, 50; S, 5-15.
P. sessilis Harvey. R, 30-32.
Nizymeniaceae
Stenocladia australis (Sond.) Silva. R, 50.
Rhabdoniaceae
Areschougia laurencia (H. & H.) Harvey. S, 20-25.
Rhodophyllidaceae
*_Rhodophyllis membranacea_ (H. & H.) Harvey. R, 22-35; S, 16-30.
R. volans Harvey? R, 30-33.
Hypneaceae
*_Hypnea episcopalis_ Harvey. R, 8-25, 50; S, 16-25.
Mychodeaceae
Mychodea carnosa Hooker & Harvey. R, 30-35.
M. compressa Harvey. S, 5-12.
M. foliosa (Harv.) J. Agardh. S, 5.
Acrotylaceae
Amphiplexia hymenocladioides J. Agardh. S, 15.
Hennedya crispa Harvey. R, 22.

RHODYMENIALES—Rhodymeniaceae
Bindera splachnoides Harvey. S, 13-25.
Coelarthrum cliftonii (Harv.) Kylin. R, 30-35; S, 20-25.
Gloiosaccion brownii Harvey. R, 20-35; S, 13-23.
Leptosomia cliftonii (J. Ag.) J. Agardh? R, 50.
*_Rhodymenia australis_ Sonder. R, (16-) 20-24 (-35), 50; S, 13-30.
Hymenocladia polymorpha (Harv.) J. Agardh. Dorothee, 1-6.
Lomentariaceae
Lomentaria corynephora (J. Ag.) Kylin. R, 30-32; S, 15-25.
Champia affinis (H. & H.) J. Agardh. R, 20-35; S, 20-30.
C. tasmanica Harvey. R, 30-35; S, 22.

CERAMIALES—Ceramiaceae
Crouanieae
Crouania mucosa Wollaston. Between South and Middle Sect., uppermost sublittoral. _Specht._
Ptilocladia pulchra Sonder. R, 20-25.
Antithamnieae
Antithamnion armatum (J. Ag.) De Toni. R, 20-25, on _Zonaria spiralis._
A. hanowioides (Sonder) De Toni. S, 16-23. Between South and Middle Sect., USL, epiphytic, _Specht._
A. verticale (Harv.) J. Agardh. R, 50, on _Myriodesma quercifolium._
Acrothamnion preissii (Sond.) Wollaston. Between South and Middle Sect., USL, on _Sargassum tristichum, Specht._
Ballia ballioides (Sonder) Wollaston. R, 22.
*_B. callitricha_ (C. Ag.) Kuetzing. R, 22-35.
B. mariana Harvey. R, 22-35.
Macrothamnion pellucidum (Harv.) Wollaston. R, 15.
M. secundum Wollaston. R, 35.
Heterothamnieae
Trithamnion vulgare Wollaston. Between South and Middle Sect., USL, on _Pterocladia capillacea, Specht._
Ceramieae
Centroceras clavulatum (C. Ag.) Montagne. Between South and Middle Sect., in pools on causeway, _Specht._
Ceramium spp. Several species occur as epiphytes or on rock; determination must await monographic study.
Wrangelieae
Wrangelia crassa Hooker & Harvey. R, 23.
W. nitella Harvey. R, 23.

Callithamnieae

Callithamnion laricinum Harvey? S, 5, on *Metagoniolithon charoides*.

Callithamnion sp. R, 33.

Spongoclonieae

Haloplegma preissii Sonder. R, 35.

Griffithsieae

Griffithsia pulvinata Baldock m.s. Between South and Middle Sect., in pools on causeway, *Specht.*

Ptiloteae

Euptilota articulata (J. Ag.) Schmitz. R, 35, 50; S, 16-23.

Dasyphileae

Dasyphila preissii Sonder. R, 50; S, 13-23.

Rhodocallis elegans Kuetzing. R, 22-35, 50: Sublittoral (on craypot) off North Sect., *Specht*

Dasyaceae

Dasya extensa Sonder. R, 23.

Dasya naccarioides Harvey. S, 5-12.

Dasyopsis clavigera Womersley. R, 20-25; S, 5-12. Between South and Middle Sect., USL, *Specht.*

Heterosiphonia crassipes (Harv.) Falk. R, 30-35.

Thuretia teres Harvey. S, 5.

Delesseriaceae

Delesserieae

Hypoglossum dendroides (Harv.) J. Agardh. R, 15.

H. revolutum (Harv.) J. Agardh. R, 50.

H. spathulatum (Sond.) Kuetzing. R, 22.

Nitophylleae

Acrosorium uncinatum (J. Ag.) Kylin. R, 8.

Hymenena multipartita (H. & H.) Kylin. R, 50.

Cryptopleura endiviaefolia (H. & H.) Kylin. R, 8-25.

Rhodomelaceae

Sarcomenieae

Sarcomenia delesserioides Sonder. R, 30.

Polysiphoniae

**Polysiphonia nigrita* Sonder. S, 6-30. Dorothee. 1-6.

P. succulenta Harv. S, 30.

Pterosiphonieae

Dictymenia tridens (Mert.) Greville. R, 50.

Pterosiphonia? R, 35.

Herposiphonieae

Herposiphonia monilifera (H. & H.) Falkenberg. R, 36.

H. versicolor (H. & H.) Falkenberg. R, 8-25.

Polyzonieae

Dasyclonium incisum (J. Ag.) Kylin. R, 50.

Cliftonaea pectinata Harvey. R, 35.

Amansieae

Amansia pinnatifida Harvey. S, 15-25.

Lenormandia muelleri Sonder. R, 50.

Osmundaria prolifera Lamouroux. R, 35; S, 20-25.

Chondrieae

Chondria sp. R, 36.

Chondria sp. Between South and Middle Sect., USL, *Specht.*

Cladurus elatus (Sond.) Falkenberg. S, 20-25.

Laurencieae

**Laurencia elata* (C. Ag.) Harvey. R, 20-35; S, 22.

L. forsteri Greville. S, 20-30.

L. gracilis Hooker & Harvey? S, 15.

L. heteroclada Harvey. R, 30-35; S, 15

L. obtusa (Huds.) Lamouroux. S, 22.

Uncertain position

Holodictyon arachnoideum Harvey. Middle Sect. 20, *Carrodus.*

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PEARSON ISLAND EXPEDITION 1969. – 8. HELMINTHS

BY PATRICIA M. MAWSON

Summary

This paper deals with helminths collected at Pearson I. (P.I.) and near-by Flinders I. (F.I.) off the western coast of South Australia. Most of them are nematodes, but preliminary identifications have been made of trematodes and cestodes. New nematodes described are *Skrjabinodon parasmythi* from *Underwoodisaurus milii* (F.I.) and *Phyllodactylus marmoratus* (F.I.); *5. leristae* from *Lerista* sp. (F.I.); *Cloacina pearsoni* from *Petrogale penicillata* (P.I.); *Rictularia pearsoni* and *Gongylonema beveridgei* from *Rattus fuscipes* (P.I.). A new genus, *Cristaceps* (? Amidostomatidae), is proposed *for Pharyngostro~zgylus woodwardi* Wood, two females of which were taken from *Petrogale penicillata* (P.I.). *Thelandros karta~za* Johnston and Mawson, recorded from *Amphibolurus fionni(?)* (P.I.), *Lerista* sp. and *Hemiergis peronii* (F.I.), is transferred to *Parapharyngodon* Chatterji. Other species recorded, mostly with some redescription and figures are: *Cloacina petrogule* Johnston and Mawson, *Labiostrongylus longispicnlaris* Wood, *Rugopharynx australis* (Monnig), and *Macropostrongylus pearsoni* Johnston and Mawson, all from *Petrogale penicillata* (P.I.); *Subulura ortleppi* Inglis from *Rattus fuscipes* (P.I.); *Pl~aryngodon kartana* Johnston and Mawson from *Underwoodisaurus milii* (F.I.). *Skrjabinelazia* sp. from *Phyllodactylus marmoratus* (P.I.), and *Physaloptera* sp. from *Rattus fuscipes,* are also recorded. Trematodes recorded are *Paradistomum crucifer* (Nicoll) from *Phyllodactylus marmoratus* (P.I.) and dicrocoeliids from *Amphibolurus fionni* (?) (P.I.) and *Rattus fuscipes* (P.I.). Cestodes recorded are *Oijchoristica* sp. from *Lerista tetradactyla* (P.I.) and *Hepatotaenia* sp. from *Rattus fuscipes* (P.I.).

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Trematodes recorded are *Paradistomum crucifer* (Nicoll) from *Phyllodactylus marmoratus* (P.I.) and dicrocoeliids from *Amphibolurus fionni* (?) (P.I.) and *Rattus fuscipes* (P.I.). Cestodes recorded are *Oöchoristica* sp. from *Lerista tetradactyla* (P.I.) and *Hepatotaenia* sp. from *Rattus fuscipes* (P.I.).

Introduction

The helminths described in this paper were collected during and after the 1969 Expedition to the Pearson Islands, organised by the Royal Society of South Australia and the South Australian Department of Fisheries and Fauna Conservation. The Pearson Islands are a small group lying about 40 miles off the coast of South Australia at the eastern end of the Great Australian Bight. The largest of these, Pearson I., is about 162 hectares in extent, the others very much smaller. Several scientific expeditions have been made to the group which is otherwise visited only by fishermen, for shelter or for bait. Accounts of the geomorphology, land and marine vegetation, and fauna, are also given in this volume of the Transactions.

The animals examined on the island for helminths were lizards and rats, collected by Dr Michael Smyth, of the Department of Zoology, University of Adelaide. Later, more helminths were collected from animals which died after being brought back to the mainland. Two nematodes from *Rattus fuscipes murrayi*, from Pearson I., believed to have been collected by the Wood Jones Expedition of 1923, and hitherto unexamined, are also included.

Flinders Island, about 32 km (20 miles) northeast of the Pearson group, is a larger island which has been grazed and farmed for many years. It was visited on the way to Pearson Island on the 1969 expedition, and parasites of lizards collected there are included in this report.

The most commonly found helminths were nematodes, which are described in this paper. Three collections of cestodes were sent to Dr. John Hickman of the Zoology Department, University of Tasmania, who has kindly given preliminary identifications for inclusion in this paper. Three collections of trematodes have been identified, as far as their condition allows, by my colleague Miss Madeline Angel, and these also are listed.

The numbers of animals dissected is too small to allow any deductions of infestation rate or of species relationships with parasites of mainland hosts. Among the lizards, the nematodes present are the same, or closely related, species as those found in other parts of Australia.

The nematodes from the Pearson Island rat are more interesting and have diverse relationships. *Subulura ortleppi* Inglis was hitherto known only from two South African rats, and is the first record of the genus from an Aus-

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tralian rat. *Gongylonema beveridgei* n. sp. represents a genus only once before reported from an Australian rodent, and never from a native *Rattus* sp., although at least 55 of these have been dissected in this laboratory and no specimens of the above genus found. *Rictularia pearsoni* n.sp. is quite different from the two *Rictularia* spp. described from northern Australian rats, and more closely resembles a species from the Philippine Islands. This genus also has not been found in southern Australian mainland rats: it was, however, collected from Pearson I. in 1923

Large numbers of nematodes were present in the stomach of two rock wallabies examined. Almost all of these belong to three species, two of which, *Labiostrongylus longispicularis* Wood and *Rugopharynx australis* (Mönnig), are widespread in macropods all over Australia, while the third, *Macropostrongylus pearsoni* Johnston & Mawson has never been found elsewhere than on Pearson I.

The type specimens of new species described will be deposited in the South Australian Museum, and paratypes retained in the Helminthological Collection of the Zoology Department of the University of Adelaide.

The occurrence of helminths in the animals collected on the expedition is shown in Table 1. No Acanthocephala were found. A list of the helminths, identified as far as possible and arranged under their hosts, is given below, and this is followed by detailed accounts of the nematodes.

Trematoda and Cestoda

Reptiles

AMPHIBOLURUS FIONNI (Proctor)?—Elongate dicrocoeliids, gall bladder and bile duct. Pearson I

PHYLLODACTYLUS MARMORATUS (Gray).—*Paradistomum crucifer* (Nicoll), gall bladder. Pearson I

LERISTA TETRADACTYLA (Lucas & Frost).—*Oöchoristica* sp., intestine. Pearson I.

Mammals

RATTUS FUSCIPES (Waterhouse) var. MURRAYI Thomas.—Elongate dicrocoeliids, gall bladder; *Hepatotaenia* sp., intestine.

Nematoda

Reptiles

AMPHIBOLURUS FIONNI (Proctor)?—*Parapharyngodon kartana* Johnston & Mawson, Pearson I

PHYLLODACTYLUS MARMORATUS (Gray).—*Skrjabinodon parasmythi* n.sp., Flinders I.; *Parapharyngodon kartana* (Johnston & Mawson). *Skrjabinelazia* sp., Pearson I.

UNDERWOODISAURUS MILII (Bory).—*Skrjabinodon parasmythi* n.sp., *Pharyngodon kartana* Johnston & Mawson, Flinders I.

LERISTA sp. (? n.sp.).—*Parapharyngodon kartana* (Johnston & Mawson). *Skrjabinodon leristae*, Flinders I.

HEMIERGIS PERONII (Fitzinger).—*Parapharyngodon kartana* (Johnston & Mawson), Flinders I.

Mammals

PETROGALE PENICILLATA (Griffith).—*Rugopharynx australis* (Mönnig), *Cloacina petrogale* Johnston & Mawson, *Cloacina pearsoni* n.sp., *Labiostrongylus longispicularis* Wood, *Macropostrongylus pearsoni* Johnston & Mawson, *Cristaceps woodwardi* (Wood), Pearson I.

RATTUS FUSCIPES (Waterhouse) var. MURRAYI Thomas.—*Rictularia pearsoni* n.sp., *Gongylonema beveridgei* n.sp., *Physaloptera* sp., *Subulura ortleppi* Inglis, Pearson I.

NEMATODA

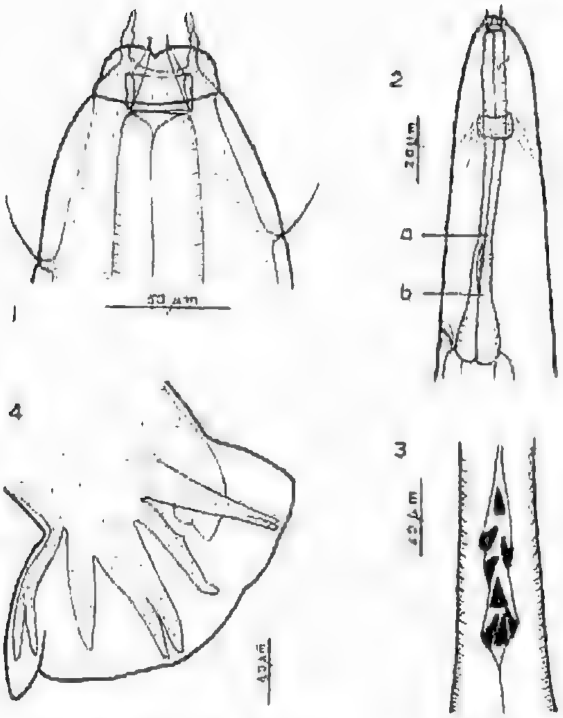
Cloacina petrogale Johnston & Mawson, 1938: 277, from *Petrogale penicillata* (syn. *P. lateralis*), Central Australia; J. & M., 1941a, from *Thylogale eugenii*, Kangaroo I.; J. & M., 1941b, from *Petrogale penicillata*, Pearson I. and *Thylogale flindersi*, Flinders I.

FIGS. 1-4

Host and locality: *Petrogale penicillata* Pearson I.

The measurements of the one male and three female specimens of the present collection are given in Table 2.

In the new material (and in the paratype material) oesophageal teeth are present in an elongate group at the level of a slight swelling of the oesophagus just in front of the terminal bulb (Fig. 3). Features which, combined, distinguish *C. petrogale* from other *Cloacina* spp. are: the elongate submedian cephalic papillae, the relatively deep and thin-walled buccal capsule, the anterior position of the cervical papillae, the rather long oesophagus with a group of teeth in the lumen just anterior to the terminal swelling, the nerve ring at about a quarter the length of, and excretory pore near the posterior end of, the oesophagus, and the spicule length about a third of the body length.



Figs. 1-4. *Cloacina petrogale.* Fig. 1.—Anterior end. Fig. 2.—Oesophageal region. Fig. 3.—Enlargement of oesophagus in region a-b in Fig. 2. Fig. 4.—Lateral view of bursa.

Cloacina pearsoni n.sp.

FIGS. 5-8

Host and locality: *Petrogale pearsoni*, Pearson I.

Six males and four females were collected; measurements are given in Table 2. The submedian cephalic papillae are small, with the distal segment of each distinctly shorter than the proximal. The buccal capsule is almost cylindrical and is relatively deep (external diameter 20-25 µm, depth 8-11 µm). The oesophagus is very slightly swollen just anterior to the nerve ring (about midlength) and has a terminal bulb. The cervical papillae are well back, a short distance in front of the level of the nerve ring. The excretory pore is in the region of the terminal bulb of the oesophagus. No oesophageal teeth were observed.

The tail of the female is conical, ending in a fine point. The vulva lies about one tail length anterior to the anus. The ovejectors join quite near the vulva but the vagina makes a short forward loop before passing to the vulva.

In the male the alate spicules are about a third of the body length. A gubernaculum is present. The bursal lobes are separated from each other by slight indentations. The arrangement of the bursal rays is shown in Fig. 8. The genital cone is well developed and bears two small rounded accessory lobes dorsally.

The species is close to *C. elegans* J. & M., 1938, *C. digitata* J. & M., 1940b, and *C. liebigi* J. & M., 1938, but differs from these in one or more of the following features: absence of thick inflated cervical cuticle, position of the excretory pore, presence of pre-neural swelling of the oesophagus, and the length and course of the vagina.

Macropostrongylus pearsoni Johnston & Mawson, 1940a, from *Petrogale penicillata*, Pearson I.

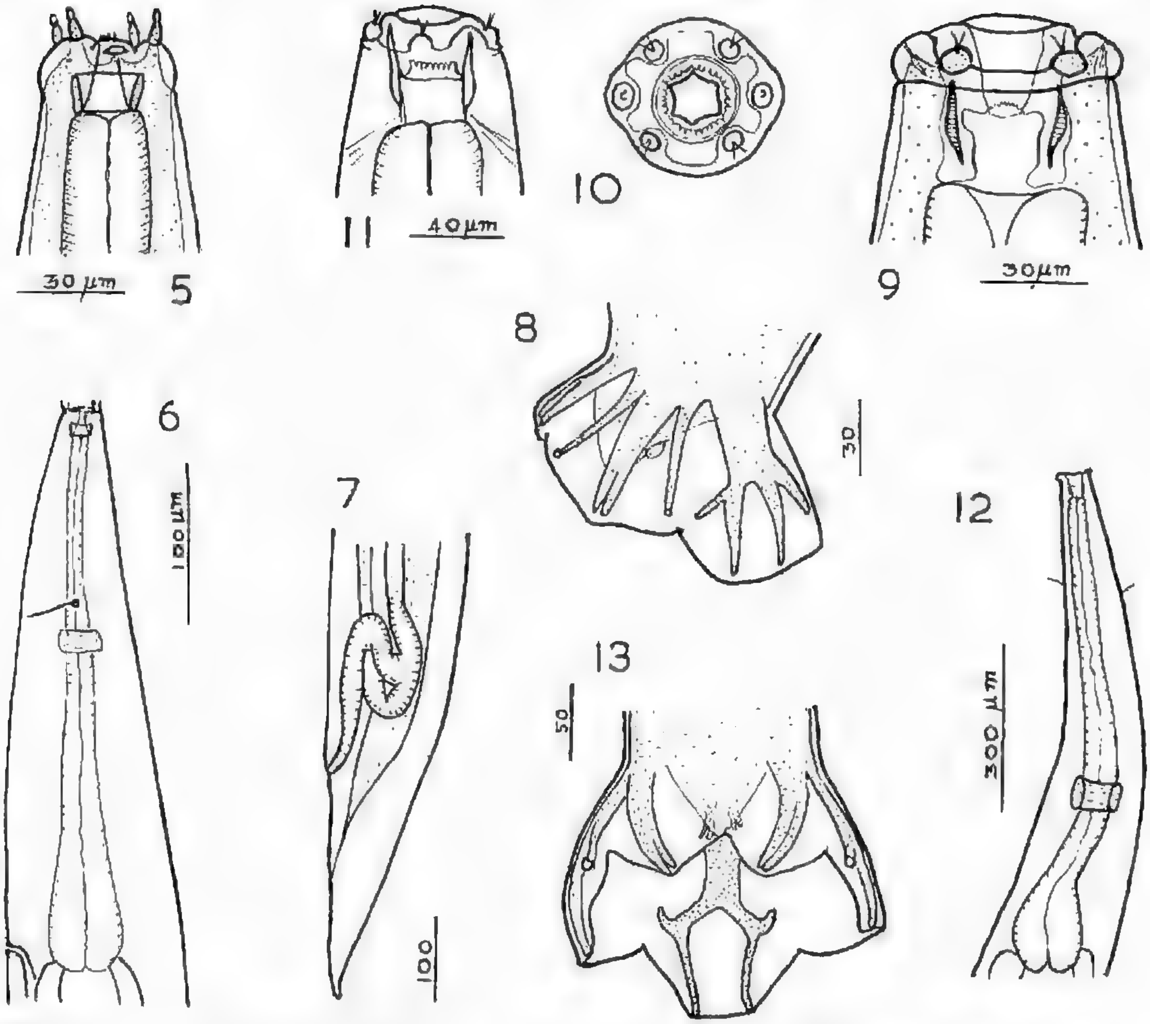
FIGS. 9-13

Host and locality: *Petrogale penicillata*, Pearson I.

The original description of this species was based on two specimens, one male and one female. Many specimens are available, as this was the most numerous nematode in the stomach of the wallaby. These are in a better condition than the old material and a fuller description can now be given. Measurements are shown in Table 2.

The cuticle over the anterior end forms a six-lobed plate, most clearly seen in *en face* view, which continues into the buccal cavity, around which it forms a more or less cylindrical wall in which the more strongly sclerotised buccal capsule itself is embedded. At about the mid-length of the buccal cavity the lining material projects into the lumen as a shelf or frill. In the type specimens this labial cuticle inside the mouth is not so thick and the shelf appears thinner and more rigid; this is the condition in a specimen (Fig. 11), which was given to me by Mr. Beveridge and which was possibly preserved differently. The shelf is not formed of "numerous tooth-like projections" but is continuous, though irregularly pleated; presumably this projecting flap, which is at different angles to the long axis of the worms, in different specimens, serves in some way to strain the food entering the mouth. The wall of the buccal capsule proper is thicker at its mid-length than at either end, and it is radially striated.

The four sub-median cephalic papillae lie between lobes of the anterior cuticular plate; each bears a pair of small forwardly directed



Figs. 5-8. *Cloacina pearsoni.* Fig. 5.—Anterior end. Fig. 6.—Oesophageal region. Fig. 7.—Posterior end of female. Fig. 8.—Dorso-lateral view of bursa.

Figs. 9-13. *Macropostrongylus pearsoni.* Figs. 9, 10.—Median and *en face* views, respectively, of head, to same scale. Fig. 11.—Head of female in which "lining" of buccal capsule is thin. Fig. 12.—Oesophageal region. Fig. 13.—Ventral view of bursa. All scales given in µm.

setae. The amphids open on a large papilla-like elevation of the cuticle, larger than the cephalic papillae. The thread-like cervical papillae are at about a third of the length of the oesophagus from the anterior end.

The anterior two-thirds of the oesophagus is cylindrical, and is followed by a slightly narrower part ending in a bulb. The nerve ring surrounds the junction of the two parts, and the excretory pore is immediately posterior to this.

The tail of the female tapers gradually to end in a short conical point. The length of the vagina is about equal to that of the tail, and the distance between vulva and anus a little less than the length of the tail. The eggs are about 150 by 60 µm. The egg length given in the original description was obviously a misprint. The spicules are 1/5.7-6.7 of the body length. They are alate for most of their length, and end in simple tips. The heart-shaped gubernaculum appears to have a keel which lies between the spicules. The bursa is longer dorsally than ventrally. The arrangement of the rays is shown in Fig. 13. The ventro-lateral rays and the externo-dorsal rays do not reach the edge of the bursa and their tips lift the bursa outwards. The tips of the two lateral branches of the dorsal ray bend inwards, pushing the bursa in. The genital cone is well developed, and the accessory cone, or dorsal lip of the cloacal aperture, bears two bifid processes (Fig. 13).

Labiostrongylus longispicularis Wood, 1930, from *Macropus bernardus*, Western Australia (?); Johnston & Mawson, 1938, from *Macropus robustus*, Central Australia; J. & M., 1940, from *Petrogale penicillata*, Pearson I.[*]

FIGS. 14-15

Host and locality: *Petrogale penicillata*, Pearson I.

Labiostrongylus longispicularis has been recorded from many species of macropods and from most parts of Australia. The present specimens are rather shorter than those previously recorded for the species. The genital cone is well developed, and the accessory cone bilobed, each lobe carrying a small projection which is bifid distally. In some specimens the distal portions are asymmetrical (Fig. 15). The dorsal ray is the typical shape for the species, although in some specimens this too is misshapen (Fig. 14). The spicules are longer in relation to the body length than in the type specimens.

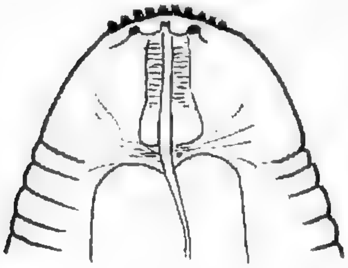
Rugopharynx australis (Mönnig); Wood, 1929, from *Macropus bernadus*, Western Australia (?); Mawson, 1964, from *Megaleia rufa*, New South Wales and Queensland; *M. giganteus*, Queensland.[†]

Spirostrongylus australis Mönnig, 1926, from *Macropus rufus*, S. Africa (Zoo).

Pharyngostrongylus alpha Johnston & Mawson. J. & M., 1938, from *Petrogale penicillata* Central Australia; J. & M., 1940a, from *Petrogale penicillata*, *Macropus melanops* Pearson I., S.A.

Pharyngostrongylus beta Johnston & Mawson J. & M., 1938, from *Petrogale penicillata*, Central Australia; J. & M., 1940a, from *Macropus melanops*, *Petrogale penicillata*, *Thylogale flindersi*, South Australia.

Host and locality: *Petrogale penicillata*, Pearson I.



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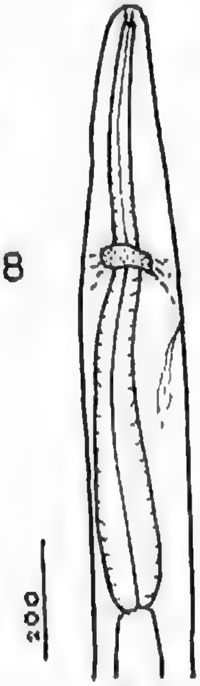

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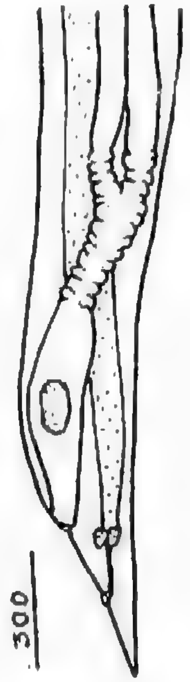

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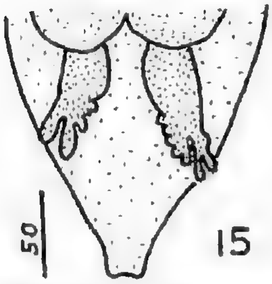

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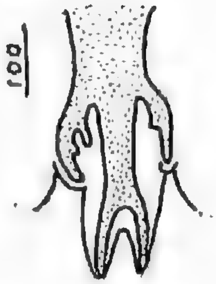

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Figs. 14-15. *Labiostrongylus longispicularis.* Fig. 14.—Dorsal ray of aberrant shape. Fig. 15.—genital cone and accessory cone.

Figs. 16-19. *Cristaceps woodwardi.* Figs. 16 & 17.—Lateral and semi-*en face* views of head, to same scale. Fig. 18.—Oesophageal region. Fig. 19.—Posterior end of body. All scales given in µm.

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[*] Records listed here are only those where some description is given, or to a Pearson I. occurrence.

[†] The records listed here are only those where some description is given or to a Pearson I. occurrence.

Rugopharynx australis is a species widespread in macropods all over Australia; it was recorded from the Pearson Island Wallaby by Johnston and Mawson (1940, p. 97). In the present collections it is the second most abundant species in the stomach. The species was redescribed (Mawson 1964, p. 245) and the new specimens, though slightly smaller, closely resemble those from the mainland hosts.

Cristaceps woodwardi (Wood) n. comb.
Pharyngostrongylus woodwardi Wood, 1930, from *Macropus bernardus* (Syn. *M. woodwardi*), Western Australia (?).

FIGS. 16-19

Host and locality: *Petrogale pearsoni*, Pearson I.

Only two females of this species were found. The collector, Mr. Ian Beveridge, stated that they were partly in the mucosa of the stomach, and were removed only with some difficulty. This is the situation in which the type specimens were found.

The unusual cuticular ornamentation of the head identifies the specimens as being close to Wood's species, and in all points they agree with his description. The small differences of measurements (Table 1) are negligible, and no new species is proposed for them, in spite of the wide geographical separation of the hosts.*

As Wood points out, there are distinct differences between this species and the type species of *Pharyngostrongylus* Yorke & Maplestone, 1926, and a new genus, *Cristaceps*, is now proposed for it, with the following diagnosis: ? Amidostomatidae; (sensu Inglis 1968). Long slender worms; anterior end rounded, with apical cuticle raised into two dorso-ventral rows of small denticles; small oval mouth between these. Four small submedian papillae and two distinct amphids lying close to, but lateral from, the rows of denticles; buccal capsule well chitinised, more or less cylindrical, striated; oesophagus narrow in first half, widening in second half. *Male:* spicules equal, similar, long and straight, bursa directed dorsally, ventral rays together, ventro-lateral separate, medio- and postero-laterals together, externo-dorsal separate but arising from lateral stem, dorsal divided to base, each branch long and slender, bifurcating near tip. Gubernaculum present. *Female:* tail conical, vulva shortly in front of anus, vagina long, uteri and ovijectors directed anteriorly. Parasitic in gastric mucosa of Australian marsupials (macropods).

Type species: *W. woodwardi* (Wood), syn. *Pharyngostrongylus woodwardi* Wood, 1931.

Systematic position of the genus. No satisfactory classification has yet been published of the strongyle nematodes from the stomach of Australian macropods, largely perhaps because of the lack of detail in the earlier descriptions of some of these. The characters of the head (the cuticular ornamentation and particularly the complete absence of any lips or "labial roll") separate *Cristaceps* from the various Trichoneminae (sensu Yorke & Maplestone 1926) from macropods and wombats, in particular from the three main groups, as follows:

1. The pharyngostrongyle group (*Pharyngostrongylus, Oesophagonastes, Rugopharynx* and *Pararugopharynx*) in which there is a buccal ring as well as a vestibule, and in which a leaf crown, internal or external, may or may not be present.

2. The labiostrongyle group (*Labiostrongylus, Zoniolaimus, Parazoniolaimus*), in which the lips are very well developed and a leaf crown absent.

3. The group including *Cloacina, Phascolostrongylus,* and *Macropostrongylus*, in which an internal leaf crown arises from a cylindrical buccal capsule.

The small simple mouth and rounded anterior end with denticulate ornamentation are also different from any genus so far described. However, the long slender body, the situation of the cephalic papillae, as well as the location in which the species is found, are suggestive of *Filarinema* spp. (Mönnig 1929, Mawson 1964). It is probable that the species may belong in the Amidostomatidae (sensu Inglis 1968), although the strongly chitinised buccal capsule is different from that of any other genus ascribed to this family. The bilateral symmetry of the head shows a convergence with the spirurid parasites of the stomach wall of other mammals and birds, as pointed out by Inglis (1965).

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* Wood gave the origin of the host, which had died in captivity in England, as Western Australia. The range of *Macropus bernardus* (Woodward's Wallaroo) is given by W. D. L. Ride (1970) as "interior of Arnhem Land", i.e. in the Northern Territory.

Inglis in his comprehensive study of Australian trichostrongyles considers that all trichostrongyloid genera recorded from Australian animals fall into the family Amidostomatidae Travassos, 1919. In his revised definition of this family, Inglis states that the laterodorsal (= externo-dorsal) rays "arise from the base of the dorsal ray". This is an oversimplification, as in many species the externo-dorsal ray appears to have no special connection with the dorsal ray, and this is the case in *Cristaceps woodwardi*, according to Wood's description.

Rictularia pearsoni n.sp.

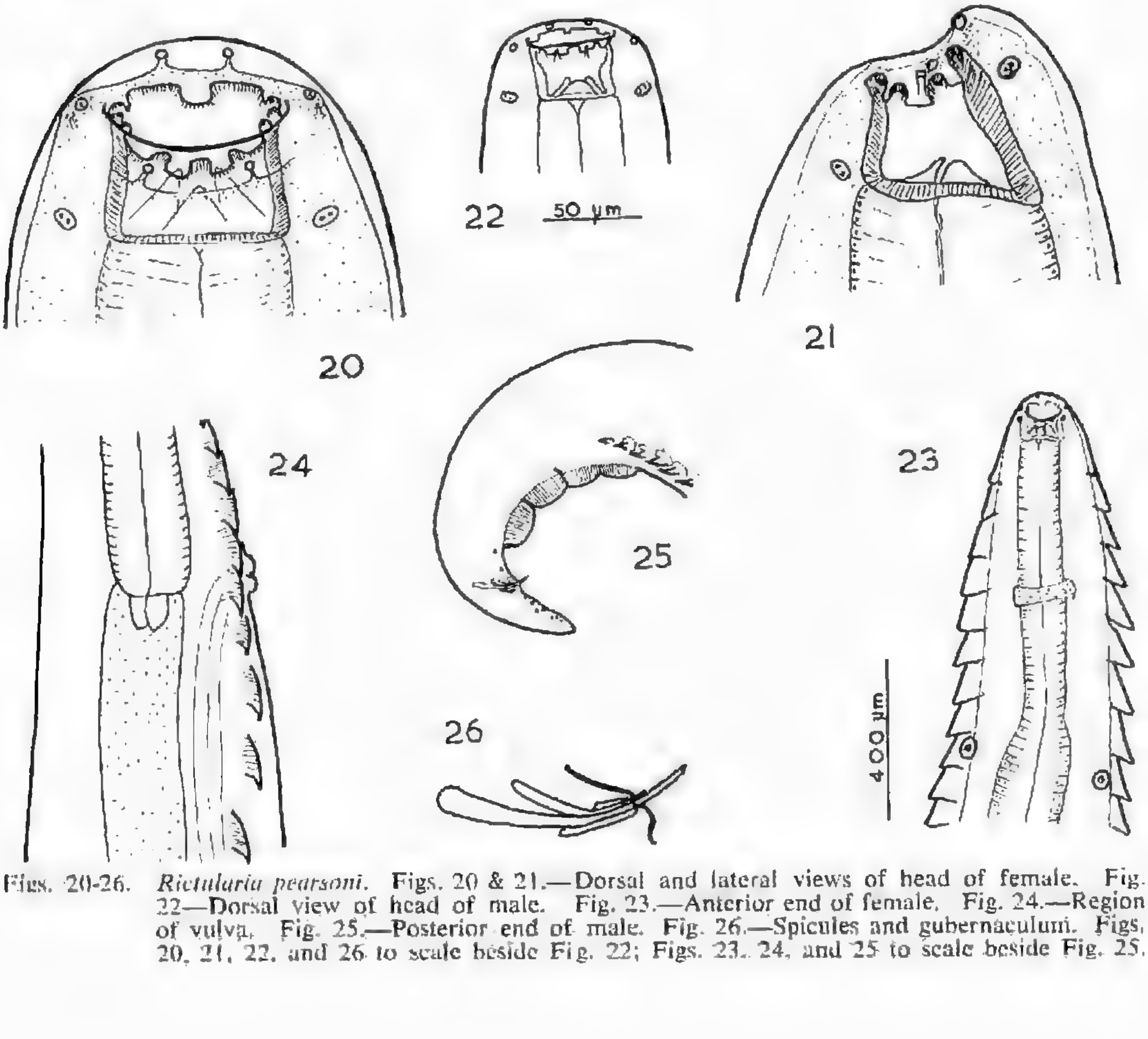
FIGS. 20-26

Host and locality: *Rattus fuscipes murrayi*, Pearson I.

Females of a species of *Rictularia* were taken from two of four rats dissected in 1969, and a male and a female of the same species are present in a collection from the same host species, apparently made during the 1923 expedition to the Pearson I. Male and females are all smaller than *Rictularia* spp. described from other Australian rats. The measurements are given in Table 2.

In both sexes the lateral spines continue throughout the body length. Those of the oesophageal region are imbricate, behind this more hook-like (Fig. 23). The mouth is more or less circular and is only slightly inclined dorsally. The teeth on the anterior border of the buccal capsule are rounded rather than pointed, and are few in number, only 10 or 12. Of these, two are very wide and occupy most of the ventral sector of the border. The two blunt ventral, and the pointed dorsal, oesophageal teeth at the base of the buccal capsule are short.

The nerve ring lies at about the middle, and the excretory pore at about three-quarters, of the anterior muscular part of the oesophagus,



Figs. 20-26. *Rictularia pearsoni*. Figs. 20 & 21.—Dorsal and lateral views of head of female. Fig. 22—Dorsal view of head of male. Fig. 23.—Anterior end of female. Fig. 24.—Region of vulva. Fig. 25.—Posterior end of male. Fig. 26.—Spicules and gubernaculum. Figs. 20, 21, 22, and 26 to scale beside Fig. 22; Figs. 23, 24, and 25 to scale beside Fig. 25.

and the cervical papillae just behind it at the level of the eighth or ninth spine.

The tail of the female is short, conical, and ends in a small point. The vulva lies a short distance anterior to the posterior end of the oesophagus; the lips of the vulva are salient, but there is no ornamentation of the cuticle around it, as in other Australian species. The eggs are about 50 by 35 μm.

In the male the spicules are unequal, the shorter about half the length of the longer; a small gubernaculum is present. There are four preanal fans. The caudal papillae are typical of the genus (Fig. 25). The cuticle around the cloaca is not rugose, as in some species of the genus.

Two species of *Rictularia* have been described from Australian rodents, *R. carstairsi* Mawson, 1971, and *R. mackerrasae* Mawson, 1971. The Pearson Island species differs from both of these in the greater number and extent of the lateral spines, in the shape and the small number of peribuccal teeth, and in the distinctly smaller size of both sexes. It differs further from *R. carstairsi* in the inequality of the spicules, and from *R. mackerrasae* in the shape of the buccal capsule. It is close to *R. whartoni* Tubangui, 1931, the male of which was described by Schmidt and Kuntz in 1967, but differs from it in the detail of the dentition, in the spicule length and in the arrangement of the caudal papillae in the male. A new species, *Rictularia pearsoni*, is therefore proposed

Gongylonema beveridgei n.sp.

FIGS. 26-30

Host and locality: *Rattus fuscipes murrayi*, Pearson I.

A species of *Gongylonema* was present in the stomach of two of four rats dissected by the author. In one there were two females and one male and in the other two females. The females of the second collection were smaller than those of the first, and although numerous eggs were present, these were without shells, and obviously infertile.

In the male the cuticular ornamentation is restricted to the left side of the body and continues only to 350 μm from the anterior end. A lateral ala is present on the right side and continues for the whole body length, widening to form the right caudal ala. In the female the cuticular ornamentation is more extensive and is developed on dorsal and ventral sides of the body, though there is very little directly beside each of the two lateral alae, which reach from just behind the cervical papillae to 1.3-1.5 mm from the head. The cuticular bosses reach to 1.5 mm from the head in a 72 mm long specimen. The buccal capsule is 60 μm long in the male and in the shortest female, and 70 μm long in the fertile females.

In both sexes the cervical papillae lie behind the level of the posterior end of the buccal capsule and just in front of the origin of the lateral alae. The nerve ring is just behind the cervical papillae, the excretory pore in the female is at about two thirds the length of the anterior part of the oesophagus, in the male nearer the junction of this with the glandular part. It has been stated by various authors that many of the measurements usually given for nematodes have no specific value in the case of *Gongylonema* spp.; Desportes, Chabaut & Campana (1949) restrict the useful measurements to lengths of the body, buccal capsule, spicules, gubernaculum and tail, the distance of the vulva from the posterior end, and the egg size. In the four female worms of the present collection there is certainly considerable variation in the distance of the nerve ring, cervical papillae, etc. from the anterior end, due largely to the state of contraction of the specimens. The specimen shown in Fig. 29 is a relaxed female, infertile, while Fig. 28 is of the largest female, which is in a somewhat contracted state.

On the conical tail of the female, the phasmids are close to the tip; the vulva lies about a ninth to a tenth of the body length from the posterior end. Eggs in the vagina are 55-60 by 35-36 μm, with thick smooth shells and containing a coiled larva.

In the male the caudal alae meet behind the body; the right ala is wider than the left. The arrangement of the caudal papillae is shown in Fig. 30. The left spicule is nine times the length of the right, the gubernaculum is shorter than the right spicule, spatulate, with a broadened tip.

There are only two records of *Gongylonema* sp. from rodents in Australia; Fielding (1928, p. 126) noted *G.* sp. from *Rattus norvegicus*, *R. rattus*, *Mus musculus*, and *Hydromys chrysogaster*, from north Queensland; and Johnston (1918, p. 61) suggested that eggs from the liver of *Mus musculus* (Sydney) were those of *G.* sp. Many native rodents, including 35 *Hydromys chrysogaster*, have been dissected in this department, but no *Gongylonema* sp. has been found, except for

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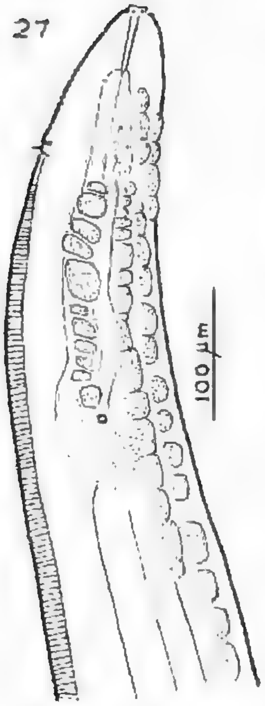

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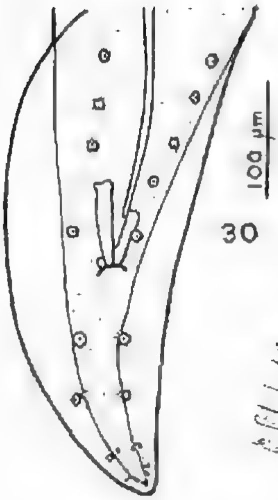

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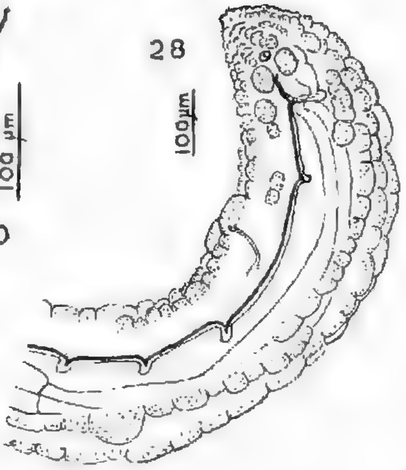

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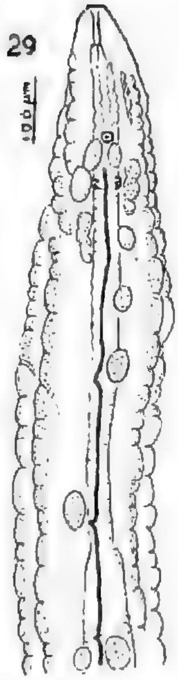

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Figs. 27-30. *Gongylonema beveridgei.* Fig. 27—Anterior end of male. Figs. 28 & 29.—Anterior ends of contracted and relaxed females, respectively. Fig. 30.—Posterior end of male.

Figs. 31, 32. *Physaloptera* sp. Fig. 31.—Lateral view of head. Fig. 32.—Inside of one pseudolabium.

the two collections from Pearson I. A new species is proposed for these, as they differ from any species of which I have seen a description, in the presence in the male of one lateral ala continuing throughout the body length. The specific name is given in acknowledgement of the help of Mr. Ian Beveridge.

Physaloptera sp.

FIGS. 31, 32

Host and locality: *Rattus fuscipes murrayi,* Pearson I.

Only one female *Physaloptera* sp. was found in the Pearson I. rat. It is 37 µm long, with very short collar surrounding only the bases of the pseudolabia. The submedian papillae are prominent. On the inner surface of each pseudolabium there are two median teeth, the inner of which is heavily built with three blunt cusps, while the other is smaller, and also blunt-tipped. The oesophagus is 6 mm long, with anterior muscular part 800 µm; the distance from the anterior end of the nerve ring is 600 µm, of the cervical papillae 1110 µm. The vulva lies shortly behind the oesophagus; there are two ovaries. Eggs in the uteri are without shells, apparently infertile.

In the absence of a male it is impossible to assign this worm to a species. It is not unlike *P. troughtoni* Johnston & Mawson, 1941, from *Rattus fuscipes greyi* from Kangaroo Island, South Australia.

Subulura ortleppi Inglis, 1960, from *Rhabdomys pumilio* and *Rattus* (*Praomys*) *namaquensis,* South Africa.

Host and locality: *Rattus fuscipes murrayi,* Pearson I.

Dr. Inglis has himself kindly verified the identification of these nematodes, and can find no difference between them and his type specimens, except that the Pearson I. ones are rather smaller. *Subulura ortleppi* was by no means uncommon in the Pearson I. rats, being present in some numbers in all four rats dissected. *Subulura* sp., not yet determined, occurs also in native rats from Queensland.

Pharyngodon kartana Johnston & Mawson, 1941: 145, from *Underwoodisaurus milii,* Kangaroo I.; J. & M. 1943, from *Phyllodactylus guntheri,* Lord Howe I.

FIG. 33

Host and locality: *Underwoodisaurus milii,* Flinders I.

Pharyngodon kartana was present in each of the three specimens examined of this host. It is apparently widespread in Australia, and is not confined to geckos, as it has been identified (unpublished) from *Hemiergis peronii* from Kangaroo Island. The present specimens differ slightly from the type and other specimens from Kangaroo Island, which have been re-examined, but the variations do not appear to warrant the erection of a new species. Measurements are given in Table 3.

The male worms are very similar to the type, although they are shorter, and the oesophagus and tail spike are slightly longer in relation to the body length. The tail spike bears a few very small spines which have not been seen in the Kangaroo Island specimens.

The female bears narrow double lateral alae from just behind the head to the level of the anus (present in the type material also). The tail spike is about a quarter to a fifth of the body length in the ovigerous female, nearly a half in young females. The spines on the tail are few and though long, are not as stout as indicated by the original figure (J. & M. 1941, Fig. 6). The vulva and the excretory pore shortly in front of the vulva, are oesophageal in all specimens, even, in some very contracted specimens, very close to the head, but in most, at or near the oesophageal bulb. In the Kangaroo Island specimens the vulva is post-oesophageal.

Skrjabinodon parasmythi n.sp.

FIGS. 34-36

Host and locality: *Underwoodisaurus milii* (typehost), *Phyllodactylus marmoratus*, Flinders Island.

A few males but no female were present in each of three *U. milii* dissected; one specimen of *P. marmoratus* contained five females, only one of which is ovigerous; it is not certain that the females belong to the same species as the males, but both are from geckos in the same region, and the females do not belong to the only other related oxyurid species (*Pharyngodon kartana*) so far found in geckos on Flinders Island.

Measurements are given in Table 3. The species is very similar to *Skrjabinodon smythi* Angel & Mawson, 1968, from geckos near Adelaide, but it is distinguished in the male by the presence of a well-developed spicule, and the relatively shorter tail spike. In the female also the tail spike is relatively shorter, and the few spines on it are slender and pointed, not rounded as in *S. smythi*. The oesophagus is longer in relation to the body length in both sexes. In these females, as in *S. smythi*, there are narrow double lateral alae.

The only other species described as having a spinous tail in the female and a spicule in the male are *S. apapillosus* (Koo, 1938) in which the tail spines are very much more numerous, and *S. sceloporі* (Caballero, 1938) in which they are very much larger.

Skrjabinodon leristae n.sp.

FIGS. 37-39

Host and locality: *Lerista* sp., Flinders I.

Although this collection consists of only one male and three female worms, and the male is without the extremity of the tail, it apparently represents a new species. Measurements are given in Table 3.

Lateral alae are present in both sexes, and are double in the female. The excretory pore and vulva in the female are at about the level of the bulb of the oesophagus. The male worm is damaged in this region, but the excretory pore cannot be seen in the rest of the body.

A spicule is absent. The arrangement of the caudal papillae of the male are shown in Fig. 39. The tail spike is spinous in both sexes. In the female the spike is 2.6-3.0 times the distance from the anus to the base of the spike. Eggs are 120-125 by 38-40 μm; polar plugs were not seen.

The species differs from *S. smythi* Angel & Mawson in the more posterior position of the anus in relation to the tail spike length, the shorter oesophagus and tail spike (both absolutely and in relation to the body length) and the presence of larger spines on the male tail. It is distinguished from *S. parasmythi* chiefly by the absence of a spicule.

Parapharyngodon kartana (Johnston & Mawson) new comb

Thelandros kartana Johnston & Mawson, 1941, from *Hemiergis peronii*, Kangaroo Is.; Angel & Mawson, 1968, from *H. peronii*, and *Phyllodactylus marmoratus*, near Adelaide, S. Aust.

FIGS. 40, 41

Hosts and localities: *Amphibolurus fionni*(?), Pearson I., *Rhodona* sp. *Hemiergis peronii*, Flinders I.

These specimens have been compared with the paratypes and with the specimens described in 1968, and it is noted that alae are present in the male for about two thirds of the body length; the female is not alate. It is there-

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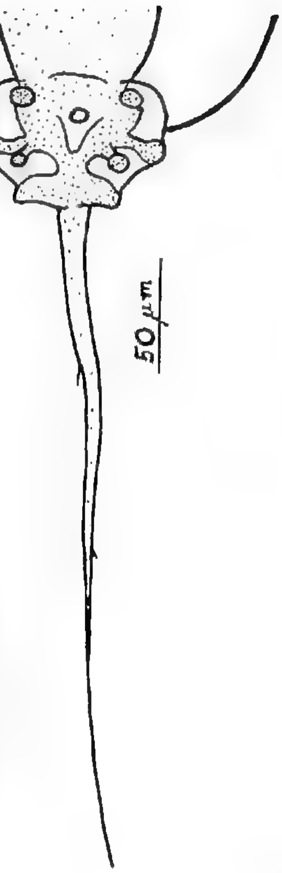

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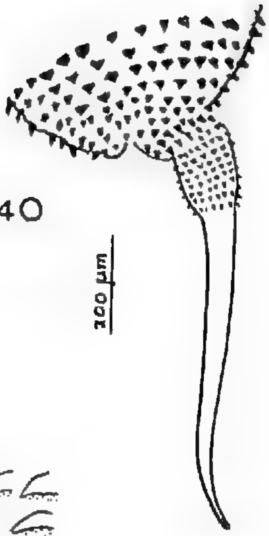

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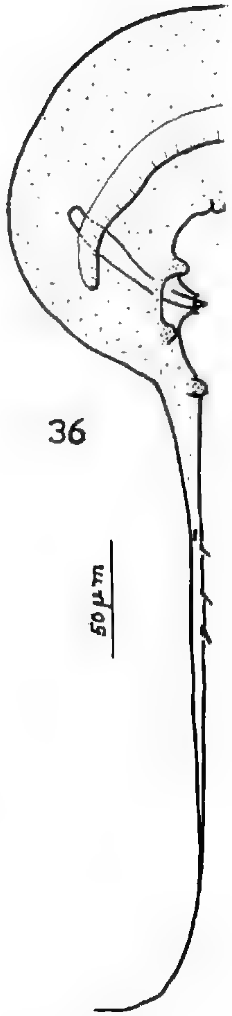

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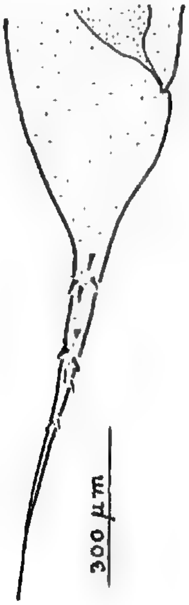

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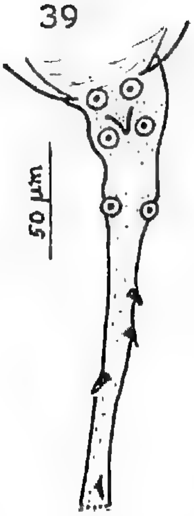

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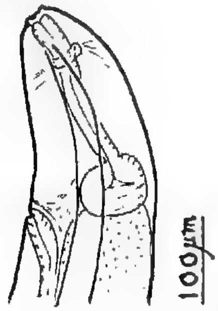

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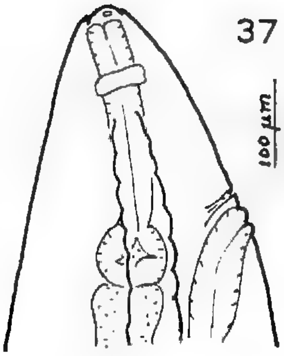

Fig. 33. *Pharyngodon kartana*, tail of male.

Figs. 34-36. *Skrjabinodon parasmythi*. Fig. 34.—Anterior end of female. Fig. 35.—Posterior end of female. Fig. 36.—Posterior end of male.

Figs. 37-39. *Skrjabinodon leristae*. Fig. 37.—Anterior end of female. Fig. 38.—Posterior end of female. Fig. 39.—Cloacal region of male.

Figs. 40, 41. *Parapharyngodon kartana*. Fig. 40.—Posterior end of juvenile. Fig. 41.—Part of the surface of the body of juvenile, near mid-length, showing cuticular spines.

fore necessary to transfer the species to the genus *Parapharyngodon* Chatterji, 1933. It may also be noted that the coils of the ovary reach around the corpus of the oesophagus, though this was omitted from the figure given in 1968 (Angel & Mawson 1968, Fig. 8).

The specimens from Pearson I. and Flinders I. are on the whole larger than those from the Adelaide region and many are larger than those from Kangaroo I. Their measurements are given in Table 3. Among them are five apparently young specimens in which the cuticle is spiny (Fig. 41); the spines are arranged in rings around the body, graduating in size from small anteriorly to large posteriorly as far as the caudal constriction, then ending in a region of tiny spines at the base of the tail spike (Fig. 40) There are no other spines on the tail. This condition appears to be similar to that found by Schad (1960, p. 116) in young specimens of his species *Thelandros salamandrae*. Among the present five small, plump, spined specimens from *Rhodona* sp. are four females and one male (spicule present). That the spinous cuticle is a feature of a very young adult rather than of a fourth stage larva is suggested by the condition in two larger but still young females in which the bases of a few spines are distinct.

Skrjabinelazia sp.

Host and locality: *Phyllodactylus marmoratus*, Pearson I.

Only three female worms are present, and in the absence of a male the generic identification is not definite. Females of a similar species were recorded from the same host species from near Adelaide (Angel & Mawson, 1968).

Acknowledgements

On Pearson I., I was indebted to my colleague, Dr. Smyth, who permitted me to examine lizards of his collection for parasites; and who collected rats for me. Grants in support of the Expedition were made by the Department of Fisheries and Fauna Conservation and the Royal Society of South Australia.

The gut of the Pearson Island Wallaby was obtained from Mrs. M. E. Christian, a veterinary surgeon, of Adelaide, and helminths from this host species and the Pearson Island rat were given to me by Mr. Ian Beveridge of the Veterinary School of the University of Melbourne. I am very grateful to these people for their help.

TABLE 1

Incidence of helminths.

This table lists only those hosts dissected by the author. Some of the specimens referred to in the text were collected by other people. P.I. indicates Pearson I., F.I. Flinders I.

Host	Locality	Number dissected	Number parasitised	Number yielding: Trematoda	Cestoda	Nematoda
Phyllodactylus marmoratus (Gray)	P.I.	6	2	1	—	2
	F.I.	5	2	—	—	2
Underwoodisaurus milii (Bory)	F.I.	3	3	—	—	3
Amphibolurus fionni (Proctor)?	P.I.	11	10	2		10
A. striatus	F.I.	1	0	—	—	-
Lerista tetradactyla (Lucas & Frost)	P.I.	5	1	—	1	1
	F.I.	2	0	—	—	—
Lerista sp. (? n. sp.)	F.I.	4	3	—	—	3
Hemiergis peronii Fitzinger	P.I.	2	0	—	—	—
	F.I.	9	5	—	—	5
Ablepharus greyi (Gray)	F.I.	3	0	—	—	—
A. lineoocellatus (Dumeril & Bibron)	P.I.	1	0	—	—	—
Petrogale penicillata (Griffith)	P.I.	1	1	—	1	1
Rattus fuscipes murrayi Thomas	P.I.	4	4	1	3	3

TABLE 2

Measurements of strongyle and spirurid species described in the text; unless otherwise indicated all measurements are in µm.

	Macropostrongylus pearsoni	*Cloacina elegans*	*Cloacina petrogale*	*Labiostrongylus longispicularis*	*Cristaceps woodwardi*	*Rictularia pearsoni*	*Gongylonema beveridgei*	
Male								
Length (mm)	5.7—6.5	3.1—5.0	6.1	19.0	—	4.6	12.0	—
Oesophagus, total length	870—930	400—430	880	5650		1400	3000	
Ant. part of oesoph.	—						400	
Ant. end—nerve ring	520—580	180—210	—	1400			195	
—cervic. pap.	150—190	115—150	80	1200			130	
—excr. pore	550—610	320—370	840	?			360	
spicule length (s)	940—1010	1200—1600	2300	10030		140	810	
						80	90	
gubernaculum							60	
length/oes. length	6.1—7.0	7.7—11.9	6.9	3.4			4	
length/spicule length	5.7—6.7	2.6—3.1	2.6	1.8				
Female							♀s(a)*	♀s(b)†
Body length	6.9—7.3	4.2—4.8	7.6	—	25.0, 29.5		64, 72	50
Oesoph.	940—990	400—430	1000		940, 1100		5200, 7200	6300
Ant. part of oesoph.							800, 920	700
Ant. end—nerve ring	500—640	190—210	300		380, 450		310, 200	325
—cervic. pap.	220—250	130—160	110		550, 700		140, 100	230
—excr. pore	530—690	370—390	950		500, 700		? , ?	590
Postr. end—vulva	740—790	270—370	210		310, 450		7800, 6200	4600
Tail	450—500	130—180	390		190, 190		340, 330	250
Length/oesophagus	7.0—7.6	9.7—12.0	7.6		26.5, 26.8		10, 12	8

* two fertile females, somewhat contracted

† infertile female, relaxed

TABLE 3

Measurements of oxyurids.

Measurements are given in μm unless otherwise stated. Under *Parapharyngodon kartana* measurements under (a) are of specimens from *Amphibolurus fionni*, those under (b) of specimens from *Lerista* sp.

Species	*Pharyngodon kartana*	*Skrjabinodon parusmythi*	*Skrjabinodon leristae*	*Parapharyngodon kartana* (a)	*Parapharyngodon kartana* (b)
Male					
length (mm)	1.30—1.64	1.5—2.0	1.3	1.6 (young specimen)	2.3—4.2
oesophagus	300—360	350	—	350	350—780
antr. end—nerve ring	140—150			150	200
—excr. pore	370—425	400—520	—	500	1150—1400
tail spike	250—280	250—300	—	40	65—90
spicule	—	60—65	—	70	60—65
length-oesophagus	4.1—5.0	4.1—5.7	—	4.6	5.3—7.5
length/tail spike	5.2—6.2	5.7—7.1	—	—	—
Female					
length (mm)	3.5—4.0	3.9	4.2—5.3	4.4—4.8	7.3—8.2
oesophagus	390—450	280	350—400	1000—1100	1500—1950
antr. end—nerve ring	40—150		100—105	—	170—200
—excr. pore	300—340	300	260—280	—	1900—2400
vulva	360—400	350	300—310	—	—
tail (incl. spike)	850—1060	1200	850—960	350—400	300—600
tail spike	710—900	900	640—700	—	—
Postr. end — vulva (mm)	—	—	—	2.6	3.7—4.2
length/oesophagus	8.4—9.3	13.9	11.7—15.7	4.4	4.3—5.3
length/tail spike	4.4—5.1	4.3	6.5—7.6	—	-

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SMALL FOSSIL VERTEBRATES FROM VICTORIA CAVE, NARACOORTE, SOUTH AUSTRALIA

I. POTOROINAE (MACROPODIDAE), PETAURIDAE AND BURRAMYIDAE (MARSUPIALIA)

by MEREDITH J. SMITH*

Summary

Abundant fossil remains of marsupials and rodents have been found in a silty deposit in Victoria Cave, near Naracoorte, South Australia. The presence of large extinct herbivores in the assemblage suggests that the deposit may be of Pleistocene age. This paper describes remains of *Potorous apicalis*, *P. platyops*, *Bettongia gaimardi* and *B. penicillata* (Macropodidae, Potoroinae), *Pseudocheirus peregrinus* and *Petaurus breviceps* (Petauridae), and *Cercartetus nanus* (Burramyidae). Extensions of the previously known ranges of *P. apicalis*, *P. platyops* and *B. gaimardi* are noted. *Potorous morgani* Finlayson, 1938 is shown to be a synonym of *P. platyops* (Gould, 1844).

Introduction

Numerous caves in the Tertiary limestone near Naracoorte, South Australia, have been known for over a century (Woods 1862), and several have been open to tourists for nearly 70 years. Naracoorte (lat. 37°0'S, long. 149°48' E) is about 320 km SE of Adelaide near the Victorian border. Victoria Cave (S. Aust. S2) is one of these tourist caves but a section previously unknown was entered in 1969 by members of the Cave Exploration Group of South Australia (CEGSA). This section included a large chamber, partially filled with silt, with a few bones and skulls lying on the surface. One member of the exploration party (Mr. R. T. Wells) recognized remains of extinct species (*Sthenurus* sp. and *Thylacoleo* sp.) and initiated a study of the deposit. This study has been pursued by CEGSA members, in close co-operation with the South Australian Government Tourist Bureau.

The deposit consists of damp, but friable, light-brown earth with bones of animals ranging in size from diprotodontids to macropodids, and down to dasyurids and rodents. Bones are most abundant in the top 15 cm. The stratigraphy will be described in detail (Wells, unpublished). Radio-carbon dates are not yet available, but the abundance of sthenurines, diprotodontids and *Thylacoleo* (Wells, unpublished) suggests that the deposit was formed during the Pleistocene and sealed before the Recent. The large marsupial herbivores typical of the Pleistocene seem to be lacking from early Recent assemblages and such genera as *Diprotodon*, *Sthenurus*, *Procoptodon* and *Protemnodon* probably became extinct at the very end of the last glacial period (Tedford 1967). No remains have yet been found of non-endemic mammals, such as rabbit, fox or house-mouse, nor of man or dingo.

Bone deposits in several other Naracoorte caves have been investigated previously. Woods (1862) described lime-encrusted bones of several modern species, rodent bones being the most abundant. From a recent deposit in the Bat Cave, Tidemann (1967) identified 27 mammal species, including the dingo, fox and rabbit. Two species of *Sthenurus* from Haystall Cave were described by Merrilees (1965). The present paper, and others following, will describe remains of small vertebrates believed to have lived in the Naracoorte area during the Pleistocene.

Methods

(a) *Location of excavation.* The silt deposit is roughly 60 m long and 15 m wide; it is at least 2.5 m deep and bone chips occur in cores taken at that depth. Near the entrance of the deposit, an area about 3 m long and 1.5 m wide has been excavated to the depth of 80 cm near its middle. (Slumping of the silt necessitates a sloping-sided pit.) Further into the chamber the top 15 cm of an irregular area about 12 m long and between 1.5 and 3 m wide has been excavated.

(b) *Preparation.* The silt surrounding large bones and skulls was gently cleared away with small metal trowels, and collected in buckets. It was sieved through either circular hand-held

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wire sieves, 60 cm in diameter, or through a suspended rectangular wire sieve, 120 cm x 60 cm. The mesh on all sieves was 8 per 25.4 mm. All tooth-bearing fragments and isolated teeth were picked from the sieves by hand, and many other bones were also retained. All bone samples were labelled with their position and depth in the deposit.

After the bones had dried for several days in the atmosphere of a normal room, the silt could be brushed away with a camel hair brush. Any lime encrustations were dissolved in 5% acetic acid, after which the bones were thoroughly washed in water. Even such a low concentration of acid made the bones extremely brittle and crumbly, and all acid-treated fragments were impregnated with Bedacryl dissolved in methyl-ethyl-ketone.

The specimens will become the property of the South Australian Museum.

(c) *Measurement.* As very few skulls of small animals were preserved, measurements were mainly confined to dimensions of teeth. The length of premolar and molar teeth was measured as the maximum antero-posterior distance on the labial side; width was taken as the greatest width across the cusps perpendicular to the antero-posterior axis of the tooth. Other measurements were taken as defined in Cockrum (1955). All were made with either Helios dial-reading calipers calibrated to 0.01 mm or with Nippon Seiki vernier calipers calibrated to 0.05 mm. Very small specimens (e.g. of *Cercartetus*) were measured with the aid of a binocular microscope at 10 x magnification.

(d) *Statistics:* As the material is fragmentary, it is possible that an individual animal is represented in the sample by more than one fragment, and in calculation of the statistics of the sample of each species, care was taken to include each animal only once. Tooth wear and molar eruption stage were considered as well as configuration (either right side or left side) in estimation of the minimum number of individuals, but location was not considered as the deposit may have been reworked by water movement in the cave.

(e) *Taxonomy and tooth nomenclature.* The classification of the mammals follows Ride (1970) unless stated otherwise. The tooth nomenclature of Tate (1948) is used, the sectorial premolars being designated $P^{3}/_{3}$ and $P^{4}/_{4}$ and the molariform premolars $dP^{4}/_{4}$.

Family **MACROPODIDAE**—Subfam POTOROINAE

Potorous apicalis (Gould, 1851)

The long-nosed potoroos have been recognized as two geographically-isolated species, *P. tridactylus* (Kerr, 1792), from eastern Australia and Tasmania and *P. gilberti* (Gould, 1841) from Western Australia (Troughton 1962), but computer analysis of cranial dimensions and proportions of animals from many populations suggests that the populations fall into two different groups, which probably still represent two distinct species. One group contains the populations from coastal New South Wales and south-western Australia (formerly part of *P. tridactylus* and all of *P. gilberti*, now named *P. tridactylus*) and the other group (formerly part of *P. tridactylus*, now named *P. apicalis*) contains those from Victoria and Tasmania (Hope Ph.D. thesis, 1969)*.

Identification of fragmentary remains of long-nosed potoroos is difficult; the Naracoorte remains are assigned to *P. apicalis* for the following reasons.

(i) The nasals are narrow, the maximum width (one skull only) being 10.0 mm.

(ii) The molar gradient is slight (Table 1, Figure 3).

(iii) The dimensions of the permanent premolars (Table 1) fall within the range of *P. apicalis* (Hope 1969).

(iv) The cutting edge of $P^{4}/_{4}$ is almost straight and in line with the molars (Fig. 3), whereas in *P. tridactylus* the posterior cusp of the tooth is offset labially, giving the tooth a curved cutting edge and concave labial face (Hope Ph.D. thesis).

Remains of *P. apicalis* occurred sporadically through the deposit. They comprised 24 mandibular and 13 maxillary fragments, and one incomplete skull. In 19 of these P3 and dP4 were present, in 13 the permanent premolar, P4, had erupted, and in 6 the stage of tooth eruption could not be determined.

The deciduous sectorial premolar $P^{3}/_{3}$ is shorter than the permanent tooth $P^{4}/_{4}$ but is similar in shape, with a conical anterior cusp projecting beyond the main cutting edge of the

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*Hope, J. H. (1969)—Biogeography of the mammals on the islands of Bass Strait with an account of variation in the genus *Potorous*. Unpublished Ph.D. Thesis, Monash University.

TABLE I
Dimensions (mm) of cheek teeth of Potorous apicalis *from Victoria Cave.*

Tooth	Dimension	Maxillary teeth				Mandibular teeth			
		N	Observed Range	Mean ± s.e.	Coeff. variation	N	Observed Range	Mean ± s.e.	Coeff. variation
P3	Length	3	3.6—4.0	3.73 ± 0.126	5.84	5	3.0—3.8	3.45 ± 0.127	8.27
	Width	3	2.1—2.4	2.21 ± 0.071	5.56	5	1.6—2.1	1.88 ± 0.089	10.62
dP4	Length	4	3.3—3.9	3.55 ± 0.161	7.88	6	3.0—3.6	3.33 ± 0.077	5.72
	Width	4	2.4—2.5	2.47 ± 0.030	2.46	6	2.0—2.2	2.13 ± 0.045	5.24
P4	Length	4	6.9—7.9	7.26 ± 0.238	6.55	6	5.4—7.0	5.92 ± 0.225	9.31
	Width	4	2.4—2.6	2.53 ± 0.059	4.68	6	2.1—2.4	2.17 ± 0.051	5.76
M1	Length	6	3.8—4.4	4.11 ± 0.089	5.30	10	4.0—4.4	4.2 ± 0.044	3.32
	Post. width	6	2.9—3.2	3.11 ± 0.050	3.98	10	2.6—3.1	2.9 ± 0.047	5.18
M2	Length	4	3.8—4.6	4.21 ± 0.164	7.81	8	4.3—4.7	4.45 ± 0.046	2.96
	Ant. width	4	3.6—3.9	3.73 ± 0.094	5.05	7	3.1—3.5	3.29 ± 0.038	3.06
M3	Length	1	3.8	..	..	9	4.2—4.9	4.44 ± 0.087	5.93
	Ant. width	1	3.4	..	..	9	3.1—3.8	3.33 ± 0.066	5.98
M4	Length	1	3.6	..	..	4	3.4—3.9	3.62 ± 0.099	5.48
	Ant. width	1	3.1	..	..	4	2.3—3.1	2.81 ± 0.172	12.21
M1-3	Length	1	11.3	..	..	6	12.3—13.0	12.76 ± 0.13	2.62

tooth. Most commonly the labial and lingual surfaces are marked by three faint grooves. These may rarely be reduced to two in $P\frac{3}{3}$ and are often increased to four in $P\frac{4}{4}$ by the appearance of an additional short groove on the posterior cusp of $P\frac{4}{4}$.

Colonies of *P. apicalis* exist in southern Victoria (Hope Ph.D. thesis; Ride 1970) and remains from McEachern Cave, near the Glenelg River in extreme south-western Victoria are referred to this species (Hope Ph.D. thesis). Bones of *Potorous* were also found at Millicent, South Australia (Finlayson *in* Tindale 1933). In an Aboriginal campsite near Mt. Burr, *P. apicalis* was found at several levels, the deepest carbon-dated as having been laid down about 7,500 years BP and the uppermost as 300 years BP (Campbell, Edwards & Hossfeld 1966*; personal observations). Tidemann (1967) did not record *Potorous* from Recent cave deposits at Naracoorte or Tantanoola. The only record of the species in South Australia in European time is a skull examined by Thomas (1888) from the Murray River.

Potorous platyops (Gould, 1844)

Taxonomy. I have examined the following specimens. Five nearly complete skulls with mandibles, from the National Museum of Victoria (N.M.V.) (C6769, C6770, C6771, C6772, C6773), three mandibular and one maxillary fragment from the Western Australian Museum (W.A.M.) (Nos. 64.10.35, 70.3.21, 70.4.11 and 70.4.66), the cotypes of *P. morgani* (South Australian Museum (S.A.M.) P168 and P3413), one topotype skull and four mandibles of *P. morgani* from Kelly Hill Caves (R. T. Wells, private collection), one skull and six mandibles from other caves on Kangaroo Island (S.A.M. M8402, M8403 and C. Tidemann, private collection), and three maxillary and four mandibular fragments from the Fromm's Landing (Shelter 2) archaeological excavation (specimens in S.A.M., Wakefield 1964b).

The broadfaced potoroo was described from specimens captured in the southwest of Western Australia (Thomas 1888). The last reliable record of live specimens is of five taken in 1875, and now lodged in the National Museum of Victoria (Ride 1970). Finlayson (1938) identified two sub-fossil skulls from Kangaroo Island, South Australia, as a broad-faced potoroo, similar to *P. platyops*, but specifically distinct. He named this new species *P. morgani*. The chief characters of the South Australian specimens, distinguishing them from the Western Australian specimens were stated to be:

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*Campbell, T. D., Edwards, R., and Hossfeld, P. S. (1966)—Archaeological excavations in the south-east of South Australia. 24 pp. Transcript A.I.A.S. Library, Canberra.

TABLE 2

Skull dimensions (mm) of Potorous platyops *from Western Australia (C6773 and C6771), Kangaroo Island (P3413, P168, M8402) and Naracoorte (P16050, P16046).*

Character	C6773 ♂	C6771 ♀	P3413	P168	M8402	P16050	P16046
Height I^1	4.8	3.6	2.8	..	..	3.2	..
Length nasals	22.6	23.1	..	25.6	..	..	..
Width nasals Max.	12.1	12.3	11.4	10.9	10.9	12.1	12.7
Width nasals Min.	4.2	3.8	4.5	4.4	4.5	-	
Least inter-orbital constriction	15.4	14.2	14.9	16.1	ca 16.6	16.7	16.2
Palatine length	22.9	ca 21.9	22.5	ca 22.7	21.7	-	..
Palatilar length	ca 27.9	ca 27.4	ca 27.9	..	26.8	..	
Distance I^3-P^4	9.0	8.6	7.9	..	7.0		
Internal width M^2-M^2 (ant. loph)	10.2	8.9	8.7	9.1	9.3	..	..
Length M^1-M^3	8.6	9.0	9.8	9.9	9.8	10.4	9.9

(i) nasals longer, less expanded posteriorly and with postero-internal and postero-external angles more acute,

(ii) inter-orbital region wider,

(iii) palate longer,

(iv) molar rows longer,

(v) first upper incisor shorter,

(vi) lower incisor more spatulate and lacking the "upward phalangerine curvature" of Western Australian animals (Finlayson 1938).

In Table 2 some of these characteristics are compared among five adult skulls ($\mathrm{P}\frac{4}{4}$–$\mathrm{M}\frac{4}{4}$ erupted). (The animals in the last two columns will be discussed below.) Although M8402 from Kangaroo Island corresponds with the cotypes of *P. morgani* in having longer, posteriorly narrow nasals, it differs from them in the conformation of the posterior margins of the nasals, and closely resembles the two Western Australian adults. There is overlap in inter-orbital width and palatine length. Although $\mathrm{I}\frac{1}{1}$ of P3413 is much shorter, all the teeth of this specimen are severely worn. Little difference could be detected in I_1 of four specimens. The permanent premolar and each of the first three molars is longer and broader on the average in Kangaroo Island animals but there is overlap in all dimensions except length and width of $\mathrm{P}\frac{4}{4}$ (Table 3, Figs. 1 and 2). The greater length of the molar row is partially compensated by shorter diastemata $\mathrm{I}\frac{3}{3}$–C and C–$\mathrm{P}\frac{1}{1}$, so that the palatilar length is similar in the two groups. The cheek teeth are morphologically similar and the description of the dentition of *P morgani* (Finlayson 1938) applies accurately to the Western Australian specimens.

Despite the greater mean size of molar teeth in the Kangaroo Island sample, the similarity in both size and morphology of skulls and morphology of teeth between Kangaroo Island and Western Australian specimens indicates that the two populations are closely related and not distinct species. Ride (1970) considered *Potorous morgani* Finlayson, 1938, a synonym of *P. platyops* (Gould, 1844).

Tate (1948) examined the type specimen of *P. platyops* and found the sectorial premolar to be 4.2 mm long. He thought that this tooth and the sectorial premolar (length approx. 4.5 mm) in the specimens examined by Thomas (1888) were possibly the deciduous premolar, $\mathrm{P}\frac{3}{3}$, but the figures in Table 3 show that they fall outside the range of $\mathrm{P}\frac{3}{3}$ and within, or very near, the range of $\mathrm{P}\frac{4}{4}$. Tate also found the inter-orbital breadth of the type to be 16 mm, which is as wide as in South Australian specimens.

Teeth of specimens from the Fromm's Landing archaeological excavation are comparable in size to those from Kangaroo Island (e.g. $\mathrm{M}\frac{1}{1}$–$\frac{3}{3}$ length 9.2, M_1–$_3$ length 9.8). Similarly Finlayson (1959) found that in five mandibles from the Devon Downs archaeological site, M_1–$_4$ length ranged from 9.7 to 10.3 (mean 10.0). Finlayson's observation that the M_1 is relatively large in mainland specimens is confirmed by a single M_4 from Fromm's Landing, with length 2.7 and width 2.3.

Naracoorte specimens. Two incomplete skulls, three maxillary fragments and 15 mandibular fragments of *Potorous platyops* were found. Of these 7 carried P3 and dP4; in 6, P4 had erupted and in 7 the stage of tooth eruption could not be determined. The shape of the skull (Table 2) and the size of the teeth (Table 4) closely resemble these characters in Kangaroo Island specimens, the cheek teeth being slightly larger than in Western Australian animals.

TABLE 3

Dimensions (mm) of cheek teeth of Potorous platyops *from Western Australia and from Kangaroo Island, South Australia.*

Tooth	Dimension	Western Australia				Kangaroo Island, South Australia			
		N	Observed Range	Mean ± s.e.	C.V.	N	Observed Range	Mean ± s.e.	C.V.
P^3	Length	3	2.7—3.0	2.85 ± .061	3.69	..	..	..	..
	Width	3	1.6—1.8	1.67 ± .043	4.49	..	..	..	..
dP^4	Length	3	2.4—2.7	2.57 ± .088	5.95	..	..	..	..
	Width	3	1.8—2.0	1.91 ± .052	4.71	..	..	..	..
P^4	Length	3	4.3—4.9	4.59 ± .159	6.01	3	5.1—5.3	5.15 ± .058	1.94
	Width	3	1.8—1.9	1.87 ± .035	3.23	3	2.0—2.1	2.02 ± .025	1.76
M^1	Length	5	2.9—3.9	3.37 ± .166	10.98	4	3.2—3.5	3.34 ± .071	4.26
	Anterior width	5	2.7—3.0	2.84 ± .057	4.52	4	3.0—3.2	3.06 ± .040	2.59
	Posterior width	5	2.4—2.9	2.62 ± .087	7.40	4	2.8—3.2	2.92 ± .082	5.61
M^2	Length	4	3.1—3.7	3.40 ± .154	9.09	4	3.4—3.6	3.50 ± .052	3.00
	Anterior width	4	3.0—3.4	3.08 ± .092	6.01	4	3.1—3.5	3.26 ± .091	5.56
	Posterior width	4	2.6—2.8	2.77 ± .049	3.56	4	2.7—3.2	2.92 ± .106	7.29
M^3	Length	3	2.6—3.0	2.77 ± .107	6.69	4	2.8—3.2	3.06 ± .078	5.77
	Anterior width	3	2.6	2.60 ± .009	0.59	4	2.6—3.0	2.80 ± .077	5.52
	Posterior width	3	2.2—2.4	2.29 ± .071	5.39	4	2.1—2.6	2.39 ± .124	10.39
M^4	Length	3	2.0—2.3	2.10 ± .084	6.95	3	1.9—2.2	1.99 ± .095	8.25
	Anterior width	3	2.0—2.1	2.04 ± .038	3.26	3	1.9—2.1	2.01 ± .064	5.47
M^{1-3}	Length	3	8.6—9.9	9.19 ± .398	7.50	4	9.8—9.9	9.84 ± .028	0.58
P_3	Length	3	2.1—2.5	2.27 ± .135	10.32	1	2.65	..	..
	Width	2	1.2—1.3	1.43 ± .125	12.41	1	1.70	..	..
dP_4	Length	2	2.3—2.4	2.30 ± .050	3.07	3	2.6—2.8	2.65 ± .076	4.99
	Width	2	1.6—1.7	1.66 ± .060	5.11	3	1.9—2.2	1.98 ± .083	7.28
P_4	Length	4	3.9—4.3	4.07 ± .095	4.65	3	4.2—4.4	4.27 ± .073	2.95
	Width	4	1.5—1.7	1.58 ± .030	3.76	3	1.7—1.8	1.73 ± .017	1.67
M_1	Length	6	2.7—3.5	3.09 ± .138	10.95	5	2.9—3.3	3.12 ± .066	4.73
	Anterior width	6	1.9—2.3	2.04 ± .051	6.18	5	2.1—2.6	2.30 ± .084	8.21
	Posterior width	6	2.2—2.4	2.28 ± .040	4.32	5	2.3—2.7	2.48 ± .062	5.64
M_2	Length	6	2.9—3.9	3.31 ± .153	11.29	5	3.4—3.6	3.50 ± .037	2.39
	Anterior width	6	2.3—2.8	2.56 ± .074	7.12	5	2.5—3.1	2.83 ± .080	6.36
	Posterior width	6	2.4—2.8	2.55 ± .064	6.18	5	2.6—2.8	2.68 ± .044	3.69
M_3	Length	4	2.7—3.3	2.96 ± .110	7.44	5	3.1—3.3	3.20 ± .044	3.65
	Anterior width	4	2.4—2.5	2.44 ± .015	1.23	5	2.4—2.9	2.68 ± .085	7.06
	Posterior width	4	2.1—2.2	2.13 ± .025	2.34	5	2.2—2.4	2.31 ± .043	4.21
M_4	Length	3	2.2—2.4	2.34 ± .055	4.08	2	1.9—2.5	2.18 ± .280	18.16
	Anterior width	3	1.9—2.1	2.04 ± .078	6.58	2	2.0	1.98 ± .020	1.43
M_{1-3}	Length	4	8.1—9.8	8.93 ± .349	7.83	5	9.2—9.9	9.59 ± .145	2.68

The P^3 is blade-like, composed of two cusps, the conical anterior cusp being larger and longer than the antero-posteriorly flattened posterior cusp, which bears a shallow vertical groove on both inner and outer surfaces. The cusps are connected by a thin ridge (Fig. 4). The tiny anterior tubercle of the anterior cusp, found in a specimen from the Nullabor Caves (Lundelius 1963) could not be detected in either of two Naracoorte specimens, nor in

TABLE 4

Dimensions (mm) of cheek teeth of Potorous platyops, *from Naracoorte.*

		Maxillary Teeth				Mandibular Teeth			
Tooth	Dimension	N	Observed Range	Mean ± s.e.	C.V.	N	Observed Range	Mean ± s.e.	C.V.
P3	Length	2	3.0	2.99 ± .035	1.66	3	2.6—2.7	2.66 ± .050	3.28
	Width	2	1.7—1.8	1.74 ± .065	5.30	3	1.4—1.6	1.50 ± .044	5.08
dP4	Length	2	2.5—2.9	2.72 ± .175	9.12	3	2.2—2.6	2.41 ± .117	8.39
	Width	2	2.0—2.3	2.11 ± .150	10.05	3	1.7—1.9	1.77 ± .052	5.08
P4	Length	2	4.7	4.69 ± .010	0.30	2	4.4—4.5	4.44 ± .015	0.48
	Width	2	1.8—1.9	1.86 ± .060	4.56	2	1.8—2.0	1.89 ± .140	10.48
M1	Length	4	3.4—3.7	3.57 ± .075	4.23	4	3.1—3.4	3.22 ± .052	3.21
	Anterior width	4	2.8—3.3	3.11 ± .097	6.25	4	2.2—2.5	2.34 ± .068	5.78
	Posterior width	4	2.5—2.8	2.72 ± .066	4.85	4	2.4—2.8	2.60 ± .067	5.19
M2	Length	4	3.3—3.9	3.56 ± .124	6.96	4	3.5—3.8	3.61 ± .073	4.03
	Anterior width	4	3.1—3.3	3.23 ± .056	3.48	4	2.7—3.0	2.87 ± .071	4.98
	Posterior width	4	2.6—2.9	2.81 ± .073	5.19	4	2.7—2.9	2.78 ± .041	2.97
M3	Length	3	2.9—3.2	3.05 ± .087	4.92	3	3.0—3.3	3.13 ± .063	3.51
	Anterior width	3	2.8	2.79 ± .020	1.26	3	2.7—2.8	2.79 ± .042	2.59
	Posterior width	3	2.0—2.4	2.23 ± .127	9.90	3	2.4—2.5	2.46 ± .030	2.11
M4	Length	1	1.9	..	..	1	2.5	..	..
	Anterior width	1	2.0	..	..	1	2.1	..	..
M1-3	Length	3	10.0—10.7	10.35 ± .207	3.47	3	9.4—9.9	9.7 ± .125	2.25

N.M.V. C6769 and C6770. The dP$^{4}/$ is subquadrangular, the antero-external cusp being produced into a flattened blade, in line with the blade of P$^{3}/$.

The P$^{4}/$ in P16066 has a dominant subconical anterior lobe as described by Finlayson (1938) and Thomas (1888), but the posterior lobe bears two shallow grooves, so that, with the groove extending upwards from the posterior edge of the anterior cusp, the tooth is 3-grooved.

The P$/_{3}$ may be similar to, but smaller than, P$^{3}/$, but in P16075 the groove on the posterior cusp is not detectable so that the tooth bears only a single groove, i.e. the groove between anterior and posterior cusps. Specimen 70.3.21 from Western Australia is similarly single-grooved. The antero-external cusp of dP$/_{4}$ is so reduced that it is virtually absent, and the tooth is triangular in occlusal view, with the antero-internal cusp flattened antero-posteriorly into a blade, in line with the blade of P$/_{3}$. The P$/_{1}$ is similar to P$^{4}/$.

Distribution. Subfossil remains of *P. platyops* have been found in coastal Western Australia near Dongara, about 430 km north of Perth, at Bremer Bay and in the southern Nullabor region (Butler and Merrilees 1971). In South Australia the species is recorded not only from Kangaroo Island, but also from Aboriginal campsites by the River Murray at Devon Downs and Fromm's Landing (Finlayson 1938, 1959; Wakefield 1964b). These Murray River specimens were at levels carbon-dated as between 1800 and 1900 years BP.

Only at Naracoorte does the range of *P. platyops* overlap the range of *P. apicalis*. In the region of Western Australia known to early collectors as King George's Sound, the ranges of *P. platyops* and *P. tridactylus* may overlap (Glauert 1950).

Bettongia gaimardi (Desmarest, 1822)

No specimens of *B. gaimardi* were found in the main bone deposit but at the edge of a nearby rockpile formed by roof collapse, four fragments of *B. gaimardi* were found close to the remains of a *Protemnodon* cf. *brehus*. They comprise two upper molar rows and two mandibles, and almost certainly were derived from only one animal. Dimensions of teeth are given in Table 5. The P^{4} is 8-grooved, P_{4} 7-grooved.

TABLE 5

Dimensions (mm) of the cheek teeth of Bettongia gaimardi *from Victoria Cave.*

Tooth	Dimension	P16097a (Upper right)	P16097b (Upper left)	P16097c (Lower right)	P16097d (Lower left)
P4	Length	7.7	7.6	7.0	7.0
	Ant. width	2.6	2.6	2.5	2.6
	Height	3.7	3.8	3.1	3.1
M1	Length	4.5	4.3	4.1	4.1
	Ant. width	4.2	4.1	3.1	3.2
	Post. width	4.0	3.9	3.6	3.6
M2	Length	4.6	4.7	4.8	4.7
	Ant. width	4.3	4.4	3.7	4.0
	Post. width	4.1	4.2	4.1	4.1
M3	Length	4.2	4.1	4.4	—
	Ant. width	4.2	4.1	4.0	—
	Post. width	3.5	3.5	3.4	—
M4	Length	3.5	—	4.2	3.9
	Ant. width	3.4	—	3.5	3.5
	Post. width	2.6	—	3.1	3.1
M1-3	Length	12.9	12.9	13.0	—

These fragments are identified as *B. gaimardi* rather than *B. leseur* because

(i) the upper molar rows are almost straight (Fig. 5) whereas in *B. leseur* they are decidedly arched,

(ii) the molar size gradient is slight, whereas in *B. leseur* M_{4} is very small relative to M_{1} and M_{2},

(iii) the lower mandible is less robust than in *B. leseur.*

The mainland population of *B. gaimardi*, presumably now extinct, occurred as a modern animal about the Eastern Highlands and adjacent coastal tracts of south-eastern Australia from south-eastern Queensland to south-western Victoria (Wakefield 1967). The Tasmanian subspecies, *B.g. cuniculus*, is extant. Finlayson (1959) found sub-fossil *B. gaimardi* at Tantanoola in far south-eastern South Australia and in an Aboriginal midden at Mt. Burr (Finlayson *in* Campbell, Edwards & Hossfeld 1966, Transcript A.I.A.S. Library, Canberra). Its presence at Naracoorte extends the western extremity of its known range about 100 km northwards.

Bettongia penicillata Gray, 1837

Two incomplete skulls, two maxillary fragments and ten mandibular fragments of *B. penicillata* were identified. The permanent premolar had erupted in only 2 specimens and the remaining eleven retained P3 and dP4. In at least 6 of the latter the posterior molar teeth were still erupting through the bone.

The P^{4} is 7-grooved in one specimen, P_{4} (one specimen) is 6-grooved and the P^{3} and P_{3} are consistently 5-grooved (2 and 8 specimens respectively). The size, shape and outward flexing of P^{4}_{4} or P^{3}_{3} (Figs. 6 and 7) are consistent with modern *B. penicillata* but the auditory bullae, present in one sub-adult skull only, are smaller than commonly observed in this species (length 12.25, breadth 7.75, compared with length 12.8–14.2 (mean 13.8) breadth 8.2–9.1 (mean 8.5) in 5 sub-adult skulls (Finlayson 1958). Dimensions of the molariform and molar teeth (Tables 6a and 6b) broadly overlap or slightly exceed those of the modern and Pleistocene samples measured by Finlayson (1958) and Tedford (1967) but in Pleistocene specimens from both Naracoorte and Lake Menindee the length of P^{4}_{4} and the height of P^{3} and P^{4} are much less than in modern specimens. Skull and tooth sizes vary widely within modern populations of *B. penicillata* (Finlayson 1958).

At the time of European settlement of Australia, *B. penicillata* ranged from south-western to central and eastern Australia but was absent from Victoria (Wakefield 1967). Wakefield (1964a) did not find this species in cave deposits in south-western Victoria, but its remains were found in an Aboriginal midden at Mt. Burr (Finlayson *in* Campbell et al. 1966, transcript A.I.A.S. Library, Canberra). *B. gaimardi* and *B. leseur* also occurred in the midden.

Bettongia leseur (Quoy and Gaimard, 1824) has not been found in the deposit, although it is common in recent cave deposits in the same area (Tidemann 1967) and in south-western Victoria (Wakefield 1964a).

Family PETAURIDAE

Pseudocheirus peregrinus (Boddaert, 1785)

The selenodont section of the Petauridae was represented by three maxillary and six mandibular fragments which were considered to be similar to the modern species of ringtail possum (*Pseudocheirus peregrinus*) and different from *Schoinobates volans* for the following reasons.

(i) P^{4} consists of 3 cusps, almost in line, but with the middle cusp offset labially. The pointed anterior cusp is separated from the middle cusp by a deep cleft, but a ridge joins the middle and pos-

TABLE 6a

Dimensions (mm) of upper cheek teeth of Bettongia penicillata *from Naracoorte and from two other populations.*

Source		Naracoorte, ? Pleistocene				Lake Menindee, Pleistocene*			S. Aust. and W. Aust., modern†		
Tooth	Dimension	P16092	P16082	P16095	P16091	N	O.R.	Mean	N	O.R.	Mean
P^3	Length	4.5	..	4.4	..	2	4.1—4.9	4.50	?	4.0—4.6	4.4
	Crown height	2.7	..	3.4	..	2	3.0—3.1	3.05	?	3.5—4.3	4.0
dP^4	Length	3.4	..	3.7	..	2	2.9—3.1	3.00	7	3.0—3.6	3.3
	Width	2.7	..	2.9	..	3	2.5—3.1	2.80	7	3.0—3.3	3.1
P^4	Length	..	6.1	..	6.7	3	5.6—6.6	6.17	?	7.0—7.4	7.1
	Crown height	..	3.7	..	3.7	3	3.6—4.1	3.80	?	4.3—4.6	4.4
M^1	Length	4.2	4.3	4.6	..	6	3.4—4.2	3.80	11	3.7—4.2	4.0
	Post. width	3.6	4.1	4.0	..	6	3.7—4.3	3.92	11	3.7—4.3	4.0
M^2	Length	4.6	4.4	..	..	6	3.6—4.2	3.83	11	3.6—4.5	4.0
	Ant. width	4.0	4.3	..	..	6	3.5—4.1	3.90	11	3.8—4.4	4.0
M^3	Length	4.5	4.0	..	..	3	3.3—3.6	3.50	11	3.5—4.0	3.7
	Ant. width	3.7	3.6	..	..	2	3.3—3.4	3.35	11	3.2—3.8	3.6
M^4	Length	..	2.9	..	..	1	2.0	..	11	2.2—3.0	2.5
	Ant. width	..	2.7	..	..	..	..	..	11	2.0—2.9	2.5
M^{1-3}	Length	..	11.9	..	..	3	11.2—11.9	11.47	11	11.0—12.7	11.8

* From Tedford (1967) † From Finlayson (1958)

TABLE 6b

Dimensions (mm) of some lower cheek teeth of Bettongia penicillata *from Naracoorte and from two other populations.*

Source		Naracoorte, ? Pleistocene			Lake Menindee, Pleistocene*			S. Aust. and W. Aust. modern†		
Tooth	Dimension	N	O.R.	Mean ± s.e.	N	O.R.	Mean	N	O.R.	Mean
P_3	Length	5	3.8—4.3	4.02 ± 0.085	3	3.4—4.4	4.00	?	3.7—4.1	4.0
	Crown height	5	3.3—3.6	3.48 ± 0.068	3	3.3—3.4	3.37	?	3.5—4.4	3.9
dP_4	Length	5	3.1—3.3	3.25 ± 0.042	3	2.7—3.0	2.83	7	2.8—3.5	3.0
	Width	5	2.4—2.9	2.62 ± 0.082	2	2.3—2.6	2.45	7	2.4—2.7	2.5
P_4	Length	1	5.8	..	3	5.8—6.1	5.93	11	6.2—6.7	6.4
	Ant. height	1	3.9	..	3	3.7—4.2	4.00	11	4.1—4.3	4.2
	Width	1	2.5	..	3	2.2—2.8	2.50	11	2.7—3.0	2.9
M_1	Length	6	3.8—4.3	4.17 ± 0.089	3	3.4—3.7	3.57	11	3.5—4.0	3.7
	Post. width	6	3.4—3.8	3.61 ± 0.059	3	3.2—3.7	3.53	11	3.5—4.1	3.6
M_2	Length	4	4.0—5.0	4.51 ± 0.196	2	4.0—4.2	4.10	11	3.8—4.2	4.0
	Ant. width	4	3.6—4.0	3.83 ± 0.080	2	3.7—3.9	3.80	11	3.7—4.1	3.9
M_3	Length	2	3.8—4.0	3.85 ± 0.100	1	3.2	..	11	3.5—3.9	3.7
	Ant. width	2	3.5—3.7	3.55 ± 0.100	1	3.4	..	11	3.5—4.0	3.7
M_4	Length	1	2.8	..	1	2.5	..	11	2.7—3.5	3.0
	Ant. width	1	2.8	..	1	2.4	..	11	2.7—3.2	3.0
M_{1-3}	Length	2	11.2—12.1	11.64 ± 0.485	1	10.9	..	11	11.1—12.5	11.5

* From Tedford (1967) † From Finlayson (1958)

terior cusps. In *Schoinobates* the anterior and middle cusps are also joined by a ridge.

(ii) There is no lingual ridge on the middle cusp of P^3_3 whereas in *Schoinobates* a lingual ridge curves postero-lingually from near the apex of the central cusp and fades out near the postero-lingual corner of the tooth.

(iii) There is only one posterior valley on P^4_4, whereas in *Schoinobates* there is a second cingular basin postero-lingual to the ridge of the central cusp.

(iv) The labial cusps (paracone and metacone) of the upper molars are simple, not ridged, whereas a strong postero-internal ridge runs from the apex of paracone and of metacone of the upper molars of *Schoinobates*.

(v) There is no ridge in the valley between the entoconid and the hypoconid of M^1_1 and M^2_2. This ridge is present in M^1_1 and M^2_2 of *Schoinobates*, and in M^1_{1-4} of *Pseudocheirus archeri*, but is absent in *Pseudocheirus peregrinus*.

However, the teeth are larger than the mean of a sample of 10 modern specimens of *P. peregrinus laniginosus* from southern Australia (Tables 7a and 7b) and are consistent with those of *P. antiquus* Broom, 1896 where M^{1-3}_{1-3} measured 12.7, 12.9 and 13 mm respectively in three specimens. The alveolus of P^1_1 is so

TABLE 7a

Comparison of dimensions (mm) of maxillary teeth of Pseudocheirus peregrinus *from Victoria Cave with those of a modern sample.*

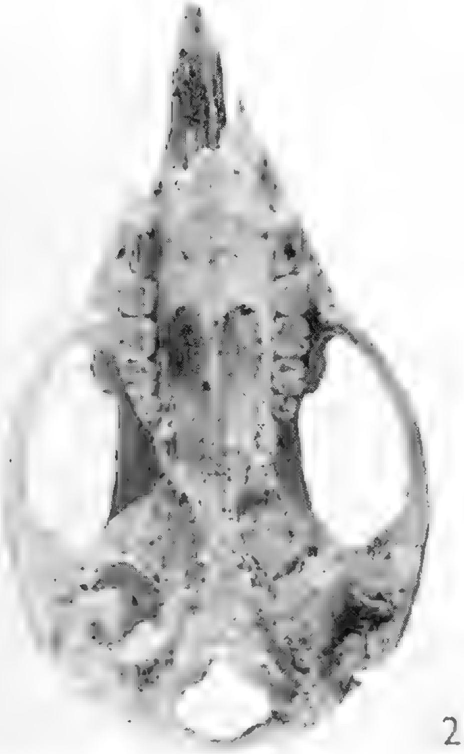
Tooth	Dimension	*Pseudocheirus peregrinus* Victoria Cave			*Pseudocheirus peregrinus* South-east Australia, modern, N = 10	
		P16099c	P16099e	P16099f	Range	Mean ± s.e.
P^3	Length	2.5	. .	2.6	2.1—2.7	2.41 ± 0.053
	Width	2.2	. .	2.2	1.5—2.0	1.80 ± 0.043
P^4	Length	3.5	3.1	3.5	3.0—3.4	3.24 ± 0.057
	Width	2.5	2.4	2.7	2.2—2.5	2.30 ± 0.034
M^1	Length	4.7	4.8	4.6	4.1—4.5	4.32 ± 0.048
	Width	3.9	3.8	4.0	3.3—3.9	3.58 ± 0.035
M^2	Length	4.3	4.4	4.5	3.9—4.2	4.08 ± 0.031
	Width	4.0	3.7	3.9	3.2—3.8	3.49 ± 0.065
M^3	Length	. .	4.3	. .	3.9—4.2	4.03 ± 0.046
	Width	. .	3.5	. .	3.2—3.7	3.37 ± 0.058
M^{1-3}	Length	. .	12.8	. .	11.8—12.5	12.09 ± 0.080

TABLE 7b

Comparison of dimensions (mm) of mandibular teeth of Pseudocheirus peregrinus *from Victoria Cave, with those of a modern sample.*

Tooth	Dimension	*Pseudocheirus peregrinus* Victoria Cave				*Pseudocheirus peregrinus* South-east Australia, modern, N = 10	
		P16099a	P16099b	P16099d	P16105h	Range	Mean ± s.e.
P_4	Length	. .	. .	3.9	. .	3.0—3.6	3.41 ± 0.064
	Width	. .	. .	1.8	. .	1.6—1.8	1.72 ± 0.027
M_1	Length	. .	. .	4.7	4.3	4.0—4.5	4.27 ± 0.052
	Width	. .	. .	2.5	2.4	2.0—2.5	2.27 ± 0.045
M_2	Length	4.2	4.4	. .	4.2	4.0—4.3	4.10 ± 0.036
	Width	2.5	2.4	. .	2.5	2.3—2.6	2.40 ± 0.034
M_3	Length	4.0	4.3	. .	. .	3.8—4.1	3.93 ± 0.038
	Width	2.5	2.4	. .	. .	2.2—2.5	2.39 ± 0.034
M_4	Length	4.0	. .	. .	. .	3.8—4.5	4.18 ± 0.075 (N = 8)
	Width	2.2	. .	. .	. .	2.1—2.5	2.30 ± 0.040 (N = 8)

1



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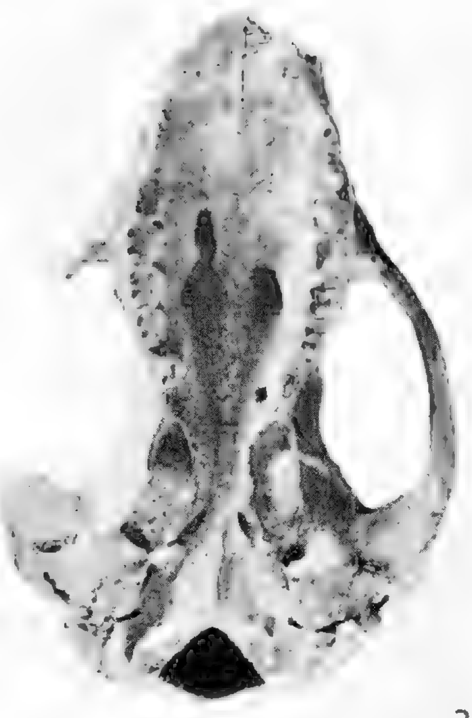

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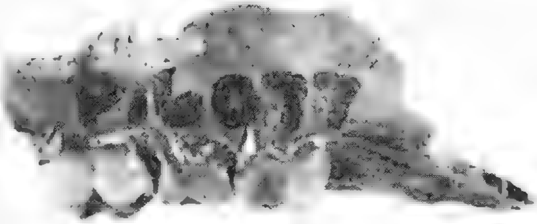

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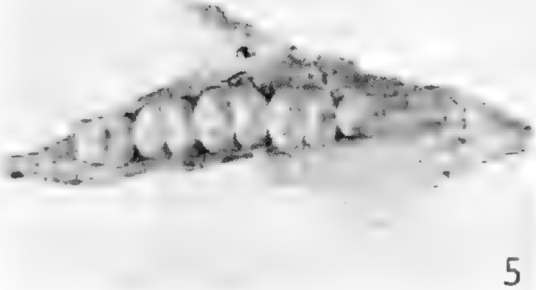
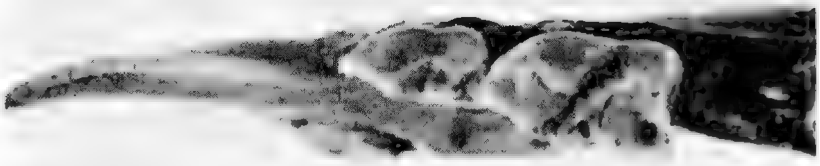


5

Fig. 1. Ventral view of skull of adult *Potorous platyops* from Western Australia, N.M.V. C6773, X 1.5.
Fig. 2. Ventral view of skull of cotype of *P. morgani* (adult), S.A.M. P168, X 1.5.
Fig. 3. Ventral view of skull of adult *P. apicalis*, P16051, X 1.4.
Fig. 4. Labial view P^3 dP^4 M^1 of sub-adult *P. platyops*, P16077, X 3.4.
Fig. 5. Occlusal view P^4-M^1 of adult *Bettongia gaimardi*, P16097a, X 1.9.

6



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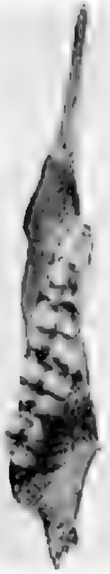

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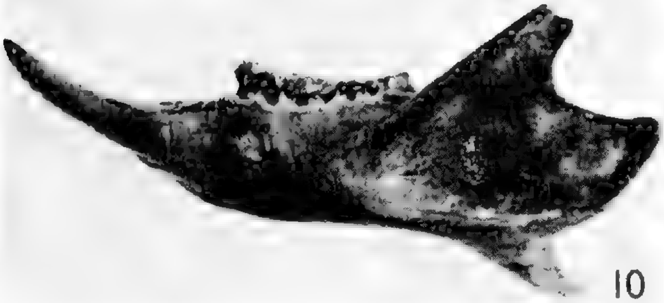

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11

Fig. 6. Labial view of right mandible of sub-adult *B. penicillata*, P16093, X 1.6.
Fig. 7. Occlusal view of the same. X 1.6.
Fig. 8. Occlusal view of right mandible of *Pseudocheirus peregrinus*, showing P_4 and M_1, P16099d. X 5.2.
Fig. 9. Lingual view of the same. X 4.5.
Fig. 10. Labial view of left mandible of *Petaurus breviceps*, P16100b, X 2.6.
Fig. 11. Labial view of right mandible of *Cercartetus nanus*, P16101x, X 4.3.

close to that of P^3 as to be almost confluent with it, as in Broom's specimens. It is probable that further study of Broom Cave specimens will show that *P. antiquus* is conspecific with *P. peregrinus*, and until such a study is made, the Naracoorte specimens will be referred to as *P. peregrinus*.

The P$^4_1$ (one specimen only) (Figs. 8 and 9) differs from that of *P. peregrinus*. In the Naracoorte specimen the anterior cusp is marked by three sharp ridges from the apex, one anterior, the others postero-internal and postero-external respectively. The latter is continuous with an antero-posterior ridge of the posterior cusp. A strong posterior ridge from the median cusp deflects labially near the posterior end of the cusp and meets the medial surface of the posterior cusp. A ridge from the posterior cusp forms the posterior edge of the tooth and ends at the postero-lingual corner. In modern *P. peregrinus* the anterior cusp is smoothly conical, marked only by a blunt anterior ridge. The median and posterior cusps are closely adjacent and indistinctly ridged. The anterior cuspule is scarcely distinguishable in the Naracoorte specimen; this cuspule is variably developed in *P. peregrinus* and consistently well-developed in *Schoinobates volans*.

Petaurus breviceps Waterhouse, 1839

Seven mandibles (Fig. 10) and one maxillary fragment of the Sugar Glider, *Petaurus breviceps*, were found. They were distinguished from *P. norfolcensis* by the size of the molar teeth, which are relatively large in *P. norfolcencis* (Calaby, 1966) and from *Gymnobelideus leadbeateri* by the lower incisors, which are small, delicate and almost procumbent in *G. leadbeateri*. In modern *P. breviceps* and in the Naracoorte specimens the lower incisors are robust and markedly upturned near the tip. Dimensions of the cheek teeth of *P. breviceps* from Victoria Cave are given in Table 8.

The Sugar Glider is not uncommon in the Naracoorte area at present.

TABLE 8
Dimensions (mm) of the cheek teeth of Petaurus breviceps *from Victoria Cave.*

Tooth	Dimension	Upper P16100c (right)	P16100a (right)	Lower P16100b (left)	P16100d (right)
P4	Length	1.45	..	...	..
	Max. breadth	1.00	..	..	.
M1	Length	2.50	2.20	2.35	2.45
	Max. breadth	2.10	1.45	1.50	1.45
M2	Length	..	2.00	2.25	2.15
	Max. breadth	..	1.65	1.60	1.55
M3	Length	..	1.75	1.85	1.75
	Max. breadth	.	1.30	1.40	1.35
M4	Length	..	1.50	1.60	
	Max. breadth	..	1.10	1.10	...
M1-3	Length	..	5.95	6.35	6.25

Family BURRAMYIDAE

Cercartetus nanus (Desmarest, 1818)

A total of 41 mandibular and 2 maxillary fragments of *C. nanus* were found. The diagnostic P$_1$ and the presence of only three molar teeth showed the tooth-bearing mandibles to be referrable to this species (Wakefield 1963) (Fig. 11), and examination of the alveoli of edentulous mandibles indicated that they too were of *C. nanus*. Both maxillary fragments bore the distinctly bicuspid P^4 characteristic of *C. nanus*; the P^4 of *C. concinnus* is only very slightly bilobed (Wakefield 1963).

The pigmy possum most commonly found as a modern species in South Australia is *C. concinnus*, although *C. nanus* occurs in south-ern Victoria and its range extends into the extreme lower south-east of South Australia (Wakefield 1963). The S.A.M. collection includes a single South Australian specimen of *C. nanus* (M7373) and that was collected in the Naracoorte Caves area in 1965. The length of the lower molar row of that specimen is less than that of the Naracoorte fossil specimens (Table 9), but the range of the latter overlaps that of three Tasmanian specimens (*C. nanus*) in the South Australian Museum.

Tidemann (1967) identified both *C. nanus* and *C. concinnus* from a surface deposit in the Bat Cave at Naracoorte. I have examined five mandibles assigned by him to *C. concinnus* and

TABLE 9
Length (mm) of lower molar row in Cercartetus nanus *from several populations.*

Specimens	N	Length M_1 M_3 Observed range	Mean ± s.e
Victoria Cave, Naracoorte	7	4.1—4.3	4.2 ± 0.045
Bat Cave, Naracoorte (Tidemann)	2	3.9—4.0	3.95 ± 0.05
Naracoorte, modern (M7373)	1	3.7	
Tasmania, modern (M7924, 7925, 8261)	3	3.8—4.1	4.03 ± 0.088

of these, three have the large $P/_1$ characteristic of *nanus* and in the other two the alveoli suggest that $P/_1$ was similarly large. In one of these specimens, $M/_1$–$/_4$ = 3.9 mm and in a specimen correctly referred by Tidemann to *C. nanus* $M/_1$–$/_4$ = 4.0 mm. These specimens are therefore intermediate in size between the modern specimen and the fossils.

Discussion

(a) *Method of accumulation of deposit.* The smaller species considered here are represented by adults and sub-adults in similar proportions, whereas the sample of the largest species, *Bettongia penicillata*, is biased in favour of sub-adults. This may indicate that these animals were victims of a predator able to take prey no larger than an adult *Potorous apicalis* or a sub-adult *B. penicillata.* The identity of the possible predator cannot be considered until the carnivores in the deposit have been investigated. Large owl species must not be overlooked.

Alternatively the cave may have been a simple pitfall trap, or animals that died elsewhere may have been washed in.

(b) *Climatic interpretations.* Virtually nothing is known of the environmental requirements of the extinct *Potorous platyops*; *P. apicalis* is today found in south-eastern Australia, including Tasmania, where the January average maximum temperature does not exceed 28°C and the average annual rainfall is greater than 760 mm (Hope Ph.D. thesis). *Bettongia penicillata* has been found in a wide range of environments, from high rainfall forests to spinifex plains (Finlayson 1958) whereas the warren-dwelling *B. leseur* inhabits comparatively arid areas, or, in wetter regions, chooses small areas which provide the terrain necessary for warren-digging. The two species co-exist in woodlands and plains but *B. leseur* is absent from sclerophyll forest (Tedford 1967).

This limited evidence suggests that the cave deposit may have been laid down in an area of sclerophyll forest, rather than the woodland of modern times. The total environment will be considered in detail when the stratigraphy of the deposit and the animal remains have been more fully investigated.

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STRATIGRAPHIC NOTES ON LOWER CAMBRIAN FOSSILIFEROUS METASEDIMENTS BETWEEN CAMPBELL CREEK AND TUNKALILLA BEACH IN THE TYPE SECTION OF THE KANMANTOO GROUP, FLEURIEU PENINSULA, SOUTH AUSTRALIA

BY B. DAILY AND A. R. MILNES

Summary

Hyolithids and other Lower Cambrian fossils occur within marbles in low-stage metamorphic rocks (Forktree Limestone and Heatherdale Shale) forming the core of a north-east plunging regional anticline, overturned to the south-east. A great thickness of partially bioturbated Kanmantoo Group metasediments, dominantly clastics, but including sulphide-rich calc-phyllites of the Talisker Calc-siltstone, conformably overlie the Heatherdale Shale.

The rapidly deposited clastics, including numerous thin conglomerates, are interpreted as products of the Kangarooian Movements known to have affected the region now occupied by Investigator Strait and Gulf St. Vincent.

The newly proposed stratigraphic subdivision for that part of the Group discussed should lead to a more reliable picture of the occurrence and the relationships of these rocks to other sequences within the Mt. Lofty Ranges and Kangaroo Island.

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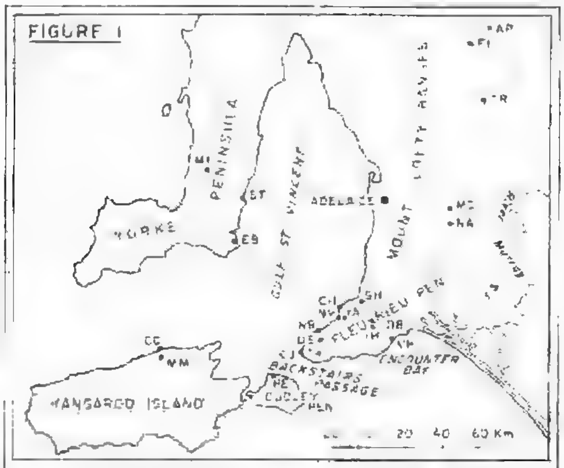
Introduction

The Fleurieu Peninsula south of Adelaide, South Australia, holds the key to the age relationships of the metasedimentary rocks constituting the Kanmantoo Group. This vast sequence crops out in an arcuate belt extending from Australia Plains, north-east of Eudunda in the eastern Mt. Lofty Ranges, through Fleurieu Peninsula and across large sections of Kangaroo Island (Fig. 1). Sprigg and Campana (1953, p. 14) defined its type locality as "the section observable along the south coast of Fleurieu Peninsula, between Campbell Creek and Rosetta Head, Victor Harbour, where the formations are well exposed and very characteristic".

The present paper gives the results of our investigations of the geology of the lower part of the Kanmantoo Group, beautifully exposed along the rugged southern coastline of Fleurieu Peninsula between Campbell Creek and the western extremity of Tunkalilla Beach[1]. It is anticipated that subsequent papers will:

(a) complete the stratigraphic scheme for the Kanmantoo Group within its type area;

FIGURE 1



GEOGRAPHICAL LOCALITY MAP

LEGEND

AP	AUSTRALIA PLAINS	MM	MOUNT McCONNELL
CC	CAPE CASSINI	NA	NAIRNE
CJ	CAPE JERVIS	NV	NORMANVILLE
CH	CARRICKALINGA HEAD	PE	PENNESHAW
DE	DELAMERE	RB	RAPID BAY
DB	DEVIL'S BACKBONE	SH	SELLICK HILL
EB	EDITHBURGH	ST	STANSBURY
EL	EUDUNDA	-	TALISKER MINE
IH	INMAN HILL	TR	TRURO
MI	MINLATON	VH	VICTOR HARBOUR
MC	MOUNT CHARLES	YA	YANKALILLA

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[1] Where possible, our traverse was along the base of the cliffs. Certain stretches, never more than 200 metres in length, were impossible to negotiate and in these cases we were forced to collect data along the top of the cliff.

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(b) test the newly devised scheme by applying the results to the geology of the Dudley Peninsula, Kangaroo Island;

(c) present the results of a remapping programme for part of Fleurieu Peninsula;

(d) comment on the progressive metamorphism of certain key stratigraphic horizons from the chlorite, through the biotite and into the andalusite grades of metamorphism; and

(e) discuss preliminary rubidium-strontium geochronological data for the Kanmantoo Group

PROBLEMS OF THE AGE AND RELATIONSHIPS OF THE KANMANTOO GROUP

Opinions regarding the age of the Kanmantoo Group metasedimentary rocks have varied. Rocks now known to belong to the group were originally described by Woolnough (1908) as part of the Barossa series of Precambrian age. The first hint of their true age was given by Madigan (1925) who, from an examination of the coastline between Sellick Hill and Victor Harbour, argued with some reservations that *all* the pre-Permian rocks of Fleurieu Peninsula south of Yankalilla valley were likely to be Cambrian in age.

The earliest mention of the Kanmantoo Group (*actually Kanmantoo Series*) was by Sprigg, Whittle and Campana (1951) in the legend of the Adelaide 1:63,360 sheet. This showed the "series" occurring east of the Nairne Fault, which separated it from rocks belonging to the Proterozoic Era (Adelaide System), Torrensian, Sturtian and Marinoan Series [or using the style of nomenclature of Daily (1963), the Late Precambrian (Adelaide Supergroup), Torrens, Sturt and Marino Groups respectively]. Its age was shown as "? Early Palaeozoic Era"

In addition to defining its type area, Sprigg and Campana (1953, p. 13) pointed out that the Kanmantoo Group follows above "a limited band of '(?) algal structured' marble" and the "(?) coprolitic phyllite slates four miles south-east of Cape Jervis". Our mapping substantiates these observations, and shows that the Kanmantoo Group conformably overlies metamorphosed beds which we correlate with the Forktree Limestone and Heatherdale Shale of Abele & McGowran (1959), the type area for which is in the northern part of Fleurieu Peninsula. The age of the lower part of the group is therefore considered to be Lower Cambrian. Sprigg and Campana (1953) suggested that the group may extend into the Ordovician.

From their mapping of the Echunga 1:63,360 sheet, Sprigg and Wilson (1954) showed that the Kanmantoo Group followed above the Macclesfield Marble which, because of its position in the sequence, was equated by Sprigg (*in* Sprigg & Campana 1953) with the Archaeocyatha-rich limestones on the western side of the Mt. Lofty Ranges. In addition, the Echunga sheet showed the main distribution of the Kanmantoo Group to be to the east of the Nairne Fault, in contact with rocks to the west ranging from the Marinoan Series up to and including the lower parts of the Kanmantoo Group. On the Gawler 1:63,360 sheet, Campana (1953) did not use the term Nairne Fault. Nevertheless, the Kanmantoo Group is shown in fault contact with the Torrensian Series west of the northern continuation of the Nairne Fault, the same relationships as drawn on the Adelaide 1:63,360 sheet.

The mapping of the Yankalilla and Jervis 1:63,360 sheets (Campana & Wilson 1954a, 1954b; Campana, Wilson & Whittle 1955) showed that contrary to Madigan's earlier interpretations, parts of Fleurieu Peninsula contained areas of metasedimentary rocks and intrusives referred to the Archaean Era, the Adelaide System, and Cambrian as high as the phosphate-rich Heatherdale Shale. All these formations were older than the Kanmantoo Group as defined by Sprigg & Campana. Subsequent re-mapping by Thomson and Horwitz (1962) largely substantiated these conclusions. However, Daily (1963) showed that the regional structure between Rapid Bay and Delamere as portrayed on the Jervis 1:63,360 and Barker 1:250,000 sheets was incorrect, and that large areas mapped as Kanmantoo Group belonged to the Sturt and Marino Groups. Further, the discovery of Lower Cambrian fossils above the Marino Group in both the Mount Terrible Formation and Sellick Hill Limestone (metamorphosed phase) confirmed the Lower Cambrian age of the Delamere marbles, and proved conclusively that the Kanmantoo Group in the Delamere region *conformably* overlies the Heatherdale Shale (phyllite phase), and that its basal formation is the Carrickalinga Head Formation (metamorphosed phase) and likewise Lower Cambrian in age.

Earlier, several publications had already dismissed the concept of the Nairne Fault. Campana & Horwitz (1956) were the earliest to do this when they postulated that the Kanmantoo Group was transgressive across rocks varying in age from Archaean to the Lower Cambrian Heatherdale Shale (phyllite phase). Daily (1956) accepted this unconformity hypothesis (but see below). However, Horwitz, Thomson & Webb (1959), Horwitz (1960), Horwitz & Thomson (1960) and Thomson & Horwitz (1961) argued that not only was the Kanmantoo Group transgressive, but that the earliest Cambrian represented by the basal arkose of the Mount Terrible Formation was also transgressive across folded Adelaide System rocks in the Sellick Hill area. We are in agreement with the transgressive nature of the Mount Terrible Formation (Daily 1963), but we dispute the transgressive character of the Kanmantoo Group as well as many of the stratigraphic correlations made by Horwitz, Thomson & Webb (1959) involving metamorphic and unfossiliferous rocks on the eastern side of the Mt. Lofty Ranges, which they referred to under the term "basal Cambrian". (Under present stratigraphic nomenclature, this would embrace rocks of Lower Cambrian age from the base of the Mount Terrible Formation to the top of the Heatherdale Shale.) For example, there is already evidence in hand indicating that many occurrences of their "basal Cambrian" involve rocks of Late Precambrian age. Moreover, we note that Thomson *in* Parkin (1969, p. 103) now doubts the validity of the "basal Cambrian" age of the Macclesfield and Mount Barker Quartzites and believes that they "are also probably members of the Strangway Hill Formation". In addition, we note that the phosphatic slate regarded by Horwitz, Thomson & Webb (1959) as the equivalent of the Heatherdale Shale, is shown in their stratigraphic succession above the Macclesfield and Mount Barker Quartzites.

We are of the opinion that the main bulk of the Kanmantoo Group in the eastern Mt. Lofty Ranges is in fault contact with rocks ranging from the Barossa Complex to the Heatherdale Shale, and we do not believe that the group is transgressive as postulated by Campana & Horwitz (1956) and Horwitz, Thomson & Webb (1959). We think that when key areas which we are now re-investigating have been re-mapped, faulting will be shown to have played a prominent role in the distribution of Kanmantoo Group rocks not only in the Mt. Lofty Ranges and Fleurieu Peninsula, but also for Kangaroo Island. In support of this we cite three examples:

1. Thomson *in* Parkin (1969, p. 102) regards the Kanmantoo Group as resting unconformably on Barossa Complex rocks south-east of Yankalilla Hill. However, this contact is quite clearly a fault contact[2].
2. The Kanmantoo Group as mapped by Coats & Thomson (1959) on the Truro 1:63,360 sheet almost certainly occupies a graben structure. As mapped, its contact with the Lower Cambrian metamorphic rocks about 2 km south of Truro is best regarded as a fault contact.
3. Along the Devil's Backbone, almost 2 km north-west of Inman Hill, Horwitz & Thomson (Milang 1:63,360 sheet, 1960) show Cambrian rocks resting unconformably on Sturtian rocks[3], the latter being regarded by Forbes (1957) as basal Strangway Hill Beds. Forbes mapped a fault between his Strangway Hill Beds and the underlying Grey Spur Beds, which he regarded as resembling the Adelaide System. We agree that the fault as mapped is correct. Further, we regard the basal Strangway Hill Beds of Forbes as equivalent to the Tapley Hill Formation (phyllite phase), and the overlying "Cambrian marble" and "pyritic shales interbedded with quartzites" of Horwitz & Thomson (1960) as the Brighton Limestone (marble phase) and basal Marino Group metasediments respectively. Thus we believe that most of the type Strangway Hill Beds of Forbes does not belong to the Kanmantoo Group. Further, the mapping by Horwitz & Thomson (1960) suggests that a major fault separates the Kanmantoo Group from what we regard as Sturt and Marino Group rocks. Thus because of the uncertainty regarding both the stratigraphic position of the Strangway Hill Beds in their type area, and their relationships to rocks in the type area of the Kanmantoo Group, and in view of the fact that Strangway Hill Formation

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[2] Campana (1955) interpreted this as a fault contact. One of us (B.D.), in conjunction with the University of Adelaide Geology III class for 1964, excavated the contact to show the relationships of the Kanmantoo Group to the underlying Barossa Complex.

[3] Thomson & Horwitz (Barker 1:250,000 sheet, 1962) show "basal Cambrian" resting on Torrensian rocks instead of Sturtian rocks as in their earlier contribution.

has been used by later authors to refer specifically to the basal part of the Kanmantoo Group, we believe that the terms are best discarded. Further credence is given to this suggestion in view of the stratigraphic scheme developed in this paper for the lower part of the Kanmantoo Group within its type area along the southern coastline of Fleurieu Peninsula.

In connection with the relationships of the Kanmantoo Group in the eastern Mt. Lofty Ranges, we are reluctant to dismiss the concept of the Nairne Fault as pertaining to the Adelaide 1:63,360 sheet. Kleeman & Skinner (1959, p. 70) have pointed out that the Nairne Fault as delineated on the Echunga 1:63,360 sheet was "disproven by the mapping of marker horizons and structural features across the line of the supposed fault". The mapping of the Strathalbyn Anticline by Offler (1963) is in agreement with this statement. However, we are of the opinion that the Nairne Fault exists on the Adelaide 1:250,000 sheet (Thomson 1969) where, in the Mount Charles region, Thomson has interpreted a double unconformity bounding "basal Cambrian" rocks. We prefer to interpret the same relationships as a consequence of faulting, namely the Nairne Fault. We predict that when the structure of the eastern Mt. Lofty Ranges has been resolved, the boundary separating the younger Kanmantoo Group from mainly Precambrian rocks lying to the west will be a set of *en echelon* faults, and not an unconformity as shown on the more recent maps published by the Geological Survey of South Australia. It should be noted, however, that where Lower Cambrian rocks are overlain by Kanmantoo Group rocks without structural discordance, conformity between them can be expected.

Finally, we do not accept the proposition put forward by Kleeman and Skinner (1959) that the base of the Kanmantoo Group should be placed at the base of the "Nairne Pyritic Formation", because the base of the group as defined by Sprigg & Campana (1953) has priority, and is well below the Nairne Pyrite.

The Geology of the Type Kanmantoo Group between Campbell Creek and Tunkalilla Beach

STRATIGRAPHY

In presenting the geology of this 16 km of coastline we have been forced to abandon the term Strangway Hill Formation as discussed above, and also the term Inman Hill Formation (see Footnote 7), and to introduce a number of new stratigraphic names. The new scheme is given in Table 1 and the distribution of the stratigraphic units recognised is shown on the accompanying geological map, Fig. 2. Whilst the position of the boundaries between the formations and various members are accurately portrayed on the coastline, we must point out that we have not mapped them as far inland as the map might suggest. Their projection inland is for the sake of clarity only.

All but one of the formations are fossiliferous. The whole sequence is regarded as being Lower Cambrian in age from its fossil content, and by analogy with the Lower Cambrian sequence occurring on the north coast of Kangaroo Island (Daily 1956; Horwitz & Daily *in* Glaessner & Parkin 1958, Fig. 14; and Daily 1969).

A. FORKTREE LIMESTONE (MARBLE PHASE) AND HEATHERDALE SHALE (PHYLLITE PHASE)

Marble and phosphatic nodular phyllites (Figs. 3–10) occupy the core of a north-easterly plunging *regional anticline* whose western limb is overturned[8]. Evidence for this overturning is given by facings from cross-bedding in the stratigraphically younger Carrickalinga Head Formation on the western limb of the fold, and also by cleavage bedding intersections and the sense of the parasitic folds on the same limb. Both the Heatherdale Shale and the Forktree Limestone can be inspected in Madigan Inlet[9] and just east thereof.

The area of outcrop of the Heatherdale Shale along the south coast is greatly exaggerated on the Jervis 1:63,360 sheet, where it is shown

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[8] The regional anticline with an overturned western limb was first recognised jointly during an excursion to Madigan Inlet in 1963 by one of us (B.D.) and Dr. R. J. George, who in the same year presented a thesis towards a B.Sc.(Hons) Degree entitled "The geology of the Talisker Mine Area". We wish to record that we have consulted that work during the preparation of this paper.

[9] This geographic feature is named in recognition of the important discoveries made by the late Dr. C. T. Madigan, who first recognised and correctly interpreted the occurrence of the Delamere marble (Madigan 1925, p. 209), and later in 1939, the phosphatic nodular phyllites (see comment by Sprigg *in* Sprigg and Campana 1953) at this locality.

extending from just west of Campbell Creek to just east of Madigan Inlet. Our interpretation of the geology and structure of the same area is radically different. It also differs from that given in Thomson (1963), where failure to recognise the closure of the regional anticline at Madigan Inlet and the overturned western limb of the fold has resulted in an incorrect stratigraphic column and structure for the area. Moreover, these errors have led to unwarranted assumptions of facies changes from Cambrian carbonates at Delamere to quartz-rich clastics on the coastline. We reiterate the statement made by Daily (1963) that both Precambrian and Cambrian sequences on Fleurieu Peninsula show "remarkable constancy of facies".

The north-easterly plunge of the mottled upper member of the Forktree Limestone is visible on the extreme point on the eastern side of Madigan Inlet. On the eastern and normal limb of the fold, hyolithids and spicules of the sponge *Chancelloria* were discovered in the uppermost 2 m of the Forktree Limestone. They are visible as phosphatic steinkerns on bedding surfaces within the marble, just above a wave-cut platform. All the fossils have been deformed tectonically.

The contact between the Forktree Limestone and the lower member of the Heatherdale Shale is marked by the appearance of phyllite bands up to 8 cm thick. The almost black phyllites separate thin interbeds of dark blue-grey limestone up to 10 cm thick, and the sequence as a whole is far better bedded than the lighter coloured streaked and mottled marbles of the Forktree Limestone. Phosphatic nodules occur from the base of the member, but these are sparse. Hyolithids occur sporadically through the lower 12 m, but are abundant in a band of thin limestone about half way up the cliff face at the top of this interval. The band can be traced to the break in slope above the cliff, where fossils can be collected safely. Non-calcareous and black metasiltstones with minor impure limestone interbeds to 15 cm thick occur above the fossiliferous interval. Black phosphatic nodules elongated towards N70° at 47° are abundant from this interval onwards. Higher in the member there is a marked increase in carbonate content, resulting in a sequence of flaggy limestones with thin calc-phyllite partings. This part of the sequence is reminiscent of the topmost members of the Parara Limestone of the Billy Creek, Chace Range, and several other sections in the Flinders Ranges. (Curiously, phosphatic nodules and stringers of phosphate occur within the Parara Limestone in many areas of the Flinders Ranges.)

The calcareous beds give way to an upper member consisting of black and non-calcareous phyllites, in which the abundant phosphatic nodules plunge towards N85° at 60°. However, the phyllites do contain ovoid (*stretched*), calcareous concretions up to 1 m across and elongated in the same direction as the phosphatic nodules. Hyolithids occur sparsely in the concretions, which recall similar large concretions (also fossiliferous) occurring in the upper member of the same formation at Carrickalinga Head. The upper member contains sulphides, and their presence is readily discernible from the rusty stains seen on the surface of the rocks.

The newly discovered fossils are not in themselves diagnostic enough to fix the age of the sequence with any precision. However, identical fossils occur in the same formations in the same stratigraphic positions in the Normanville-Sellick Hill area. Recently, one of us (B.D.) has located hyolithids in the basal parts of the Heatherdale Shale along Stockyard Creek east of the Cape Jervis-Delamere road, thus realising the third predicted position "where fossils might reasonably be expected to occur in these metamorphosed rocks" (Daily 1963, p. 581).

The overturned limb of the Heatherdale Shale is notably attenuated by shearing, and inspection will show that whereas a complete sequence is found on the normal limb, parts of the formation on the overturned limb have been eliminated by faulting. Such faulting is characteristic of most of the other formations occurring on the western and overturned limb of the regional anticline, and will be alluded to below. We have not plotted a fault on the map simply because none was to be found. Nevertheless, it is quite obvious that beds present on the other limb of the very tight fold are not present on the overturned limb.

B. The Kanmantoo Group

(i) *Carrickalinga Head Formation*

A radical and fundamental change in sedimentation is ushered in at the base of the Kanmantoo Group (Figs. 8–18). There is *no* transition, and consequently the contact between its basal member, herein termed the Madigan Inlet Member, and the Heatherdale Shale is perfectly sharp. It is visible on the eastern side of the first indentation east of

Madigan Inlet, where black phyllites to metasiltstones, stained from the breakdown of sulphides, are in contact with a thin grey phyllite marking the base of the Kanmantoo Group. Black phosphatic nodules occur right up to the contact (Fig. 10). The member is characterised by phyllites (frequently bedded) alternating with more massive beds of impure metasiltstones to metasandstones. The proportion of phyllite to the coarser clastics varies within the member. For example, the thin phyllite interbeds are absent in the upper parts of the member where metasiltstones to fine grained metasandstones are dominant. Abundant small scale sedimentary structures, especially ripple phenomena, are prominent in this interval. Small north-easterly plunging folds are evident in the same beds. Characteristic of the coarser clastics are large actinolite-garnet nodules or segregations which make their appearance about 30 cm above the base of the member. These are directed towards N50° at a moderate angle. Pale grey ovoid nodules up to 2 cm across, and stringers of the same material occur in distinct layers through about 25 cm of a dark grey phyllite interbed on the overturned limb of the Madigan Inlet Member. The nodules consist predominantly of phosphate. Abundant pegmatite stringers, consisting of quartz, chlorite, muscovite, calcite and opaque mineral cut the metasedimentary rocks on both limbs of the regional anticline. Small garnet porphyroblasts are developed in the metasedimentary rocks immediately adjacent to some of the pegmatites.

The middle member of the formation, herein referred to as the Blowhole Creek Siltstone Member (phyllite phase), rests conformably on the Madigan Inlet Member. It is seen between the mouth of the first creek west of Blowhole Creek and a small inlet just east of Campana Creek[6]. The sequence consists almost entirely of pale grey laminated phyllites which are deformed into a series of minor folds plunging up to 45° towards the north-east. Where fine sand and silt interbeds occur, as in the upper parts of the member, minor sedimentary structures such as small scale current ripples and current-bedding, fossils in the form of *worm-casts,* and minor folds with steep, short and overturned western limbs are very evident. It is seen that the minor folds faithfully mimic the style of the major anticline for the region.

Pegmatite veins containing quartz, chlorite and biotite are common in the Blowhole Creek Siltstone Member. An amphibolite dyke about 3 m wide cuts the phyllite sequence, and can be inspected just west of the beach fronting Blowhole Creek. It is intersected by quartz pegmatites which indicate intrusion of the dyke prior to the final phase of metamorphism. Another amphibolite dyke, which cuts the Madigan Inlet Member, can be seen on the first point south of the contact with the top of the Heatherdale Shale.

The lower boundary of the overlying Campana Creek Member is gradational (over about 1 m) from the underlying member, and is seen in the cliff in the small inlet just east of Campana Creek. Fallen blocks indicate the change in gross lithology, and show the abundant small scale and deformed sedimentary structures to perfection (Fig. 11) in the thinly laminated beds made up of alternations of grey phyllites and paler grey metasiltstone and metasandstone layers. Many beds show bioturbation features (Fig. 12).

The section described above is to be considered as a *subsidiary type section* for the Carrickalinga Head Formation, described informally by Daily (1963) and used formally in Daily (1969). For the first time a definite upper limit can be given and its three-fold division specified. Moreover, it is now clear that the Carrickalinga Head Formation and the Mount McDonnell Formation (Daily 1969) are synonymous, the two uppermost members of the former being the metamorphic counterparts of the shales, silts and minor coarser clastics found below the Stokes Bay Sandstone along the north coast of Kangaroo Island, north-west of Mount McDonnell. Both formations are characterised by the high incidence of bioturbation within the sequence. It is proposed that the Mount McDonnell Formation be discarded as a stratigraphic term because of its identity with the Carrickalinga Head Formation.

(ii) *Backstairs Passage Formation*

A thick sequence of metasandstones overlies the Carrickalinga Head Formation and is in turn overlain by a sequence of calc-phyllites.

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[6] So named to honour the significant contributions made to the understanding of the geology of the Mt. Lofty Ranges by Dr. Bruno Campana.

We propose to refer to this sandstone sequence as the Backstairs Passage Formation, named after the strait separating Fleurieu Peninsula from Kangaroo Island.

The formation boundary is drawn on the east side of a 6 m wide gulch in which no outcrop is seen. However, conformity between the two formations is assumed. From the base upwards, most of the rocks are well laminated, with grey metasandstone being the dominant rock type. In the basal parts of the formation abundant silt is present, and this is very evident where differential erosion of the thin grey metasandstones and darker grey metasiltstones has produced thinly ribbed or striped outcrops. Bioturbated intervals are present particularly in these lower silt intervals. Some small scale cross-bedding with sets up to 25 cm thick are noticeable in the more massive sandstones near the base of the formation. Here, too, thin metasiltstones up to 1 m thick break the monotony of the laminated metasandstones.

With the decrease in silt content, the laminated sandstones make bolder and more massive outcrops and appear much paler than the earlier described clastics due to the better sorting resulting in less fines and the consequent decrease in dark micas. Mica is still present but evenly dispersed, giving the weathered rocks a "salt and pepper" appearance. Although the rocks are still well laminated, cross-bedding becomes a prominent feature from about a third of the way through the formation. The sets are generally about 1 m or less in thickness, although 2 m thick sets were recorded. The sands fill low amplitude channels cut into the laminated beds and are themselves laminated. Small and large scale slumps have resulted from movement down the direction of the cross-bedding. The variability in direction of slump axes precludes any conclusions regarding a source direction for the sediment.

It is uncertain whether the flat laminations represent a very high energy regime, or were produced under shallow water and less energetic conditions. Whatever the answer, it seems clear that they represent rapid deposition because of the instability of the cross-bedded sets of laminated sands involved in the slumping, and also because of the absence of bioturbation in the same beds as compared with the high incidence of bioturbation seen in the lower portions of the formation. Presumably these were deposited under much less energetic conditions. It is possible that the formation could be subdivided into two members on the basis of its silt content and type of bedding, but we do not wish to do this at present.

On the overturned limb of the regional anticline between Campbell Creek and Madigan Inlet, the Carrickalinga Head Formation and in particular the Backstairs Passage Formation have been greatly attenuated by shearing and faulting. This is especially so for the latter, which has been all but eliminated on the coastline. A fault, although not observed, is shown on our map to take account of the missing interval.

It is probable that the Backstairs Passage Formation and the Stokes Bay Sandstone of northern Kangaroo Island are synonymous. However, further work needs to be carried out on the Stokes Bay Sandstone before any finality can be attained. Until an adequate comparison can be made we will continue to employ the Backstairs Passage Formation as a workable stratigraphic unit.

(iii) *Talisker Calc-siltstone (phyllite phase)*

This newly named formation is the most characteristic member of the Kanmantoo Group so far encountered in our traverse along the south coast. The formation is unfossiliferous. Its contact with the adjacent formations is sharp. The calc-phyllites are strongly banded and predominantly light and dark grey in colour. The lighter bands are generally more calcareous. In places the lighter bands are coarse grained marbles, occurring as thin, discontinuous stringers within the formation due to the strong deformation within the area. Minor folds are ubiquitous. Sulphide-rich zones are evident from the rusty colouring on the exterior of the phyllites.

On the overturned limb of the regional anticline, the formation appears to occupy about twice the width of outcrop as on the eastern limb. In fact it is better examined there because of its easy accessibility. A dry weather track, suitable only for four-wheel drive vehicles, passes to the west of the Talisker Mine and is readily negotiated as far as Campbell Creek. From this point the calc-phyllites occur eastward for nearly 1 km. Again they are characteristically banded, and differential weathering in places gives the rock a ribbed appearance. Segregations of quartz-chlorite-muscovite pegmatite are prominent as on the normal limb of the regional anticline. Perhaps the most conspicuous feature of the overturned limb is the intensity of the small scale folding so beautifully expressed in the cliff faces. Near

Campbell Creek, southerly plunges are common, but further east the plunges are towards the north-east at varying angles, generally shallow. Mineral streaking on bedding planes is directed towards the south-east between N110° to N150°. Sulphide-rich (predominantly pyrrhotite) bands of calc-phyllites are common, particularly near the basal and middle parts of the formation. One sulphide band about 10 m thick lies immediately east of a 60 cm thick quartzite, and is conspicuous from the oxidation colours on the phyllites. Cleavage within the band is commonly enhanced by the presence of sulphides and their oxidation products. Other similar sulphide-rich bands occur in the formation to the east but are not shown on Fig. 2. Indeed, the whole sequence contains varying amounts of sulphides, and the zones are so numerous that it is impracticable to plot them on the scale of our map.

A strongly boudinaged amphibolite dyke cuts the formation, and is visible on the coastline in about the middle of the formation on the eastern limb of the regional anticline.

(iv) *Tapanappa Formation*[7]

On the normal limb of the regional anticline, an enormously thick and extremely monotonous sequence of dark coloured and dirty metasandstones with thin grey phyllite interbeds rests conformably on the Talisker Calc-siltstone. In general aspect, the formation recalls the basal member of the Carrickalinga Head Formation, in that the metasandstones are are split by thin phyllites, and in limited exposures could be confused with it. The metasandstones include fine grained to coarse grained varieties, the latter being the commoner, and in these there is obvious biotite and feldspar. Internally the sandstone beds, generally of the order of less than 1 m and rarely more than 2 m in thickness, are poorly bedded to well bedded. Cross-bedding is common, and in some intervals large scour channels filled with cross-bedded sands are obvious, for example between Porpoise Head and Deep Creek. Flat bedded and small scale current bedded sandstones are also present. Actinolite-garnet nodules are again common within the metasandstones, but they do occur in some of the metasiltstone to phyllite interbeds.

In some parts of the formation the metasandstones are highly cleaved, no doubt due to large amounts of fines in the original sediment, which have recrystallised to micas. The only fossils found within the formation were *worm-casts* in metasandstones interbedded with metasiltstones in the vicinity of Porpoise Head.

The phyllites are generally grey to dark grey in colour, and tend to weather olive-green away from the coast. They vary in thickness from mere partings to beds up to 10 m thick, but the latter are exceptional. They are commonly less than 0.5 m thick. Overall, there seems to be more phyllite present from Tunkalilla Beach eastwards. The phyllites occasionally are well-bedded, and in some localities, for example east of Deep Creek and in the old coastal cliffs inland from Tunkalilla Beach, porphyroblasts of micas and chlorite are randomly oriented within the rocks.

The only other rock type present is conglomerate. This first appears in the sequence in the cliffs just west of Aaron Creek. Similar thin bands occur sporadically and higher in the formation, but assume more importance as Tunkalilla Beach is approached. The conglomerates appear to be lenticular, and are generally less than 2 m thick. They are cut-and-fill into the underlying sediments, and are frequently cross-bedded and contain pebbles of quartz (including blue opalescent quartz), feldspar, quartzite, gneisses, rare phyllites, and limestones and dolomites. The carbonate pebbles (marbles) are always present and make up a significant proportion of some bands. The maximum pebble size seen was approximately 8 cm in diameter. The significance of the conglomerates is discussed below.

Two significant sulphide-rich bands were located within the Tapanappa Formation during our traverse, and these are shown on Fig. 2. Both are approximately 2.5 m thick, and consist of calcareous laminated phyllites interbedded with thin metasiltstone beds up to 8 cm thick. The phyllites show small scale current-bedding. The sulphide is fine grained and evenly disseminated through the phyllites and metasiltstones, and is shown by petrographic

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[7] The formation has been named after the geographic feature called Tapanappa Hill. On the Barker 1:250,000 sheet, the Inman Hill Formation (Forbes 1957) as shown on the south coast of Fleurieu Peninsula includes the metasediments we have mapped as Backstairs Passage Formation, Talisker Calc-siltstone, and Tapanappa Formation. As we are uncertain that the beds herein termed Tapanappa Formation are the same as included in the type Inman Hill Formation, we prefer to use the former term. (See also Table 2.)

examination to be dominantly pyrrhotite. One unusual feature of the sulphide band near Porpoise Head is the presence of abundant fine grained sphene. This is absent from the band to the east of Boat Harbour Creek.

The finding of major sulphide-rich bands within the Tapanappa Formation, and in fact their occurrence throughout much of the basal part of the Kanmantoo Group as described herein, has interesting implications. This is especially important in view of the fact that the presence of sulphide bands within Kanmantoo Group metasedimentary rocks is a characteristic feature of the Nairne Pyrite Member, and it has been the tendency of earlier workers to map this Member on the basis of the sulphide-rich "marker beds". Clearly, the presence of sulphides is not a valid *single* criterion for the recognition of the Nairne Pyrite, and such use may lead to quite incorrect stratigraphic and structural interpretations of the geology in parts of the southern and eastern Mt. Lofty Ranges.

The position of the lower boundary of the Tapanappa Formation on Fig. 2 lies about 1 km further east than the boundary of the Inman Hill Formation on the Barker 1:250,000 sheet. It would appear that Thomson & Horwitz have included the Backstairs Passage Formation and the Talisker Calc-siltstone in what they have called the Inman Hill Formation. They are specifically excluded from the Tapanappa Formation as used herein because they are distinct units, capable of being recognised and mapped elsewhere, and their inclusion in the Tapanappa Formation would destroy the uniformity of that formation. For the purpose of this paper, we have tentatively located the upper boundary of the Tapanappa Formation on the normal limb of the regional anticline approximately 2.5 km west of Tunk Head. Here, in the cliffs inland from Tunkalilla Beach, the Tapanappa Formation is overlain conformably by a 10 m thick band of dark coloured and laminated phyllite, followed above by a sequence of fine grained to coarse grained metasandstones with thick phyllite interbeds. On the overturned western limb of the regional anticline, we interpret the Talisker Fault (Jervis 1:63,360 sheet), along the coastline just west of Campbell Creek, as a conformable boundary between the Talisker Calc-siltstone and the stratigraphically younger Tapanappa Formation.

As seen from Fig. 2, the Tapanappa Formation is mainly east-facing, except where folds intervene. Fold plunges are shallow, with axes directed towards the north-east or south-west. In this regard they mimic the axial direction of the regional anticlinal closure at Madigan Inlet. We have been unable to locate major faulting within the formation. However, shearing is associated with the folding but is apparently not significant on a macro scale.

STRUCTURE

Our observations to date mainly apply to the eastern limb of a regional anticlinal structure, in which the western limb is overturned and shows evidence for considerable tectonic thinning. All mesoscale folds so far observed conform to the style of the regional structure. They are inclined and asymmetric, with east limbs of anticlines longer than west limbs, and an axial plane cleavage dipping steeply towards the south-east. In many cases, dislocation of the overturned west limbs of mesoscale anticlines and the east limbs of mesoscale synclines has taken place along thrust zones which nearly parallel the axial plane cleavage. As described, these folds correspond to the F_1 folds of Offler & Fleming (1968).

A π-diagram, plotted from measured bedding attitudes, shows the overall fold axis to be plunging at a very shallow angle towards approximately N45°. However, mesoscale fold axes are spread along a great circle. This spread is substantiated from measurements of long axes of phosphate nodules in the Heatherdale Shale, and actinolite-garnet rods in the Carrickalinga Head Formation and the Tapanappa Formation, and is interpreted as indicating refolding of F_1 folds by a second deformation. Bedding plane lineations in the Forktree Limestone and the Talisker Calc-siltstone, due to the elongation of calcite crystals and sulphide mineral grains respectively, plunge towards approximately N115° at about 65° and may correspond to the fold axis of the second generation folds. The bedding plane lineations are the only evidence so far observed for second generation structures. We have seen similar relationships in adjacent areas including the Encounter Bay area and Dudley Peninsula, Kangaroo Island. However, the further definition and understanding of these overprinting relationships will be dependent on the extension of our present traverse along the south coast of Fleurieu Peninsula.

Considerable tectonic thinning of formations has occurred on the western limb of the regional anticline. For example, as discussed above, much of the Heatherdale Shale, the upper two members of the Carrickalinga Head Formation, and all but the uppermost few metres of the Backstairs Passage Formation are missing from this section. We prefer to ascribe the absence of much of the Carrickalinga Head Formation and the stratigraphically younger Backstairs Passage Formation as the result of faulting, but we were unable to find such a fault. Consequently, a tentative fault has been drawn in the appropriate place on Fig. 2 to account for the missing interval. We believe it probable that the Heatherdale Shale has been thinned as a result of thrusting along cleavage planes, which are closely spaced and dipping at a shallower angle than the bedding, although faulting within the formation must remain a possibility.

We wish to make quite clear that any thicknesses of formations and members computed from Fig. 2 can have no meaning because of the ubiquitous small scale folding. In all but the most competent formations and members, the folds are generally not of sufficiently large scale to show on our map. The incompetent carbonate-rich formations and the fine grained phyllite and metasiltstone members of the Carrickalinga Head Formation particularly, are complexly folded on a small scale, with folds varying in amplitude from several centimetres up to several metres.

METAMORPHISM

Offler & Fleming (1968) have assigned the metasedimentary rocks along the southern coastline of Fleurieu Peninsula to the biotite zone of metamorphism, passing eastwards into the higher grade andalusite-staurolite zone. The lower boundary of their andalusite-staurolite zone intersects the coastline at about the position of the regional anticlinal axis at Madigan Inlet, and has been defined by the "incoming of andesine or andesine + epidote in calc-schists and calc-silicate rocks". However, they stress that the boundary is only approximately located on parts of Fleurieu Peninsula, including the southern coastline, "because of the lack of suitable rock types".

Our investigations have shown that the following mineral assemblages occur in the metasedimentary rocks between Campbell Creek and Tunkalilla Beach:

(a) in calc-silicate rocks—
andesine, ± calcite, actinolite, garnet, ± chlorite, + epidote, ± biotite;

(b) in calc-phyllites and calcareous metasiltstones—
andesine, ± muscovite, biotite, calcite, ± actinolite, ± garnet, ± chlorite;

(c) in phyllites and metasiltstones—
andesine, biotite, chlorite;

(d) in impure metasandstones—
andesine, chess-albite, biotite, ± garnet, ± epidote, muscovite.

Quartz is ubiquitous in all assemblages. We have not observed staurolite, andalusite or cordierite, nor have we seen the andalusite-type knots consisting of quartz, muscovite, chlorite, ± albite described by Offler & Fleming (1968) as preceding the first appearance of andalusite in pelitic schists elsewhere in the Mt. Lofty Ranges. Thus we are not able to locate the lower boundary of the andalusite-staurolite zones as defined by the staurolite or andalusite isograds. However, on the basis of the coexistence of plagioclase with calcite, epidote, and actinolite, and because of the stability of the assemblage quartz + chlorite, it is possible to locate the grade of metamorphism at the top of the low-stage (as defined by Winkler 1970) between the almandine garnet isograd and the staurolite isograd.

Discussion and Conclusions

As a result of our study of the Kanmantoo Group in its type area, several facts emerge from which a number of conclusions can be drawn.

(a) *Stratigraphic Relationships*

On Fleurieu Peninsula, the Kanmantoo Group rests conformably and with sharp contact on the Heatherdale Shale. Moreover, in the same region, there is no evidence for either unconformity or disconformity at its base, as proposed initially by Campana & Horwitz (1956) and most recently by Thomson *in* Parkin (1969). In all areas where Kanmantoo Group rocks rest on rocks older than the Heatherdale Shale, faulting can be shown to explain the situation, as for example south-east of Yankalilla Hill. Similar fault relationships are believed to exist through much of the eastern Mt. Lofty Ranges, where the unconformity concept has been applied by many geologists to explain relationships first interpreted by Sprigg, Whittle & Campana (1951) as due to faulting.

(b) *The Kangarooian Movements and Kanmantoo Group Sedimentation*

The clear-cut contact between the Heatherdale Shale and Kanmantoo Group indicates the suddenness with which the new type of sediments became available and were brought into the basin of deposition. They were essentially non-calcareous and in contrast to the earlier deposited Cambrian sediments. The new sediments were mainly unsorted sands and silts eroded from newly emergent land masses uplifted in response to movements in the present Investigator Strait and Gulf St. Vincent[5]. Other areas involved were the Gawler Nucleus and its southerly prolongation onto and perhaps even beyond the present continental shelf. Such Lower Cambrian movements, both positive (for source areas) and negative (for depositional areas) and their connection with Kanmantoo Group sedimentation were first alluded to by Sprigg (1955) and later documented by Daily (1956, pp. 99–100, 125–128, 138–140), Campana (*in* Glaessner & Parkin 1958, pp. 17–18), Horwitz & Daily (*In* Glaessner & Parkin 1958, p. 55), Daily (1963, p. 596; 1969, p. 52) and elsewhere[6]. Daily & Forbes (1969) named these movements the Kangarooian Movements (after the locality Kangaroo Island, along the north coast of which their effects are best recorded) in preference to the term "orogeny" as initially suggested in 1956. Thomson (*in* Parkin 1969, p. 99; 1970, p. 215) has used the terms Cassinian Uplift and Waitpingan Subsidence to account for the same movements; however, it is proposed here that the term Kangarooian Movements is more appropriate because it retains the spirit of the concept as used in Daily (1956).

In addition, the movements as recorded on both Kangaroo Island and Yorke Peninsula were multiple in character. Moreover, the instability in the latter region, as shown in the sedimentary record, extended from the Lower Cambrian into the Middle Cambrian. Periods of quiescence punctuated the positive phases of the movements, and at these times limestones were deposited.

On Fleurieu Peninsula, the Kanmantoo Group metasediments reflect an almost continuous supply of clastics from the nearby tectonic lands. The sands are impure and poorly sorted, and on the whole indicate rapid deposition in a rapidly subsiding basin. However, deposition was not rapid enough to prevent organisms from reworking the newly laid sands, as in parts of the Carrickalinga Head Formation and Backstairs Passage Formation. The Talisker Calc-siltstone is an exception in that there is a general fall off in the supply of coarse clastics at the time of its deposition, but it would seem that negative movements within the basin were such that the depositional interface was brought to depths where stagnant bottom conditions favoured the deposition of abundant sulphides.

The Tapanappa Formation contains many lenses of small scale conglomerates. Rock fragments are commonly angular, and hence show evidence of little transport. Many pebbles are of older Precambrian gneisses and other crystalline rocks, and the high incidence of marbles, by analogy with Kangaroo Island and Yorke Peninsula, presumably represent the stripping of Lower Cambrian limestones and dolomites, and the underlying crystalline basement, from nearby rising fault blocks. The high feldspar content of metasandstones within the Kanmantoo Group is an indication of the strong role played by the crystalline basement in supplying much of the sediment.

(c) *The New Stratigraphic Scheme for the lower part of the Kanmantoo Group*

The stratigraphic scheme as given in Table 1 will form the basis for our future investigations elsewhere within the area of distribution of the Kanmantoo Group. We regard the Talisker Calc-siltstone as a marker bed, and wish to

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[5] Several unpublished reports by one of us (B.D.) and held on open file by the South Australian Mines Department, have developed this theme, especially for the Yorke Peninsula Region.

(a) Daily, B (1957).—Progress report on the Cambrian sequence met with in the Minlaton Stratigraphic Bore 1, Section 153, Hd. Ramsay, Yorke Peninsula, South Australia. Unpublished report to S.A. Mines Department.

(b) Daily, B. (1967).—Stansbury West No. 1 and Edithburgh No. 1 Wells—Subsurface Stratigraphy and Palaeontology of the Cambrian Sequence. Unpublished report to Beach Petroleum N.L.

(c) Daily, B. (1968).—Stansbury Town No. 1 Well—Subsurface Stratigraphy and Palaeontology of the Cambrian Sequence. Unpublished report to Beach Petroleum N.L.

As mentioned in (c), a discussion of a correlation chart for all wells mentioned in (a), (b) and (c) was presented to the South Australian Division of the Geological Society of Australia, July 27, 1967.

TABLE 1

Stratigraphic scheme for the lower part of the Kanmantoo Group in its type section

Kanmantoo Group	Tapanappa Formation	
	Talisker Calc-Siltstone	
	Backstairs Passage Formation	
	Carrickalinga Head Formation	Campana Creek Member
		Blowhole Creek Siltstone Member
		Madigan Inlet Member
	Heatherdale Shale	Upper member (unnamed)
		Lower member (unnamed)
	Forktree Limestone	Upper member (unnamed)

point out that we have recognised it recently on both limbs of an overturned anticline on Kangaroo Island. It is imperative that a search be made inland on Fleurieu Peninsula for these calc-phyllites, particularly in the type section of the Inman Hill Formation (Forbes 1957) as well as further north.

As shown in Table 2, three stratigraphic schemes have been applied to the type section of the Kanmantoo Group. We reject the lowest two units in the Thomson & Horwitz scheme for the reasons stated above, but can not comment on the Brukunga Formation as this interval is still to be investigated by us. With regard to the two other schemes, it is important to note that the formation boundaries mapped both by Dr. R. J. George (see footnote 4) and us on the normal limb of the regional anticline are practically coincident. We differ from George essentially in the choice of names for the formations recognised. George chose his nomenclature because he was impressed by the occurrence of sulphides in the Talisker Calc-siltstone, and because it lay stratigraphically above a cross-bedded, slumped arkosic formation, and below a greywacke sequence. These three formations he equated with the Nairne Pyrite, the Inman Hill Formation, and the Brown Hill Greywacke respectively. There would be considerable merit in this action but for the fact that on the Barker 1:250,000 sheet, the Brukunga Formation is mapped along the south coast of Fleurieu Peninsula as commencing nearly 16 km to the east of the upper limit of the Talisker Calc-siltstone. We cannot ignore the possibility that George is correct in equating the Talisker Calc-siltstone with the Nairne Pyrite, which incidentally does contain calcareous metasedimentary rocks. If this suggestion is correct, then the geology of the Kanmantoo Group on the Barker 1:250,000 sheet is in need of much greater revision than we presently propose.

TABLE 2

Schemes of Stratigraphic Nomenclature utilised in the type section of the Kanmantoo Group between Campbell Creek and Rosetta Head

		Thomson & Horwitz (1962) Thomson *in* Parkin (1969)	George (unpublished)	Daily & Milnes (this paper)
KANMANTOO GROUP	Brukunga Formation	Brown Hill Greywacke Member*	Not investigated	Not yet investigated
		Nairne Pyrite Member		
		Inman Hill Formation	Greywacke of Brown Hill	Tapanappa Formation
			Nairne Pyrite Equivalent	Talisker Calc-siltstone
			Inman Hill Formation	Backstairs Passage Formation
		Strangway Hill Formation†	Carrickalinga Head Formation	Carrickalinga Head Formation

* Thomson & Horwitz (1962) have not mapped this member along the coastline within the type section.

† The term Strangway Hill Formation was not used in the legend of the Barker 1:250,000 sheet (Thomson & Horwitz 1962) for the rocks exposed along the coastline between Campbell Creek and the base of the Inman Hill Formation. However, the Strangway Hill Formation is shown in Fig. 44 in Thomson *in* Parkin (1969), as occupying this interval of coastline. In fact, as seen from our Fig. 2 the same coastal section contains rocks within the regional anticline ranging from Forktree Limestone to the Talisker Calc-siltstone.

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EXPLANATION OF FIGURES

Fig. 3. Anticlinal closure in mottled marbles of the Forktree Limestone forming the core of the north-easterly plunging regional anticline, east side of Madigan Inlet.

Fig. 4. Deformed mottled marbles on the overturned limb of the regional anticline, east side of Madigan Inlet. View looking towards N200°. Coin 2.3 cm in diameter.

Fig. 5. Flaggy outcrops of marbles with thin phyllitic partings, near top of upper member of the Heatherdale Shale, east limb of regional anticline, small bay just east of Madigan Inlet.

Fig. 6. Deformed ovoid limestone concretions in upper member of Heatherdale Shale, immediately east of Fig. 5. Hammer length 28 cm.

Fig. 7. Aligned black phosphatic nodules in dark coloured phyllites on overturned limb of Heatherdale Shale, creek exposure at Madigan Inlet. Coin 2.8 cm in diameter.

Fig. 8. View looking south showing the extremely attenuated Heatherdale Shale on the overturned limb of the regional anticline, Madigan Inlet. From left to right—Marbles of Forktree Limestone on point, phyllites of Heatherdale Shale forming bay and in creek exposure in right foreground, and metasandstones and phyllites of Carrickalinga Head Formation on coast. Figure 1.3 m tall.

Fig. 9. Contact between light coloured basal beds of the Kanmantoo Group and the black sulphide-rich phyllites of the underlying Heatherdale Shale, cove just east of Madigan Inlet. View looking south.

Fig. 10. Hammer on contact between Heatherdale Shale and basal phyllite of the Kanmantoo Group. Note elongated dark coloured actinolite-garnet nodule in metasandstone about 35 cm to right of hammer.

Fig. 11. Deformed bedding in interbedded metasandstones and metasiltstones near base of Campana Creek Member of the Carrickalinga Head Formation, just east of Campana Creek. Hammer handle lies parallel to cleavage.

Fig. 12. Bioturbated beds near base of Campana Creek Member of Carrickalinga Head Formation, same locality as Fig. 11. Pen is 14 cm long.

Fig. 13. Well laminated metasandstones, lower portion of the Backstairs Passage Formation, 0.5 km south-east of Blowhole Creek. Lens cap 7 cm in diameter.

Fig. 14. Laminated (top) and slumped (bottom) metasandstones of the Backstairs Passage Formation, 1 km south-east of Blowhole Creek.

Fig. 15. Banding in dark and light grey (calcareous) phyllites of the Talisker Calc-siltstone on the overturned limb of the regional anticline, just east of Campbell Creek. Note pegmatitic segregations of quartz and chlorite (also light coloured).

Fig. 16. Parasitic folds (plunging towards N50°) in Talisker Calc-siltstone on the overturned limb of the regional anticline, about 0.5 km south-east of Campbell Creek. Note short overturned limbs and long normal limbs of folds, and shearing of overturned limbs.

Fig. 17 Band of small scale conglomerate with overlying laminated metasandstone in Tapanappa Formation, just west of Tunkalilla Beach.

Fig. 18. Large partly rounded pebbles of quartzites and gneiss in small scale conglomerate, same locality as Fig. 17. Maximum diameter of pebble (upper right) is 7 cm.

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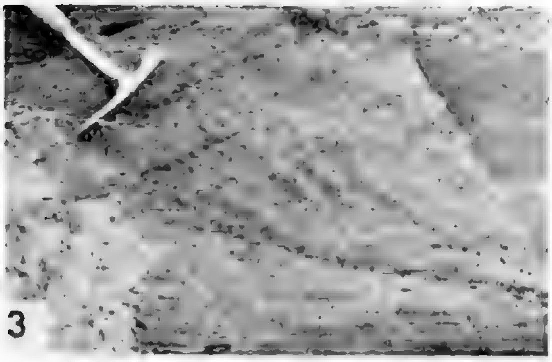
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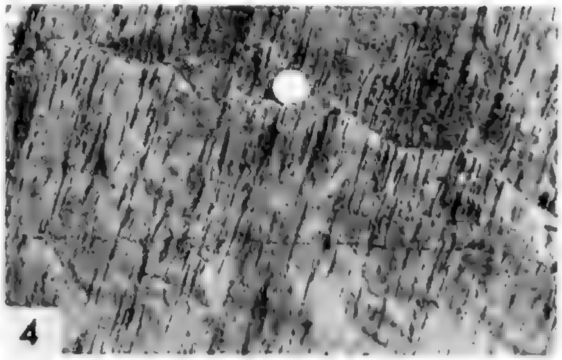
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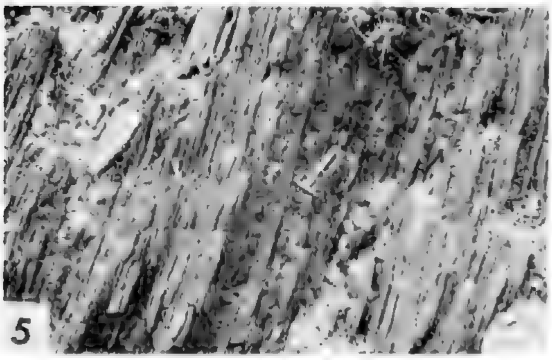
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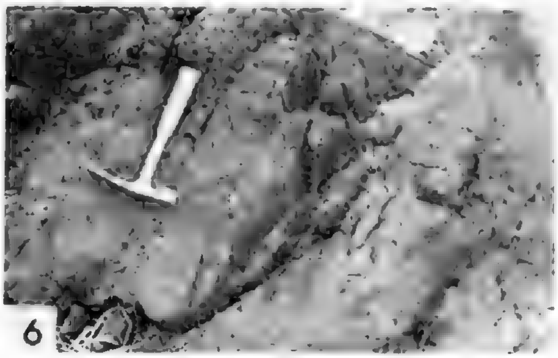
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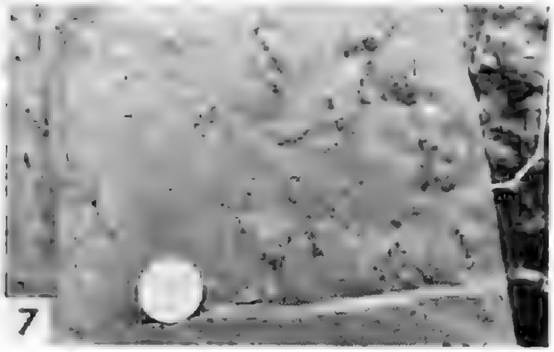
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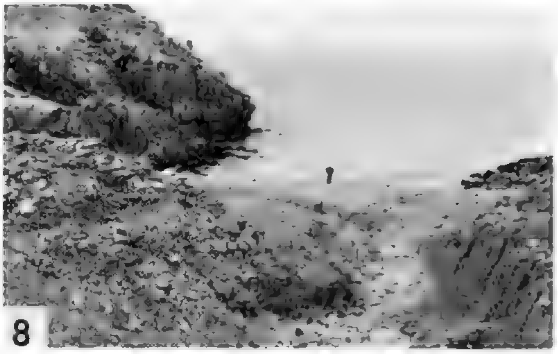
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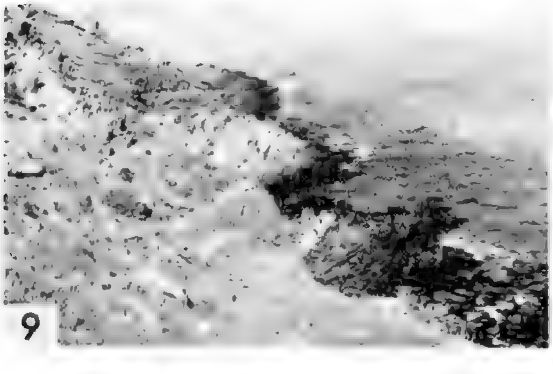
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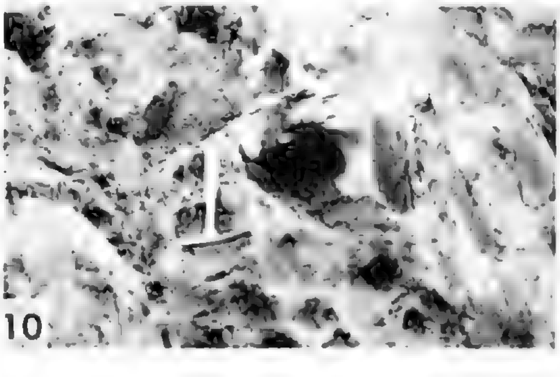
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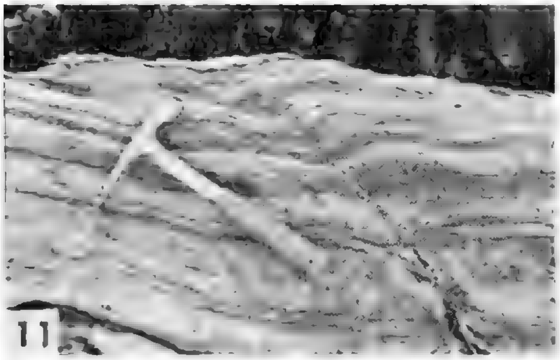
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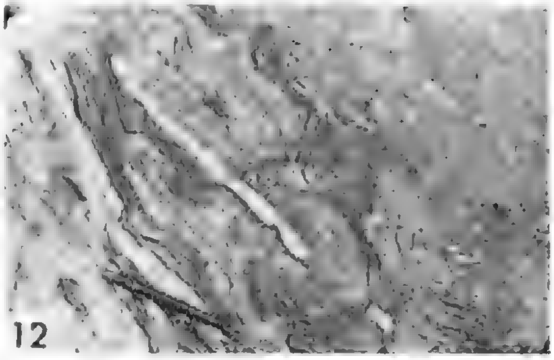
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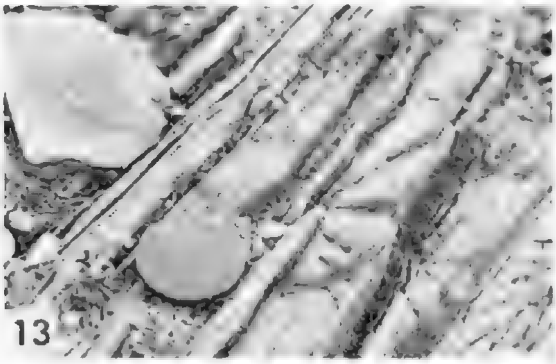
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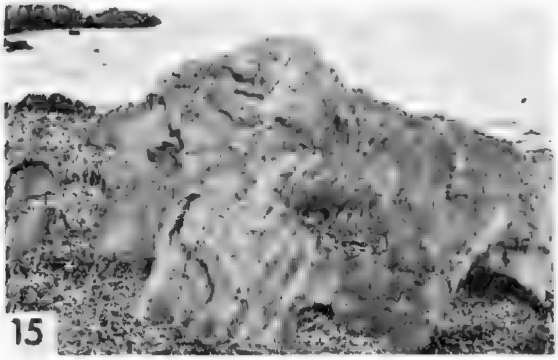
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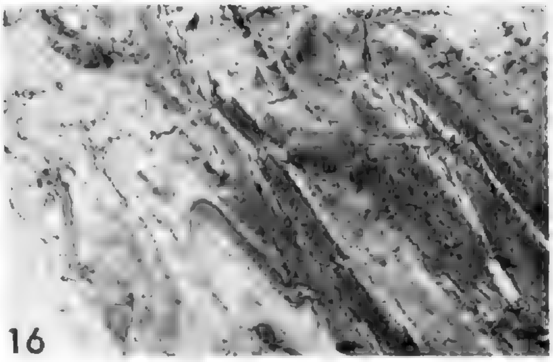
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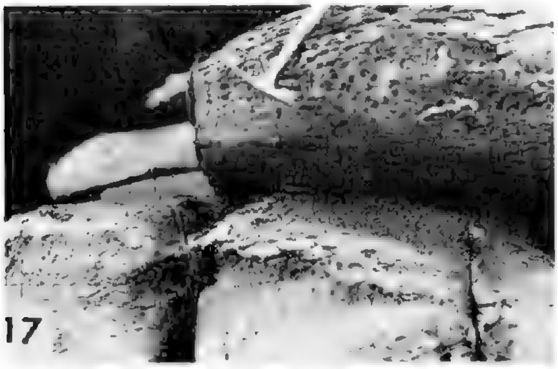
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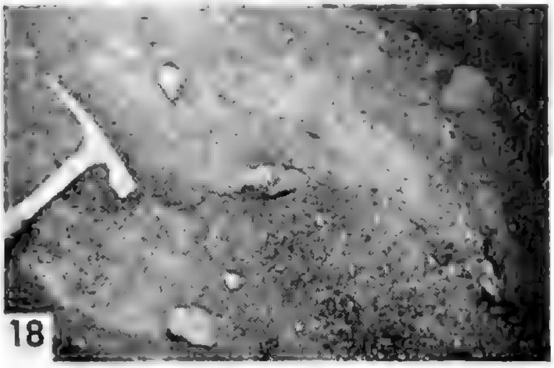
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DISCOVERY IN THE EVERARD RANGES OF A SPECIES OF LEPTODACTYLID FROG NEW TO THE FAUNA OF SOUTH AUSTRALIA

BY M. J. TYLER

Summary

Pseudophryne occidentalis (a species of leptodactylid frog formerly known from Western Australia) is reported from the Everard Ranges in the north-west of South Australia. Morphological data are provided and the species is compared with *P. bibroni* and *P. douglasi*. The Everard Ranges population bridges a major disjunction in the geographic distribution of *Pseudophryne*; it is uncertain whether it constitutes a relict in the path of a Pleistocene pluvial migration, or is the result of a more recent migration during arid conditions.

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Introduction

In November 1970, Dr. E. Matthews of the South Australian Museum visited the Everard Ranges in the north-west of South Australia, and there obtained six frogs that fell into some cardboard cups which he had sunk in the soil to trap insects. One of the specimens is *Neobatrachus centralis*, a leptodactylid species widely distributed throughout southern and central Australia and previously known to occur in the Everard Ranges. The remaining five are considered to be representatives of the leptodactylid *Pseudophryne occidentalis* Parker, previously known only from localities in the southern interior of Western Australia

Here I provide data on the morphology of the South Australian population of *P. occidentalis*, with evidence in support of the specific identification, and discuss the significance of the presence of the genus and species in this part of South Australia.

Morphology

The series comprises four adult males with snout to vent lengths of 23.3–26.1 mm, and one gravid female (26.5 mm) which have been allotted the South Australian Museum registration numbers R.11738-11742. The specimens differ from the original description of Parker (1940) only in the colour of the dorsum (dull slate in preservative instead of dull brown), and skin texture (dorsally smooth in four specimens and sparsely and very finely tubercular in the fifth; "regularly beset with small warts above, except on the snout" in the type).

Comparison With Other Species

Two species of *Pseudophryne* were previously known to occur in South Australia: *P. semimarmorata* Lucas in the lower south-east, south of Naracoorte (Woodruffe & Tyler 1968); and *P. bibroni* Gunther, extending from the northern limit of *P. semimarmorata* (with which it hybridizes) to the Flinders Ranges.

Pseudophryne semimarmorata, *P. bibroni* and all other *Pseudophryne* species occurring in south-eastern Australia possess oval-shaped, dermal glands on the distal portion of the posterior surface of the femora. In contrast, the three species of *Pseudophryne* occurring in Western Australia (*P. douglasi* Main, *P. guentheri* Boulenger and *P. occidentalis*), and the frogs collected in the Everard Ranges, lack such glands.

Main (1964) characterises *P. guentheri* by its comparatively large size (maximum snout to vent length 30 mm; 26 mm in *P. occidentalis*), single phalanx in inner toe (two in *P. occidentalis*) and possession of supra-scapular folds (absent in *P. occidentalis*).

Because Main (1964) stated that the dorsum of *P. occidentalis* and *P. bibroni* bears flattened confluent warts whereas *P. douglasi* does not, I compared the frogs from the Everard Ranges with a series of *P. douglasi* (Western Australian Museum R. 11531, 11532, 11534) and examined the skin texture of these three species. In specimens from South Australia the dorsum of *P. bibroni* varies from completely smooth to conspicuously warty, with a complete intergradation of textures. A smaller sample of Western Australian *P. occidentalis* includes some individuals with sparsely tubercular skin and others with large confluent warts, whereas the *P. douglasi* have only minute, conical tubercles more sparsely distributed than in Main's (1954) illustration of that species. Skin

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* South Australian Museum, North Terrace, Adelaide, S. Aust. 5000.

texture is evidently more variable than has been acknowledged previously: *P. douglasi* differs in this character only in the absence of the extremely warty condition.

Pseudophryne douglasi also differs from *P. occidentalis* in its habitat. Main (1971) considered the requirements of the former species to be "some form of cover associated with shallow water beneath which adult frogs can shelter", and noted that the localities at which this species has been collected are within the tropics. This contrasts with *P. occidentalis* which does not enter the tropics but extends into areas of low and unreliable rainfall, where it exists near temporary pools (Main 1965).

Habitat of the South Australian Population

The frogs were collected at Victory Well (132°30′E; 27°3′S) at the southern foot of the Everard Ranges, approximately sixty-five kilometres west of Everard Park Homestead (Fig. 1).

The pool beside which the frogs were trapped was approximately two metres in diameter and 0.3 metres deep. At the time of collection the pool was rapidly drying up, and the ground surrounding it was devoid of vegetation. Data on rainfall in this portion of South Australia assembled by the Commonwealth Bureau of Meteorology are limited, and the only data for Everard Park are for 1948 when 99 mm (3.9 inches) were recorded. At the Ernabella Mission in the Musgrave Ranges 100 km to the north of the collection site, rainfall records for the period 1935-1968 are: annual mean 234 mm (9.22 inches); maximum 424 mm (16.71 inches); minimum 52 mm (2.06 inches).

Discussion

Littlejohn (1967) lists eight anuran species (representing six genera) occurring in south-eastern Australia that form pairs with closely related species in south-western Australia, separated by a distance of at least 1,600 km. *Pseudophryne occidentalis* is included in this list and is regarded as the south-western representative of the south-eastern species *P. bibroni*. The geographic distribution of these two species is shown in Figure 1.

The postulated mechanism for speciation in such genera, viz. the multiple invasion through the intermediate area, requires evidence that on more than one occasion a corridor has existed with a higher rainfall than at present (Main, Lee & Littlejohn 1958; Littlejohn 1961; Lee 1967). The site of the corridor is considered to lie south of the Nullabor Plain, perhaps because such a traverse would minimise the distance travelled by the migrating populations. The migrations are believed to have occurred in the Pleistocene pluvial periods.

The discovery of *P. occidentalis* in the Everard Ranges extends the known geographic range of this species eastwards by 880 km, and is of importance for three reasons. Firstly, it represents the most easterly penetration of any of the south-western species; secondly, it largely bridges the 1,600 km gap between the south-western and south-eastern members of the genus; and thirdly, it lies far to the north of the postulated corridor.

At present it is unknown whether the Everard Range population represents an isolate (i.e. a portion of a formerly more widespread population now restricted by increasing aridity to a small suitable habitat), or the most eastern limit of the now continuous distribution of a species which may have invaded the area during climatic conditions comparable to the present.

Each hypothesis and explanation seems plausible, because *P. occidentalis* is particularly well adapted to desert conditions and is the only species occurring in the desert environment that lays eggs out of water (Main, Littlejohn & Lee 1959; Main 1968). The ecological versatility of this species reported by Main (1959) might have enabled it to penetrate east during conditions inhospitable to the migration of other south-western species.

The initial entry of *Pseudophryne* into Western Australia need not have been via the route utilised by species dependent upon moister conditions, and not necessarily contemporary with the migration of such species:

Fig. 1. Distribution of *Pseudophryne occidentalis* and *P. bibroni*. Distribution of *P. occidentalis* provided by Dr. G. Storr; *P. bibroni* distribution derived from specimens in S.A. Museum and published data of Moore (1961) and Littlejohn (1967).

More intensive collecting in the north-west of South Australia would clarify the matter.

Acknowledgements

I am indebted to Dr. Glen Storr (Western Australian Museum) for the loan of specimens of *Pseudophryne douglasi* and for data on the distribution of *P. occidentalis*.

Rainfall data were provided by the Commonwealth Bureau of Meteorology. Dr. W. G. Inglis (South Australian Museum) and Dr. Storr constructively criticised the manuscript.

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STRATIGRAPHIC SUBDIVISION OF THE POUND QUARTZITE (LATE PRECAMBRIAN, SOUTH AUSTRALIA)

BY B. G. FORBES

Summary

The Bonney Sandstone Member and Rawnsley Quartzite Member of the Upper Proterozoic Pound Quartzite are defined and described in a section measured in Bunyeroo Gorge about 380 km north of Adelaide, South Australia.

The Bonney Sandstone Member, previously known as the lower red member of the Pound Quartzite, is composed of reddish sandstone and siltstone, and is 305 m thick in the type section. The overlying Rawnsley Quartzite Member is composed predominantly of white sandstones, contains in its lower part the Ediacara fauna and is about 508 m thick. Both Members display a variety of sedimentary structures suggestive of shallow water conditions. To the north of the type section the members are readily identified in Brachina Gorge but not so readily in Parachilna Gorge.

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Introduction

The purpose of this paper is to name and define the already known lower reddish and upper white members of the Upper Proterozoic Pound Quartzite, South Australia. This is largely at the suggestion of Wade (1970) who has described the fossil fauna of the upper member and incidentally given much information on the lithology and distribution of the Pound Quartzite.

The term "Pound Quartzite" appears to have been used first by Mawson (1938, p. 255) who described a section just north of Parachilna Gorge. This section may thus be accepted as the type section of the Pound Quartzite, and Dalgarno & Johnson (1966) have shown its approximate position (approximate because Mawson did not show the section line on a map) on the PARACHILNA 1:250,000 geological map. On this map the upper and lower members of the Pound Quartzite have been shown between Hawker and Parachilna; this is substantially in agreement with the subdivision proposed here and that which Mawson (1941) described. Mawson recognised the two members at Wilpena Pound in a section near St. Mary Peak.

Other authors who have more recently described the Pound Quartzite and commented on previous work are Goldring & Curnow (1967, upper member at Ediacara) and Leeson (1970, Beltana area). Dalgarno & Johnson (*in* Thomson et al. 1964) discuss the Pound Quartzite in its setting in the Wilpena Group.

Stratigraphy

General

In order to arrive at a useful subdivision of the Pound Quartzite a section was measured with tape and compass in Bunyeroo Gorge, about 58 km north of Hawker, or 380 km north of Adelaide (see Fig. 1) and sections examined further north in Brachina and Parachilna Gorges.

The Pound Quartzite in Parachilna Gorge is uncharacteristic because of the extensive occurrence of reddish beds in the upper member. A more significant discrimination of the two members of the Pound Quartzite can be made in Bunyeroo Gorge in which, therefore, their type sections were measured. They are described in detail in the Appendix with a less detailed description of the Pound Quartzite type section near Parachilna Gorge.

Since no previous workers have placed any limestones in the Pound Quartzite, the base of the Pound has been chosen above the limestones of the gradational interval between the typical Wonoka Formation and the overlying Pound.

Bonney Sandstone Member of the Pound Quartzite

The Bonney Sandstone Member is named after Point Bonney on the eastern edge of Wilpena Pound. The type section of the Member is Bunyeroo Gorge, approximate lat. 31°25′S and long. 138°33′E. The Member is characterised by reddish sandstones, siltstone

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* Geological Survey of South Australia, 169 Rundle Street, Adelaide, South Australia, 5000. Published with the permission of the Director of Mines.

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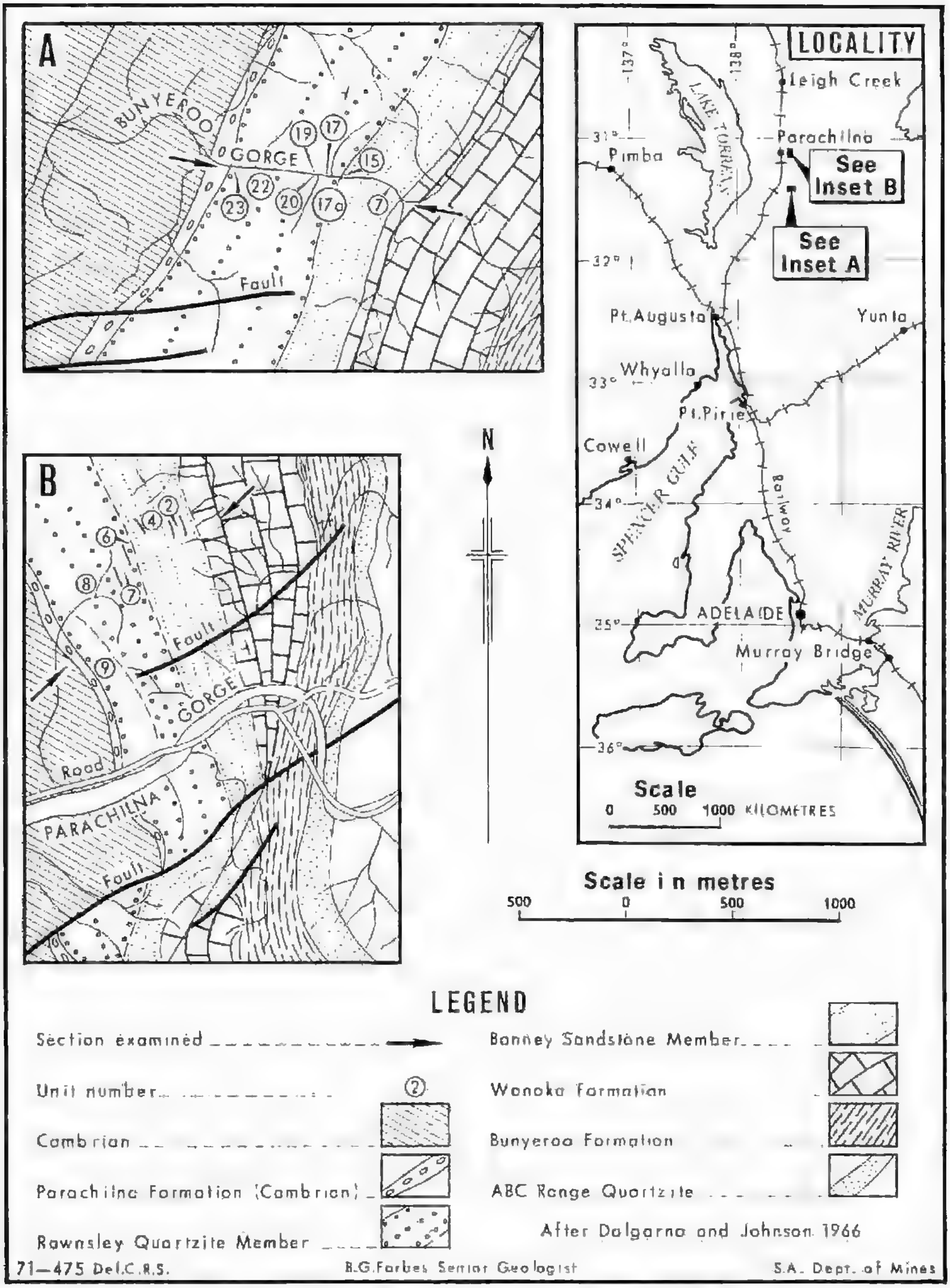

Fig. 1. A: Location of type section of Members of Pound Quartzite in Bunyeroo Gorge.
B: Section in Pound Quartzite north of Parachilna Gorge. Geology after Dalgarno & Johnson 1966.

and quartzite, flaggy to medium bedded, which overly flaggy limestone and siltstone of the Wonoka Formation and underly the harder, more quartzitic white upper member of the Pound Quartzite. The Member is about 305 m thick and dips about 55 degrees north-westerly. Harder sandstone or quartzite beds form prominent strike ridges; see Fig. 2.

The basal bed is reddish, micaceous silty sandstone which overlies a calcitic greyish or olive sandstone-siltstone sequence (Wonoka Formation) on limestone. The uppermost beds are pale reddish medium- and coarse-grained sandstones.

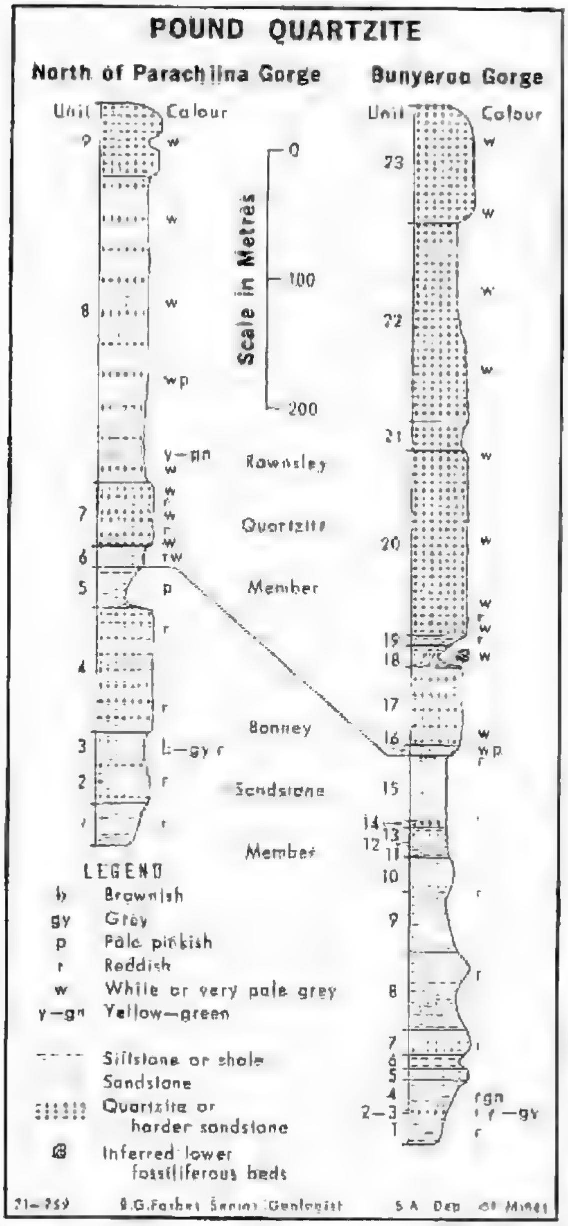

Fig. 2. Stratigraphic columns for the Pound Quartzite in Bunyeroo Gorge and north of Parachilna Gorge.

Rawnsley Quartzite Member of the Pound Quartzite

The Rawnsley Quartzite Member is named after Rawnsley Bluff, the south-eastern rampart of Wilpena Pound. The type section locality is as for the underlying Bonney Sandstone Member. Characteristic rocks are white or very light grey quartzite and sandstone; these form more prominent ridges than the underlying reddish sandstones of the lower member and the overlying softer white sandstone of the Cambrian Parachilna Formation. The Member is about 508 m thick.

The base of the Member is distinguished mainly by colour—white, as against the predominant red of the Bonney Sandstone. About 69 m above the base, succeeding sandstone and quartzite beds, are flagstones, the lowest fossiliferous bed 3 of Wade (1970, Fig. 4B). This is overlain by reddish sandstone and siltstone, then a thick sequence of sandstone and quartzite, the lowermost beds of which are fossiliferous while the higher beds form a prominent ridge. No fossils were found by the writer during measurement of the section, but Wade (1970, Table 1) lists indeterminate medusoids, *Ediacaria flindersi* Sprigg, a new species of medusoid and a trace fossil, form B of Glaessner (1969).

Recognition Elsewhere

The red and white members of the Pound Quartzite have been recognized widely in the COPLEY and PARACHILNA 1:250,000 map areas and in the north-west and eastern part of the ORROROO 1:250,000 map area, but a precise choice of boundary between the Members defined here is not always easy.

In Brachina Gorge, south side, pale reddish flaggy sandstone of the Bonney Sandstone Member is overlain by 2.2 m of white sandstone, then a thick sequence of hard, more prominent white quartzite. Since the colour boundary here between red and white sandstones is irregular the base of the Rawnsley Quartzite Member is best placed at the base of the prominent quartzite.

In Parachilna Gorge and the section examined just north of there, choice of boundary is guided by position of the lowest fossiliferous beds and by lithologic correlation of pale reddish sandstones of unit 5, Parachilna Gorge, with unit 15, Bunyeroo Gorge. The Rawnsley Quartzite Member contains many more soft sandstones and red beds in the Parachilna Gorge than in Bunyeroo Gorge.

Environment

Sedimentary structures in the Pound Quartzite have been noted in the Appendix (Bunyeroo Gorge Section) and include tabular and trough cross-beds, micro-cross-lamination, parting lineation, ripple marks, mud cracks, prints resembling rain prints, clay flakes, wavy bedding, flaser bedding (resembling lenticular deposits in ripple troughs) and slump structures.

Prints like rain prints have only been found on loose flagstones and their orientation is yet to be established. If correctly identified, they indicate subaerial exposure of muds. Mud cracks may also develop under these conditions, but none were seen at the level of the prints. Shrinkage of clay can occur under water, as indicated by White (1961; noted by Goldring & Curnow 1967, p. 207). Flaser bedding may originate in a tidal flat environment (Reineck & Wunderlich 1968). Troughs are commonly a few centimetres deep, but one of 30 cm depth was noted. Shallow marine, to possibly tidal flat, conditions are thus indicated.

Current trends shown by ripple marks and cross-bedding vary widely. In the Bonney Sandstone Member there is a slight predominance of transport to the north-east while in the Rawnsley Quartzite Member it is to the south-east. Ripple marks tend to trend both north-easterly and south-easterly in each Member. Not much significance can be attached to these results because of the few observations made.

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Appendix

In the descriptions below, quartzite refers to hard, prominently outcropping sandstones which may not all be quartzite in the strict sense; cross-beds refers to tabular cross-beds and the accompanying dimensions are the maximum thickness of the unit; ripple mark length is wave length or distance between adjacent ridges; beds refers to distance between joints which are parallel to bedding.

A. *The Pound Quartzite in Bunyeroo Gorge.*

The section was measured by 100 feet tape and compass and thicknesses of beds calculated with the aid of tables by Mandelbaum & Sanford (1952). It is underlain by the upper part of the Wonoka Formation which contains red beds very similar to the lower member of the Pound Quartzite. Colours have been described with reference to the Rock Colour Chart of the Geological Society of America.

Bonney Sandstone Member

Unit	Notes	Thickness (metres)
1	Sandstone, slightly micaceous, silty, pale reddish, fine to medium-grained, well laminated, 2–4 cm cross-beds, lenticular bedding, wavy bedding, small scale slump structures, ripple marks with 2–5 cm length and restored trends 030°, 055°, mud cracks, 5 mm–1 cm clay flakes, beds 2–30 cm; slight ridge.	26
2	Quartzite, pale reddish, weathering pale brownish grey, fine to medium-grained, laminated, ripple marks with 2–4 cm length and restored trends 20°, 045°, 100°, 3 cm cross-beds, mud cracks, 1 cm clay flakes, beds 3–12 cm; valley edge.	0.5
3	Quartzite, finely micaceous in darker laminae, pale brownish to yellowish grey, pale brownish weathering, fine to medium-grained, laminated, wavy and lenticular bedding, small-scale slump structures, beds 5 mm to 8 cm; valley edge.	0.7
4	Sandstone, siltstone, finely micaceous in part, pale greenish grey, moderate red to greyish red, weathering greenish and reddish, fine to medium-grained, laminated, ripple marks 7–10 cm length and restored trend 085°, mud cracks, cross-bedding, minor 1 cm sandy lenses, clay pellets up to 6 cm, beds 3 mm–5 cm; valley and slope.	25
5	Sandstone, moderate reddish, weathering dark reddish and pale brownish, fine to medium-grained, laminated, parting lineation with restored trend 170°, micro-cross-lamination, transport approximately NE and ?NW, beds 1–22 cm; ridge.	8
6	Partly covered interval, flaggy reddish siltstone and quartzite similar to (4); valley.	10
7	Sandstone, slightly micaceous, feldspathic, moderate red and pale to greyish red bleached in patches to pale orange, weathering pale brownish and reddish, medium-grained, laminated, cross-beds 122 cm, 10 cm and 50 cm (trough), 1 cm mud flakes; irregular to rounded ½ cm concretionary nodules stand out on weathered surface; beds 5–70 cm; ridge.	20
8	Sandstone, feldspathic, micaceous, minor shaly sandstone, siltstone, reddish colour, similar to (7), medium-grained, laminated, 10 cm cross-bed, micro-cross-lamination, trough cross-bed 30 cm by 3 m in section, nodules 1–2 cm, beds up to 65 cm; ridge and slope.	59
9	Sandstone, micaceous, feldspathic, silty, moderate red to greyish red, weathering light and dark reddish, fine to medium-grained, laminated, 4 cm cross-beds, 1–2 cm ripple marks with restored trend 160°, beds 5 mm–20 cm; poor outcrop in upper part.	47
10	Sandstone, feldspathic, micaceous, pale to moderate reddish, weathering reddish brown, grey, medium-grained, laminated, cross-beds 2 cm to 1 m, trough cross-beds 1–30 cm, beds 2 cm to 1 m; ridge-forming, but poorly outcropping.	27
11	Siltstone and flaggy sandstone, interbedded, medium reddish, fine to medium-grained, laminated, 3 cm trough cross-beds, 5 mm–9 cm beds.	10
12	Sandstone, feldspathic, pale reddish, medium-grained, laminated, 60 cm cross-bed, beds 60 cm.	0.7
13	Siltstone and sandstone, similar to (11); poor outcrop.	14
14	Quartzite and sandstone; pale reddish and reddish, weathering pale reddish to dark grey, medium-grained, 40 cm cross-bed, transport to ?ENE, ripple marks with restored trend 150°, beds 3–50 cm; slight ridge.	4
15	Sandstone, calcitic in part, ?feldspathic, very pale and darker reddish colour banding, in places moderate with white patches and veins, medium-grained with coarse-grained lenses, laminated, wavy bedding, slump structures, apparent transport to SW, ENE and NE; 6–20 cm cross-beds and trough cross-beds, somewhat massive and smooth-weathering; cave formation and pitting; 0.3 m medium-grained quartzite lens about 1.8 m below top.	50

Total thickness of Bonney Sandstone Member, units 1–15: 305 m.

Rawnsley Quartzite Member

Unit	Notes	Thickness (metres)
16	Sandstone, slightly clayey, slightly calcitic in part, white, yellowish grey, minor pale pink layers, weathering pale brownish, medium and coarse-grained, laminated, 6–20 cm cross-beds with transport ?NE and ?SE, one restored transport direction 130°, wavy bedding, flaser bedding, ripple marks with 3–4 cm length and restored trends of 020° and 030°, beds 5 cm–1 m; pitting and honeycomb weathering	8
17	Sandstone and quartzite, clayey, white, weathering greyish-orange, very pale	

Unit	Notes	Thickness (metres)
	orange, coarse and medium-grained, laminated, 5 cm cross-bed with transport ?NE, 5 cm trough cross-bed, minor layers of rounded 3 mm quartz grains; honeycomb weathering, more blocky and prominent outcrop than (16), thickness uncertain because of faulting.	69
17a	(Considered to be equivalent to 17 and apparently not faulted, south side of Bunyeroo Gorge). Sandstone and quartzite, clayey, slightly calcitic in part, white, very pale brownish, very pale pinkish coarse and medium-grained, laminated, 25 and 35 cm cross-beds with transport south-easterly, wavy bedding, penecontemporaneous faults, beds 1–60 cm; weathering pits and honeycomb weathering, ridge-forming.	61
18	Sandstone (flagstone), pale grey, pale reddish, weathering pale orange or yellowish grey, fine-grained, well-laminated, bedding slightly lenticular in places, slight cross-beds or troughs 1–2 cm, rare circular ?rain prints, flaggy, beds ½–12 cm; outcrop on valley side east of prominent ridge, northward extension of fossiliferous bed 3 (Wade 1970).	17
19	Sandstone, silty sandstone, siltstone, moderate reddish, pale to greyish red, fine-grained, well laminated, bedding partly wavy and lenticular, 4 cm trough cross-bed, beds 2 mm–13 cm averaging 1–2 cm; valley side, northward extension of fossiliferous bed 5 (Wade 1970).	8
20	Quartzite with minor reddish coarse-grained sandstone, clayey, white, weathering pale brownish or greyish orange, medium and coarse-grained, laminated, bedding slightly lenticular or wedge-like, 6–25 cm cross-beds with transport SE, SSE, raised circular ?concretionary structures, mud cracks, ripple marks with length 2½, 10 cm, one ripple trend 050°, current ripples indicate transport 290°, 330°, reddish sandstone 16–60 cm troughs trend 020–030°, 1–3 cm pale greenish grey shale pellets, 1–4 cm rounded white concretionary patches, beds 2–80 cm; minor honeycomb weathering, ridge-former; the base is fossiliferous bed 6 (Wade 1970).	145
21	Quartzite, clayey, slightly calcareous, white, pale brownish weathering, medium-grained, 2½ cm clay pellet cavities, 10 cm cross-bed, transport to SE, beds 3 cm–2 m; weathering pits, outcrop not as prominent or blocky as (20).	23
22	Quartzite, slightly clayey and slightly calcitic in part, white, very light grey, weathering pale brownish, medium and coarse-grained, laminated, 4–40 cm cross-beds, transport to SW, SE, ESE, 13–17 cm trough cross-beds, clay pellet cavities up to 6 cm, beds 3–95 cm; ridge-forming, upper part covered by colluvium.	155
23	Quartzite, slightly clayey, white to very light grey, weathering reddish brown, pale brownish, generally medium-grained, some coarse-grained layers, laminated, 12–40 cm cross-beds with transport approximately ?S, SE, W, ENE, 9–15 cm trough cross-beds, ripple marks with length 1–4 cm and restored trends approximately 010°, 045°, 120°, 135°, 180°, interference ripple marks, 1–2 cm clay pellet cavities, 1 cm white rounded concretions in upper part, good ½-25 cm layering in upper part, beds 13–85 cm; ridge forming—harder than the overlying white sandstones of the Parachilna Formation.	91

Rawnsley Quartzite Member, units 16–23:

Total thickness, 508 m.

Total thickness of Pound Quartzite: 815

B. *The Pound Quartzite in a type section north of Parachilna Gorge.*

(Position as on Blinman 1:63,360 geological map, Dalgarno, Johnson & Coats 1964). The Pound Quartzite in the area examined is underlain immediately (under unit 1) by a thin limestone, then flaggy reddish sandstone and siltstone and further thicker limestone beds of the Wonoka Formation. The Pound Quartzite is overlain by softer, coarse-grained, clayey sandstone of the Parachilna Formation. Thicknesses are approximate and have been measured from an air photo (Blinman run 2, 9521, scale approximately 1:50,000).

Unit	Notes	Thickness (metres)
	BONNEY SANDSTONE MEMBER	
1	Sandstone and siltstone, slightly micaceous, reddish, laminated, flaggy; poorly exposed on east-facing slope.	33
2	Sandstone and quartzite, slightly clayey, paler reddish and more prominently outcropping than (1); medium-grained, laminated, flaggy to medium-bedded, cross-bedding, clay pellet cavities; upper, steep, east-facing, slope.	33

Unit	Notes	Thickness (metres)
3	Sandstone, brownish-grey, and reddish, flaggy, clay pellet cavities; eastern side of ridge top.	21
4	Quartzite (and poorly outcropping sandstone), slightly clayey, pale reddish, medium-grained, laminated, medium-bedded, clay pellet cavities, ripple marks, 2 cm brown spots, 1–2 cm white concretionary spots; ridge crest and upper western slope.	97
5	Sandstone, softer, pale pinkish, medium and coarse-grained, laminated, partly flaggy, cross-bedding, smooth and massive outcrop in valley.	30
	Total thickness of Bonney Sandstone Member: 217 m.	

RAWNSLEY QUARTZITE MEMBER

Unit	Notes	Thickness (metres)
6	Sandstone, similar to and grading into (5) but with harder white rippled or wavy bedded sandstone layers ½–1 cm thick, becoming whiter in upper part, honeycomb weathering; forms an east-facing cliff.	18
7	Quartzite, slightly clayey, white or pale pinkish, medium-grained, laminated, medium-bedded to flaggy, with minor reddish, flaggy siltstone and sandstone, clay pellet cavities, ridge-former.	49
8	Sandstone and quartzite, clayey, white, very pale grey or pale pinkish, fine to coarse-grained, laminated, flaggy, cross-bedding, ripple marks; minor thin, pale yellow green siltstone layers in lower part, generally softer than adjacent units and resembling (5); honeycomb weathering.	238
9	Quartzite, partly clayey, white or very pale grey, medium and coarse-grained, laminated, medium-bedded, cross-bedding; ridge former.	58
	Total thickness of Rawnsley Quartzite Member: 363 m.	
	Total thickness of Pound Quartzite:	580

NINE NEW SPECIES OF SOLANUM FROM AUSTRALIA

BY D. E. SYMON

Summary

The descriptions and illustrations of nine new species of Solanum are given.

NINE NEW SPECIES OF *SOLANUM* FROM AUSTRALIA

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Summary

The descriptions and illustrations of nine new species of *Solanum* are given.

Introduction

Several recent collecting trips, especially in north-western Australia, have added considerably to the material available of *Solanum* and to an understanding of the genus in Australia. The area is proving to be most interesting in the distribution of some sections of the genus. All the collections known to date of the androdioecious species are concentrated in this area, and although more widespread, species belong to Section *Melongena* Nees are found mainly in the north-western parts of Australia. The infrageneric classification of the genus as a whole is still quite inadequate, partly due to the lack of any recent comprehensive monograph and the very uneven state of knowledge of the genus. The tuber-bearing Section *Potatoe* Walp. is relatively well known and has had intensive taxonomic attention, whereas there are still many undescribed species in Australia and South America in the Sections with stellate hairs.

In the following descriptions the standard abbreviations for herbaria have been used.

Solanum cleistogamum Symon sp. nov.

Herba usque 60 cm alta, effusa, perennis et fortasse colonialis vel nonnunquam annuus; caulibus pro ratione tenuibus. Partes omnes pilis stellatis densis approximatis minutis pubescentes, adspectu generali griseo-viridi plus minusve discolori. *Spinae* usque 8 mm longae, tenues, rectae et pallidae, in caule, petiolo et calyce copiosae, in pedunculo, pedicello, paginis superioribus et inferioribus pauciores vel absentes. *Folia* 3–8 x 2–5 cm, ambitu ovata usque ovato-lanceolata, margine integro vel repando cum lobis indistincte evolutis, sinu et apice loborum lato et rotundato, apice folii acutato, basi truncata usque subcordata, plerumque inaequali.

Inflorescentia cymosa 1–4 flora, flore basali saepe sessili (sed pedicellato) et pedunculo (flos basalis nullus) vel rhachis floralis 1–4 cm, floribus pauci apicem versus fasciculatis c pedicellus c. 1 cm, tubus calycis 2–3 mm spinosus; lobi calycis 2–3 mm, lineares, espinosi; corolla c. 1 cm diam., pallide caesia plerumque clausa remanens vel se tarde apertens; filamenta 1.5–2 mm, incurva; antherae 2.5–3 mm; ovarium 1 mm diam., glabrum; stylus 5 mm, pallidus; stigma viride. *Pedunculus fructifer* 2.5–4 cm, pedicellus 2–2.5 cm, elongatus et plerumque valde deflexus, calyx auctus et basem fructus tegens: *Bacca* matura c. 1 cm diam., globosa, initio pallide viridis, succulenta matura translucida vel purpureo suffusa. Semina 2.5–3 mm, pallida, minute reticulata.

> *Typus: D. E. Symon* 5418. 1.vii.1967, about 32 km north of Onslow, Western Australia. Common in small depressions in *Triodia* sand plain. Annual or short lived shrub, sprawling habit, possibly cleistogamous. (PERTH (holotypus), ADW, CANB, K, L).

FIG. 1

A sprawling *herb* to 60 cm long, an herbaceous perennial and possibly colonial or sometimes annual, stems relatively slender. All parts pubescent with close, dense, minute stellate hairs, general aspect grey-green, slightly discolorous. *Spines* to 8 mm, slender, straight, pale, common on the stem, petiole, calyx, less common or absent on peduncle, pedicel and upper and lower leaf surface. *Leaves* 3–8 x 2.5 cm, ovate to ovate-lanceolate in outline, entire or repand with a number of shallow, weakly developed lobes, the sinus and lobe apex broad and rounded, leaf apex acute, base truncate to subcordate, usually very unequal.

Inflorescence a 1–4 flowered cyme, the basal flower often adjacent to the stem and the peduncle (if no basal flower) or floral rhachis 1–4 cm, the few flowers clustered towards the end. Pedicel c. 1 cm; calyx tube 2–3 mm, spiny; calyx lobes 2–3 mm, linear, spineless; *corolla* c. 1 cm diam., rotate, pale lavender, frequently remaining unopened or opening tardily; filaments 1.5–2 mm, incurved; anthers 2.5–3 mm; ovary 1 mm diam. glabrous; style 5 mm, pale, stigma green, at or below the level of the anther pores. *Fruiting peduncle* 1.5–4 cm.

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pedicel 2–2.5 cm, lengthened and usually markedly deflexed, calyx enlarged to cover the base of the fruit. Mature *berry* c. 1 cm diam., globose; finally pale yellow-green, or slightly flushed with purple, succulent and slightly translucent, very aromatic and readily shed without the pedicel. *Seeds* 2.5–3 mm, pale, minutely reticulate; seventeen fruits from plants in cultivation from *Symon* 5418 had (27–) 40 (–54) seeds per fruit. *Chromosome number*, n = 12 (*Symon* 5418) counted by Barbara Randell.

This species has been confused with *S. ellipticum* R. Br. sensu lato and *S. horridum* Dun. It differs from the former in having smaller (about 1 cm instead of 2–3 cm diam.), paler, frequently cleistogamous flowers, smaller (about 1 cm instead of 1.5–2 cm diam.), deciduous and aromatic fruit and smaller, weakly lobed, leaves. From the latter it differs in having smaller flowers (about 1 cm instead of 1.5–2 cm diam.), more slender stems, longer and more slender peduncles (about 2.5–4 cm instead of 1–2 cm) and smaller fruit (about 1 cm instead of 2 cm diam.) of different texture. Factors controlling the opening of the flowers are not known. Plants were collected in the field in which no open flowers could be found. Plants grown from seed from these were substantially cleistogamous but did at times produce flowers which opened. Herbarium collections show that plants do at times produce open flowers in the field.

The species is widely spread across the drier areas of northern Australia, and like *S. lucani* F. Muell. may be found in two contrasting ecological sites, either in well drained sites in rocky outcrops, or in slight depressions and apparently moister areas in *Triodia* sand plains as well as being found in some mallee woodlands. A representative collection from W. Australia is *Symon* 5448, 4.vii.1967, 115 km north of Geraldton, from "Mallee woodland, with fairly dense *Cassia* and *Acacia* shrubs on a stony rise", distributed to AD, ADW, MEL, PERTH; and for the Northern Territory, *Chippendale*, 31.vii.1958, Curlew Waterhole, Lander River, 113 km north-west of Willowra H.S.—"Low spreadng perennial, corolla pale purple, infrequent in flooded soil near waterhole", distributed to ADW, CANB, NT, NSW.

The specific epithet is derived from the frequently cleistogamous habit of the species.

Solanum eburneum Symon sp. nov.

Herba vel suffrutex effusus, colonialis, perennis, usque 50 cm altus, caulibus haud diu persistentibus vel basi lignosis. Omnes partes dense pubescentes, pilis stellatis nonnunquam laxis et pallidis adspectu generali griseo-viridi leviter discolori. *Spinae* usque 5 mm longae, in caulibus pedicellis fructiferis et calyce copiosae vel dispersae, in petiolis, paginis foliorum superioribus et inferioribus pauciores. *Folia* 2.5–6 x 1–4 cm, forma modice variabilia, ambitu ovata vel elliptica, sed cum lobis 5–7 profundis vel brevioribus, sinubus inferioribus usque ad tres partes costam versus attingentibus, ceteris brevioribus, sinubus plerumque rotundatis, lobis oblongis vel rotundatis apice rotundato vel acuto, basi inaequali truncata usque cuneata; interdum foliola fere lanceolata adsunt.

Inflorescentia e flore hermaphrodito plus minusve pedunculato infra cyma florum masculorum sistens. Flos hermaphroditus: pedunculus communis 0–1 cm, pedicellus c. 1 cm spinosus, tubus calycis 2–3 mm spinosus, lobi 5 mm triangulares, acumina distincto, saepe lobis 2–3 partim conjunctis calyci adspectum bilabiatum praebentibus; *corolla* 3 cm diam., pentagona; filamenta 1–2 mm; antherae 7 mm; ovarium globosum, apice pilis paucis glandulosis praeditum; stylus c. 1 cm; stigma capitatum.

Flos masculus: rhachis floralis 1–6 cm, 3-usque multiflorus; calyx c. 5 mm longus, bilabiatus; *corolla* 2–3 cm diam., pentagona; filamenta brevis antherae c. 6 mm, oblongae, superne leviter angustatae; ovarium deficiens. *Pedicellus fructifer* 2–3 cm, deflexus, spinis dispersis; calycis lobi 1–1.5 cm, triangulares, spinosi, demum recurvati; *bacca* 1.5–2 cm diam., globosa, initio viridifasciata, demum albido-viridi-lutea. Semen 2–2.5 mm, fusco-brunneum vel nigrum, minute reticulatum.

> *Typus: D. E. Symon* 6954, 19.v.1971, about 19 km east of the East Baines River, Northern Territory. In seasonally dry shallow *Melaleuca* swamps or flats. Approximate Lat. 15°50′S, Long. 130°00′E. (CANB (holotypus), ADW, K, NT, PERTH)

FIG. 2

A sprawling, herbaceous or subshrubby, colonial *perennial* to 0.5 m wide, the stems short lived or slightly woody at the base. All parts densely pubescent with somewhat loose, pale, stellate hairs, general aspect grey-green. *Spines* to 5 mm, abundant or scattered on the stems, fruiting pedicels and the spiny calyx, less common on petioles, upper and lower leaf surfaces. *Leaves* 2.5–6 x 1.4 cm, rather variable in shape, ovate to elliptic in outline but with 5–7 deep or shallow lobes, the lower lobes cut to three-quarters of the way to the midvein, others shallower; sinuses mostly rounded, apex rounded or acute; leaf base unequal; truncate to cuneate, occasional almost lanceolate leaflets with few lobes may occur.

Inflorescence one hermaphrodite flower surmounted by a cyme of male flowers. Hermaphrodite flower: situated 0–1 cm from the base of the peduncle; pedicel c. 1 cm, spiny; calyx tube 2–3 mm, spiny; lobes 5 mm triangular, the tips distinct, often 2–3 lobes partially fused to give the calyx a two lipped appearance; *corolla* 3 cm diam. pentagonal; filaments 1–2 mm; anthers 7 mm; ovary globular with a few glandular hairs at the summit; style c. 1 cm; stigma capitate.

Male flower: peduncle 1–6 cm, with 3 to many flowers, calyx c. 5 mm long, sometimes two lipped; *corolla* 2–3 cm diam., pentagonal, filaments short; anthers c. 6 mm, oblong, slightly tapered; ovary lacking. *Fruiting pedicel* 2–3 cm, deflexed, with scattered spines; calyx lobes 1–1.5 cm, triangular, spiny, finally raised or recurved. *berry* 1.5–2.5 cm diam., globular, at first striped green, later pale whitish-greenish-yellow. *Seeds* 2–2.5 mm, very dark brown or black, minutely reticulate. Ten fruits had (29–) 57 (–99) seeds per fruit.

This species is restricted in its distribution to a few large, seasonally dry, shallow, *Melaleuca* swamps between the Victoria River and the Western Australian border in the north-west of the Northern Territory. Nine collections have been seen. The species is most closely related to *S. diversiflorum* F. Muell. with which it shares a relatively dwarf habit, lobed leaves, similar pubescence, and an andromonoecious inflorescence. It differs from *S. diversiflorum* in its sprawling rather than intricate growth habit, larger, less deeply lobed leaves, smaller number of male flowers, and in its smaller fruits with fewer and smaller seeds.

A representative collection is *Symon* 5229, 18.vi.1967, 24 km east of the East Baines river, N.T. distributed to ADW, B, CANB, K, NSW, NT, PERTH, US.

The specific epithet refers to the ivory colour of the fruits.

Solanum gilesii Symon sp. nov.

Frutex parvus et colonialis usque 0.5 m altus, effusus vel erectus, partes omnes pilis stellatis densis et approximatis pubescentes, caules et calyces, conspicue cinnamonei. Folia discolora paginis superioribus pallidis sed adspectu generali cinnamoneo. *Spinae* usque 5 mm longae, rectae tenues cinnamoneae in caule dispersae, in petiolo paucae, a foliis absentes, in calyce conspicue copiosae. *Folia* 2–4 x 1–3 cm, ambitu ovata usque oblongo-ovata 8 lobis indistincte evolutis, sinubus non profundis et rotundatis, apice folii obtuso vel acuto, margine repando, basi truncata usque late cuneata, aequali vel inaequali.

Inflorescentia cymosa brevis 1–2 flora, pedunculus 0–5 mm, floccosus ferrugineus pubescens; pedicellus 5–7 mm, calycis tubus c. 5 mm longus, lobis 1–3 mm late triangulatis. *Corolla* 2.5 cm diam., pentagonalis, filamenta 2–3 mm longa tenua, antherae 7–8 mm conspicue apicem versus decrescentes laxe rectae, ovarium glabrum, stylus 10–15 mm rectus, pilis stellatis infra sparsim pubescentes plus minusve sigmoideus, stigma terminalis capitata perixigue bilobata. Pedunculus fructifer deflexus 1.0–1.5 cm, calycis tubus 1–1.5 cm diam., auctus baccam includens (sed pauci fructus notati sunt), conspicue spinescens, lobis c. 3–5 mm longis triangularibus et sine spinis; *bacca* c. 1 cm diam. globosa; fructus maturas ab auctore non visus

Typus: A. S. George 9014, 27.vii.1967, about 11 km west of Dovers Hills, northern Gibsons Desert, Western Australia. Spreading shrub 30–40 cm, flowers pale purple. Approximate Lat. 23°05′S, Long. 128°35′E. (PERTH—holotypus).

FIG. 3

A small colonial *shrub* to 0.5 m, spreading or erect, all parts densely and closely pubescent with stellate hairs strikingly orange-brown on the younger growing points, stems and calyces. The leaves brownish green above, paler below, distinctly discolorous, general aspect brightly ferruginous golden-brown on the young parts. *Spines* to 5 mm, straight, fine, orange-brown, scattered on the stems, a few on the petiole, absent from the leaves, abundant and conspicuous on the calyx. *Leaves* 2–4 x 1–3 cm, ovate to oblong-ovate in outline and with up to 8 broad shallow lobes, the sinuses shallow and rounded, the leaf apex rounded or acute, the margin undulate-repand, leaf base truncate to broadly cuneate, equal or unequal.

Inflorescence a short cyme of 1–2 flowers; peduncle 0–5 mm, floccose ferruginous pubescent; pedicel 5–7 mm; calyx tube about 5 mm long, the lobes 1–3 mm broadly triangular; corolla 2.5 cm diam., pentagonal the interpetalar membrane not exceeding the petal tip; filaments 2–3 mm long, slender; anthers 7–8 mm distinctly tapered apically, loosely erect; ovary glabrous; style 10–15 mm erect, sparsely stellate pubescent below, slightly sigmoid; stigma terminal, capitate, very slightly bilobed. Fruiting pedicels deflexed, 1.0–1.5 cm, calyx tube 1–1.5 cm diam., enlarged to cover the fruit (but very few fruits have been seen), conspicuously spiny, the lobes about 3–5 mm long, triangular, spineless; *berry* about 1 cm diam., globular, colour and texture when mature not known. Seeds not seen.

The species is sparsely distributed in Central Australia in the general area of Lake Mackay in the northern Gibsons Desert. Eight collections have been seen. *S. gilesii* is a distinctive species and is most closely related to *S. lasiophyllum* Dun. from which, however, it differs quite clearly. The new species has discolorous rather than concolorous leaves, the tomentum on the leaves is sparse above, the leaves are also smaller and usually have a distinctly undulate-sinuate margin. The coloured spines on the tips and calyces are striking. Table 1 summarises some comparisons between *S. gilesii* and related species.

A representative collection for Western Australia is that by *George* 8909, 25.vii.1967 North-east of Sir Frederick Range. In ADW and PERTH, and for the Northern Territory is one by *Latz* 692, 30.vii.1970, 65 km south-south-west of The Granites.

The species is named after the Australian explorer, E. Giles, who first collected it in 1876.

TABLE 1

Comparisons between S. gilesii, S. lachnophyllum, *and related species.*

	Leaf tomentum	Spines	Leaf shape	Approx. leaf size cm	Fruit shape	Fruit No.
S. gabrielae Domin	sericeous	pale	ovate to ovate-lanceolate	5 x 3	globose	1–4
S. gilesii Symon	sparse above	orange-brown	ovate to oblong-ovate	3 x 2	globose	1–2
S. lachnophyllum Symon	very dense woolly	pale	ovate-lanceolate	6 x 2.5	ovoid	1–2
S. lasiophyllum Dun.	woolly	pale	ovate to broad elliptic	5 x 4	globose	1–6

Solanum karsensis Symon sp. nov.

Herba perennis, colonialis, usque 25 cm; adspectu generali griseo-viridi, plus minusve discolori; partes omnes pilis stellatis densis approximatis pallidis pubescentes. *Spinae* usque 1 cm, pallidae, firmae, plus minusve recurvatae, in caulibus sparsae vel deficientes, ceterum rarae vel nullae. *Folia* 1.5–2.5 x 1–1.5 cm, ambitu ovata, margine undulato, usque quinque-lobata, lobus brevibus et indistinctis, lobis inferioribus melius evolutis; apex laminae et loborum rotundatus; basi cuneata vel truncata; petiolo 3–10 mm longo, crassiusculo.

Inflorescentia cymosa, extra-axillaris, usque 12-flora; pedunculus 0–1 (?5) cm, rhachis floralis 1–2 (4) cm; pedicellus 4–5 mm, tubus calycis 3–5 mm; lobi 2–4 mm, triangulares; acumina 1 mm, brevia; corolla 2 cm diam., rotata, purpurea; filamenta 1 mm crassa; antherae 3 mm, oblongae; ovarium apice pilis glandulosis paucis instructum; stylus 1 cm, erectus. *Pedicelli fructiferi* 1–1.5 cm, reflexi; tubus calycis usque 7–10 mm diam. auctus, baccam includens, orificio parvo saepe lacerato; lobi calycis 2–3 mm longi, vix accrescentes; bacca c. 7 mm diam., globosa, colore et textura ignota.

Typus: A. Smith, Dec. 1961, "Tara Downs", Wentworth, New South Wales. (NSW 59352 (holotypus)).

FIG. 4

A colonial herbaceous *perennial* to 25 cm high. All parts pubescent with dense, close, pale stellate hairs, general aspect grey green, slightly discolorous. *Spines* to 1.5 cm, pale, firm, straight or slightly recurved, pubescent in the lower half, scattered on the stems, rarely lacking, rare or absent on any other parts. *Leaves* 1.5–2.5 x 1–1.5 cm, ovate in outline, margin undulate and with up to 5 shallow and weakly developed lobes, the lower lobes more often present. Leaf and lobe apex rounded, base cuneate to truncate; petiole 3–10 mm, thickish.

Inflorescence a few (to 12) flowered cyme from an extra-axillary position. Peduncle 0–1 (?5) cm, floral rhachis 1–2 (4) cm (when the peduncle is absent the lower flower is adjacent to the stem), pedicel 4–5 mm; calyx tube 3–5 mm, lobes 2-4 mm triangular, lobe tips 1 mm, short; *corolla* 2 cm diam., rotate, purple; filaments 1 mm, thick; anthers 3 mm, oblong; ovary with a few glandular hairs towards the summit; style 1 cm; erect. *Fruiting pedicels* 1–1.5 cm, deflexed, calyx tube 7–10 mm diam. enlarged to cover the berry, the orifice small, often torn, calyx lobes not much enlarged, 2–3 mm long; *berry* about 7 mm diam., globular, colour and texture not known. *Seeds* 4–5 mm long, relatively large, dark, minutely reticulate but this is frequently obscured by adherent pitch-like gum, few (about 4) seeds per fruit.

The new species is restricted in its distribution to the western parts of New South Wales, mainly between the Rivers Darling and Lachlan. Twelve collections have been seen. It is most closely related to *S. oligacanthum* F. Muell, with which it shares an erect habit, relatively small, shallowly lobed leaves, rotate corolla, small fruits and dark seeds. It differs from *S. oligacanthum* in its dwarfer stature, larger spines, longer leaves, and enlarged calyx enveloping the fruit.

A representative collection is *Macgillivray* 741, 16.x.1921, Kars Station, western N.S.W., now at ADW and NSW.

The specific epithet refers to Kars Station where it was early collected.

Solanum lachnophyllum Symon, sp. nov.

Frutex 60 cm, densus et effusus. Partes omnes pilis stellatis pallidis dense lanato-pubescentes, adspectu generali cinereo, concolori. *Spinae* usque 1 cm, inaequales, tenues, rectae, pallidae, in caule copiosae, in petiolo, paginis foliorum superioribus et inferioribus, pedunculo et pedicello pauciores. *Folia* 5–8 x 2–3 cm, ovato-lanceolata, margine integro, apice acutato, basi cuneata usque rotundata; petiolo 2–5 mm, pro ratione brevi et crassa.

Inflorescentia cymosa, extra-axillaris, 2–3 flora, pedunculus 1–1.5 cm, pedicellus 5 mm, tubus calycis c. 7 mm, campanulatus, lobi c. 5 mm triangulares, corolla 2–3 cm, pentagona. Antherae ovarium et stylus non visi. Pedicellus fructifer 1–1.5 cm, deflexus; tubus calycis usque 2 cm longus, auctus, baccam includens; *bacca* 1.5–2 cm longa, ovata usque ovato-conica.

> *Typus: C. A. Gardner* 7871, 16.x.1945, stony hillside 58 km east of Meekatharra, Western Australia. Dense, widely branched shrub 30–60 cm high, leaves thick, soft, hairy-tomentose, flowers violet. (PERTH (holotypus).)

FIG. 5

A dense, spreading small *shrub* to 60 cm high. All parts densely woolly pubescent with pale stellate hairs, general aspect grey, concolorous. *Spines* to 1 cm, unequal, fine, straight, pale, abundant on the stem, fewer on the petiole, upper and lower leaf surface, peduncle, pedicel and calyx. *Leaves* 5–8 x 2–3 cm, entire, ovate-lanceolate, apex acute, base cuneate to rounded; petiole 2–5 mm, short and thick.

Inflorescence a cyme with 2–3 flowers; peduncle 1–1.5 cm, pedicel 5 mm; calyx tube c. 7 mm campanulate, the lobes c. 5 mm, triangular; *corolla* 2–3 cm, pentagonal, anthers, ovary and style not seen. *Fruiting pedicel* deflexed, calyx tube to 2 cm, enlarged to enclose the berry completely, *berry* 1.5–2 cm long, ovate to ovate-conical, colour at maturity not known.

Except for one collection, the species is confined to an area between Wiluna and Meekatharra, Western Australia. Five collections have been seen.

It is most closely related to *S. lasiophyllum* Dun. with which it shares a dense tomentum and enlarged and enveloping calyx. It differs from *S. lasiophyllum* Dun. in having an exceptionally thick, woolly blanket-like tomentum, longer narrower leaves and ovoid rather than globose fruits. A table of comparisons with related species is given under *S. gilesii* Symon.

A representative collection is that by *Speck* 1484, 18.x.1958, 52 km west of Wiluna in the Nullagine Hills, now at CANB.

The specific epithet refers to the blanket-like tomentum on the leaves.

Solanum leopoldensis Symon sp. nov.

Frutex 0.5–1 m altus et 1–1.5 m latus intricatus effusus dioicus colonialis. *Spinae* 1–6 mm, copiosae in caule, in paginis superioribus et inferioribus in pedunculo in pedicello, in calyce spinosissimo, rectae aut plus minusve recurvatae, tenues, pallidae. Folia adspectu virida sed pilis stellatis densis minutis; pilis minutis glandulosis pubescentia. *Folia* (2–) 5 (–8) x (1–) 1.5 (–3) cm, lanceolata, lobis triangularibus in margine fere aequaliter positis, sinubus rotundatis ad tertiam partem costam versus fissis, lobo et apice acuto vel acuminato, basi cuneata aequali vel inaequali; petiolo 0–5 mm brevi.

Inflorescentia e flore singulari hermaphrodito sistentes et e cymis florum masculorum in plantis discretis. Flores masculi in cyma usque 11-flores pedunculus 0–3 cm, rhachis 2–3 cm, pedicellus c. 5–8 mm tenuis; tubus calycis brevis apertusque, lobi 5 mm obtuse triangulares ad lanceolatos interdum partim conjuncti, apices 1–2 mm lineares, *corolla* 3 cm diam., late stellata rotata, apices distincti 1–2 mm, lilacina; filamenta 1–2 mm brevia; antherae 5 mm, lanceolatae erectae; sine ovario. Flores hermaphroditi singulares; pedicellus 5–10 mm; tubus calycis 5–6 mm spinosissimus; apices 5 mm lineares discreti paucis spinis; *corolla* usque 3 cm diam. late stellata rotata; filamenta 2 mm, antherae 5 mm, decrescentes, approximate erectae, stylus 2 mm ultra antherae apices extans; stigma terminalis plus minusve magna et pallida. *Fructus* 1.5–2 cm diam., depressus globularis, in spinosissimo truncato calycis tubo inclusus, apices lobae 0.5–1 cm lineares spinosi, color et textura fructus maturi incogniti sed aliquot in herba duri et firmi inventi sunt. *Semina* 1.5–2 mm longa, distincte minute reticulata brunnea, 580 in uno fructo.

Typus: D. E. Symon 7040, 26.v.1971, from rocky gully cleft at the base of Bold Bluff, King Leopold Ranges, Western Australia. A dark green spreading fruit-bearing plant. Approximate Lat. 17°17′S, Long. 125°25′E. (PERTH (holotypus). ADW, CANB, K, L, NT).

FIG. 6

An intricate, spreading, dioecious *shrub* 0.5–1 m high and 1–1.5 m wide forming small colonies. *Spines* 1–6 mm, abundant on stems, upper and lower leaf surfaces, peduncles, pedicels, and the very spiny calyx, straight or slightly recurved, slender, pale coloured. Leaves green in aspect, but densely covered with minute stellate hairs whose central cell is very short and broad and lateral cells rather short and blunt, minute glandular hairs also present. *Leaves* (2–) 5 (–8) x (1–) 1.5 (–3) cm, lanceolate, with (7–) 9 (–13) triangular lobes fairly evenly spaced along the margin, sinuses rounded and cut one third of the way to the midrib, lobe and leaf apex acute or acuminate, base cuneate, equal or unequal; petiole 0–5 mm, short.

Inflorescences consist of solitary hermaphrodite flowers and cymes of male flowers on separate plants. *Male flowers* in a cyme of up to 11 flowers, from extra axillary position, peduncle 0–3 cm, rhachis 2–3 cm, pedicel 5–8 mm, slender; calyx tube short and open, the lobes 5 mm, bluntly triangular to lanceolate, sometimes several fused together, the tips 1–2 mm, linear; corolla 3 cm diam., broadly stellate-rotate, pubescent on petals outside, interpetalar tissue glabrous, the tips distinct 1–2 mm, pale lilac; filaments 1–2 mm, short; anthers 5 mm, lanceolate, erect; ovary lacking. *Hermaphrodite flowers* solitary, pedicel 5–10 mm, calyx tube 5–6 mm very spiny, the tips 5 mm, linear, distinct, with few spines; *corolla* to 3 cm diam., broadly stellate-rotate, petal tips distinct 1–2 mm; filaments 2 mm, anthers 5 mm, tapering, closely erect; style projecting 2 mm beyond the anther tips, stigma terminal, relatively large and pale. *Fruit* 1.5–2 cm diam., depressed globular, enclosed in the very spiny, accrescent, truncate calyx tube, the lobe tips 0.5–1 cm, linear, spiny, colour and texture of ripe fruit not known but some drying on the bush to a hard firm texture. *Seeds* 1.5–2 mm long, distinctly minutely reticulate, dark brown, 580 in one fruit.

S. leopoldensis is restricted in its distribution to the King Leopold Ranges in the north of Western Australia, where it is found in rocky gullies and creeklines at the base of the mountains. Six collections have been seen. The species does not appear to be closely related to any other androdioecious species and differs particularly in the more intricate habit of growth, the toothed margin of the leaves, the sparse tomentum and green aspect. Comparisons with the andromonoecious species *S. oedipus* Symon are given under that species. *Seedlings* grown from *Symon* 5318 produced male and hermaphrodite plants. One of these had 1 or 2 hermaphrodite flowers on a short peduncle and another had a hermaphrodite flower below the cyme of male flowers. These conditions have not been noticed in plants collected in the wild, and do perhaps indicate that the separation of the two types of flower may not be complete or may be influenced by environmental conditions.

A representative collection is *Symon* 5318, 24.vi.1967, 21 km from Inglis Gap on the north side of the King Leopold Ranges, distributed to ADW, B, CANB, K, L, NSW, PERTH.

The specific epithet is derived from the Leopold Ranges where the species occurs.

Solanum oedipus Symon sp. nov.

Frutex usque 2 m altus erectus sparsim ramosus colonialis paucis caulibus, quorum juvenes virides spinosique, seniores fusci et lignosi perpaucis spinis. *Spinae* 5–10 mm in caulibus copiosae, in superioribus et inferioribus paginis dispersae, petiolo pedunculo dispersae; absentes ex pedicello, copiosae et conspicuae in calycis tubo et lobis, spinae erectae, tenues, pallidae. Folia aspectu virida, glabra, praeter minutos stellatos pilos in foliorum axillis et in petiolis et in juvenibus foliorum basibus. *Folia* (7–) 9 (–20) x (3–) 5 (–8) cm, ambitu elliptica sed usque ad 19 lobos triangulares in margine; lobi 1–2 minoribus dentibus, incisi, sinus rotundati vadosi rarim ad plus quam quartam partem costam versus fissi, apices folii et lobi acuti vel acuminati; basis folii cuneata inaequalis, petiolis 1–3 cm.

Inflorescentia flos singularis hermaphroditus in basi cymae florum masculorum. Inflorescentia non visa. Pedunculus florum masculorum 4–20 cm longus ferens usque ad 60 flores. Pedicellus fructifer 2 cm, crescens et auctus ad 5–6 mm diam., in basi calycis tubi. Tubus calycis 5–6 mm lobi 1.5–2 cm longi triangulares, apices lineares et fructum excedentes. *Bacca* 1.5–2 cm globosa sub viridis. *Semina* 4–4.5 mm longa pro ratione crassa, nigra, muricata. 37 et 38 semina in duobus fructibus visis.

> *Typus: D. E. Symon* 7119, 29.v.1971, from low quartzite outcrop between Kalumburu Mission and Longini Landing, Kimberley Division, Western Australia. An erect shrub to 2 m, bright green in aspect, forming a colony of a few stems. Approximate Lat. 14°15′S, Long. 126°36′E. (CANB, (holotypus), ADW, K, L, NT, PERTH).

FIG. 7

An erect, sparsely branched, *shrub* to 2 m high forming small colonies of a few stems, the young stems green and spiny, older ones brown, woody, and almost spineless. *Spines* 5-10 mm, abundant on the stems, scattered on the upper and lower leaf surface, petiole and peduncle, absent from the fruiting pedicel, abundant and conspicuous on the calyx tube and lobes, the spines straight, slender and pale. Leaves green in aspect, glabrous except for minute stellate hairs in the leaf axils and on the petioles and leaf bases of young leaves. *Leaves* (7–) 9 (–20) x (3–) 5 (–8) cm, elliptic in outline and with up to 19 triangular lobes along the margin; the lobes with 1–2 smaller lobes, the sinuses rounded, shallow, rarely cut more than one quarter of the way to the midrib, leaf and lobe apex acute or acuminate; leaf base cuneate, unequal; petiole 1–3 cm.

Inflorescence a single hermaphrodite flower at the base of a cyme of male flowers. Flowering state not seen. Rhachis of the male flowers 4–20 cm long and bearing up to 60 flowers. Fruiting pedicel 2 cm, tapered and enlarged to 5–6 mm diam. at the base of the calyx tube. Calyx tube 5–6 mm, the lobes 1.5–2 cm long, triangular, the tips linear and exceeding and enclosing the fruit which is visible between the lobes. *Berry* 1.5–2 cm, globular, very slightly bilobed in the few seen, pale green. *Seeds* 4–4.5 mm long, relatively thick, black, distinctly muricate, 37 and 38 seeds in two fruits examined.

This species is known only from the type collection and one made by A. Cunningham at Montague Sound. Although very distinctive and quite large, this species has been rarely collected. It does not appear to be at all closely related to the other Australian andromonoecious species. This species differs in its bright green aspect, very sparse stellate hairs, swollen pedicel and thicker, larger, muricate seeds. It is possibly more closely related to *S. leopoldensis* from which it differs in being andromonoecious and not androdioecious, and in addition has longer swollen pedicels, exposed fruit, much larger seeds, and an erect sparsely branched habit compared with *S. leopoldensis* which is relatively intricate. However few plants of *S. oedipus* are known. On each of two days they were visited, the plants at Kalumburu were heavily attacked by grasshoppers.

The specific epithet uses the name of King Oedipus well known for his swollen foot and refers indirectly to the enlarged and swollen pedicel of the mature fruit.

Solanum papaverifolium Symon sp. nov.

Herba usque 30 cm, erecta vel effusa, colonialis, perennis, basi vix lignosa, caulibus et videtur ultra unum annum haud persistentibus, adspectu generali viridi concolori. Planta inter spinas glabra, praeter pilos minutos glandulosos in novellis pilis stellatis ut videtur nullis. *Spinae* usque 5 mm, tenues, rectae, pallidae, in caule, utraque pagina folii, pedicello et calyce obviae. *Folia* c. 5 x 4 cm, ambitu ovata, sed in lobos 5–11 penitus dissecta, quoque lobo 1–2 x 0.5 cm, sinubus fere usque ad costam profunde dissectis, lobis iterum lobulis vel dentibus 1–5 instructis; apice laminae et lobi acuto, basi cuneata inaequali; petiolo 1–1.5 cm.

Inflorescentia cymosa, e caulis parte superiore, exorta, floribus 1–6; pedunculus c. 1 cm, rhachis floralis 1–2 cm; pedicellus c. 1 cm, tenuis; calycis tubus 2–3 mm, lobis 3–5 mm lanceolatis, acuminibus parvis; *corolla* 2 cm diam., stellata; filamenta c. 1 mm; antherae 3.5–4 mm, oblongae; ovarium pilis paucis glandulosis praeditum; stylus 5–6 mm, stigma leviter bilobatum. *Pedicellus fructifer* 1–2 cm, firme curvatim deflexus; calyx auctus basem fructus tegens, lobis fructum includentibus et excedentibus; *bacca* 12–18 x 10–12 mm, depresse globosa, flavovirens, leviter intensius viridi-vittata.

> *Typus: V. N. Gilley*, 11.vi.1969, on the property of Dr. Thomas, "Maneroo", Graman, about 56 km north-west of Inverell, New South Wales. (NSW (holotypus), ADW, BRI, CANB, K, MEL.)

FIG. 8

An erect or sprawling, colonial, perennial *herb* to 30 cm, scarcely woody at the base, the stems probably lasting one season only, general aspect green, concolorous. Plant glabrous between the spines except for minute glandular hairs on the young growths, stellate hairs absent. *Spines* to 5 mm, fine, straight, pale, present on the stems, upper and lower leaf surface, pedicel and calyx. *Leaves* c. 5 x 4 cm, ovate in outline but deeply dissected into 5–11 lobes, each 1–2 x 0.5 cm, the sinuses deeply cut almost to the midvein, the lobes themselves with 1–5 lobes or teeth, leaf and lobe apex acute, base cuneate, unequal; petiole 1–1,5 cm.

Inflorescence a cyme from the upper parts of the stem, with 1–6 flowers; peduncle c. 1 cm, floral rhachis 1–2 cm; pedicel c. 1 cm, slender; calyx tube 2–3 mm, the lobes 3–5 mm lanceolate, acumens small; *corolla* 2 cm diam., stellate; filaments c. 1 mm, anthers 3,5–4 mm, oblong; ovary with a few glandular hairs; style 5–6 mm; stigma slightly bilobed. *Fruiting pedicels* 1–2 cm, firmly curvedly deflexed, calyx enlarged to cover the base of the fruit, the lobes enclosing and exceeding it. *berry* 12–18 x 10–12 mm, depressed globular, greenish yellow, with faint stripes of deeper green.

This species occurs in southern Queensland and northern New South Wales between Dalby and Quirindi on heavy, black soils and is frequenly described as a weed of cereal crops. Twenty-three collections have been seen. *S. papaverifolium* is most closely related to *S. adenophorum* F. Muell. from which it differs in its much more deeply cleft leaves, lack of stellate hairs, fewer minute glandular hairs and smaller flowers.

A representative collection from Queensland is: *S. L. Everist*, Nov. 1951, Yandilla, now at BRI, and from New South Wales: *C. Moore*, undated, Liverpool Plains, now at BM, K, and NSW. The specific epithet was chosen because of the similarity of the leaves of the new species to those of *Papaver hybridum* L.

Solanum tumulicola Symon sp. nov.

Herba perennis, colonialis, effusa, usque 30 cm alta, inermis. Partes omnes pilis stellatis densis approximatis minutis pubescentes, adspectu generali griseo-viridi plus minusve discolori. *Folia* (2,5–) 4 (–8) x 0,4–0,8 cm, lineari-lanceolata, margine integro, apice acutato, basi cuneata, foliis exsiccando saepe secus nervum medium plicatis; petiolo pro rata brevi.

Inflorescentia cymosa, extra-axillaris, 1–6 flora; pedunculus 1–1.5 cm; pedicellus 1 cm, gracilis; calyx 2–3 mm, lobi 1–1,5 mm, obtuse triangulares, acuminibus brevibus; corolla 2 cm diam., stellata; filamenta c. 1 cm; antherae 4 mm oblongae, sursum angustatae; ovarium apice pilis stellatis paucis praeditum; stylus c. 6 mm, erectus; stigma capitatum. *Pedunculus fructifer* 2–3 cm, leviter elongatus; pedicellus c. 1–5 cm, deflexus; calyx auctus, basin fructus tegens; bacca 1–1.5 cm diam., matura flavida.

Typus: D. E. Symon 5085, 7.vi.1967, about 40 km east of the Stuart Highway at Daly Waters, Northern Territory. "In a seasonally dry swamp with many mounds about tree stumps and ant hills. The *Solanum* was common on the mounds, and always above the lower levels, colonial, straggly, flowers blue, few fruits seen (too early), the plants were in active growth." (ADW 33286 (holotypus), AD, B, CANB, K, NSW, NT, US).

FIG. 9

A sprawling, colonial, perennial *herb* to 30 cm tall. All parts pubescent with dense, close, minute, stellate hairs, general aspect grey green, slightly discolorous. Plant spineless. *Leaves* (2,5–) 4 (–8) x 0.4–0.8 cm, linear lanceolate, margin entire, apex acute, base cuneate, leaves of herbarium specimens often folded along the mid vein; petiole 0.5–1 cm, relatively short.

Inflorescence a cyme from an extra axillary position and with 1–6 flowers; peduncle 1–1.5 cm; pedicel 1 cm, slender; calyx 2–3 mm, lobes 1–1,5 mm bluntly triangular, lobe tips short; *corolla* 2 cm diam., stellate, filaments c. 1 mm; anthers 4 mm, oblong, tapered upwards; ovary with a few stellate hairs at the summit; style c. 6 mm erect, stigma capitate. *Fruiting peduncle* 2–3 cm, somewhat lengthened, pedicel c. 1.5 cm, deflexed; calyx enlarged to cover the base of the fruit, berry 1–1.5 cm diam., yellowish when ripe. *Chromosome number*, n = 12 (Symon 5085, ADW 33286), counted by Barbara Randell.

S. tumulicola occurs in the central areas of the Northern Territory, several collections coming from near Elliott; it also occurs in adjacent parts of Queensland. Fourteen collections have been seen. This species is closely related to *S. esuriale* Lindl. and is at times difficult to separate from it. It shares with *S. esuriale* the herbaceous habit, spinelessness, relatively narrow unlobed leaves, and uniform close tomentum. It differs from *S. esuriale* in its more slender habit and much narrower leaves and its chromosome number, that of *S. esuriale* being n = 24 (*Symon* 2146, 3951, 3977). It may also appear similar to some narrow leaved forms of *S. coactiliferum* J. M. Black from which it differs in its herbaceous perennial habit rarely making second year growth, while the latter is a small woody undershrub with stems generally lasting several years and frequently bearing slightly recurved spines, and it usually has depressed globular fruits on short peduncles.

A representative collection from the Northern Territory is that by *Perry* 3491, 16.iii.1953, 19 km west of Tobermorey Station, distributed to AD, BRI, CANB, NSW, K, and from Queensland one by *Blake* 17839, 18.v.1947, halfway between Brunette Downs and Rockhampton Downs, distributed to BRI, CANB, K.

The specific epithet refers to the occurrence of the species on low mounds and on the raised ground at the base of trees at the type locality.

Acknowledgements

I am grateful to Mr. Airy-Shaw and Mrs. H. M. Jackson for assistance with the Latin diagnoses, and Mrs. Barbara Randell for chromosome counts in several species.

Fig. 1. *Solanum cleistogamum* Symon, holotype.

2

Fig. 2. *Solanum eburneum* Symon, holotype.

3

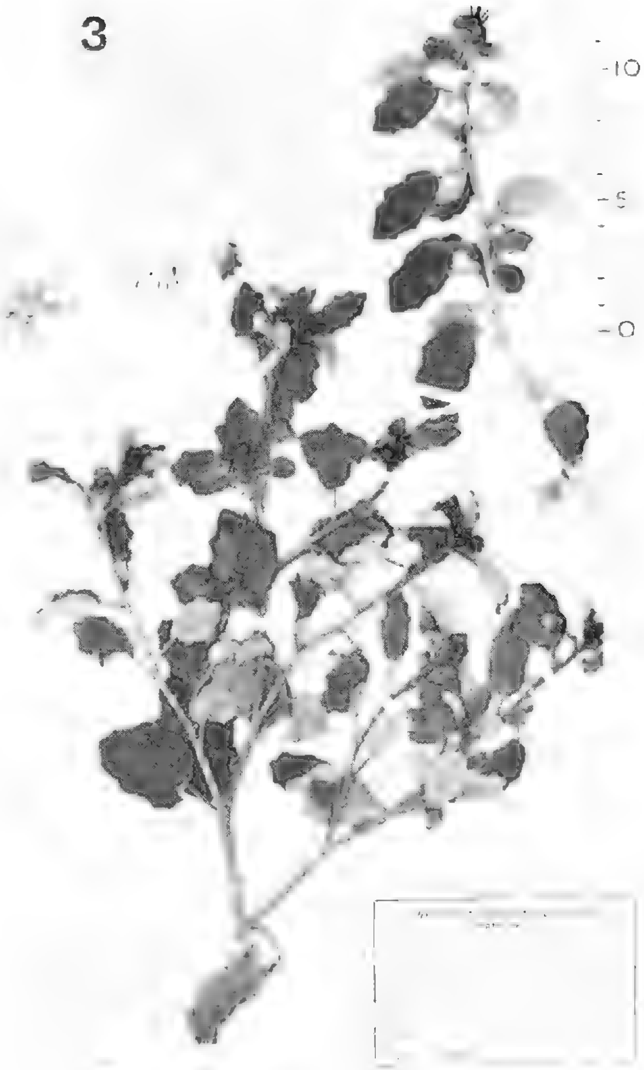

Fig. 3. *Solanum gilesii* Symon, holotype.

4

Fig. 4. *Solanum karsensis* Symon, holotype.

5

Fig. 5. *Solanum lachnophyllum* Symon, holotype.

Fig. 6. *Solanum leopoldensis* Symon, holotype.

Fig. 7. *Solanum oedipus* Symon, holotype.

8

Fig. 8. *Solanum papaverifolium* Symon, holotype.

9

Fig. 9. *Solonum tumulicola* Symon, holotype.

OBITUARY: SIR JAMES HARRISON

Summary

On the 16th of September, 1971, His Excellency, Major-General Sir James Harrison, K.C.M.G., C.B., C.B.E., died suddenly on a flight from Sydney to Honolulu. The Fellows of the Royal Society of South Australia felt the untimely death of Sir James with deep sorrow and as a sad and severe loss. Sir James was 59 years of age.

HIS EXCELLENCY MAJOR-GENERAL SIR JAMES HARRISON,

K.C.M.G., C.B., C.B.E.,

GOVERNOR OF SOUTH AUSTRALIA

Patron of the Royal Society of South Australia, 1969–1971

On the 16th of September, 1971, His Excellency, Major-General Sir James Harrison, K.C.M.G., C.B., C.B.E., died suddenly on a flight from Sydney to Honolulu. The Fellows of the Royal Society of South Australia felt the untimely death of Sir James with deep sorrow and as a sad and severe loss. Sir James was 59 years of age.

The Society received the honour of the patronage of Sir James in April 1969, and although his term of office was only a short one he will be remembered as few before. Sir James was not only patron of this Society in name but one who was keenly interested in its affairs and demonstrated his interest by active participation at a number of functions during the past years. Although troubled by ill health, Sir James also contributed. He was the first patron to speak to a meeting of the Society for many years. In his address in April 1970, entitled "The Scientist under the Microscope", Sir James presented a searching scrutiny of the role of the scientist in present-day society, concluding with a word of caution against isolation in self-determined detachment.

Those who were privileged, as I was, to accompany Sir James on one of his inspection trips to the outback, soon became aware of his acute powers of observation, his straight-to-the-point questions, and above all his broad and balanced outlook. His keen interest in industrial development and mineral exploration, for instance, matched a rare understanding of the need for conservation. His appreciation of science was combined with concern about overzealous applications of some results of scientific research and the influence on the natural environment of such applications. Ever present there was a deep concern for the country and his fellow man.

The Royal Society of South Australia will always remember Sir James, the patron and the man.

H. WOPFNER, *President.*

OBITUARY: JOHN BURTON CLELAND

Summary

At the time of his death, Sir John Cleland was the oldest member of the Royal Society of South Australia, having been a fellow for over 75 years and Honorary Fellow since 1949. During this time he served the Council of the Society in various offices and always took an active interest in the activities of the Society.

JOHN BURTON CLELAND.
KT., C.B.E., M.D., CH.M., F.R.A.C.P.

OBITUARY

JOHN BURTON CLELAND, Kt., C.B.E., M.D., Ch.M., F.R.A.C.P.

22.vi.1878 – 11.viii.1971

At the time of his death, Sir John Cleland was the oldest member of the Royal Society of South Australia, having been a fellow for over 75 years and Honorary Fellow since 1949. During this time he served the Council of the Society in various offices and always took an active interest in the activities of the Society.

Sir John Cleland chose medicine for his professional career, specializing in pathology and public health. He rose to eminence in these fields, but in addition made notable contributions in botany, ornithology, anthropology, wild life conservation and natural history generally. During his long lifetime he contributed some hundreds of articles to the scientific and more general literature. The present account attempts to deal more particularly with his contributions to general biological science; his achievements in the field of medicine will be mentioned only incidentally, as they will be dealt with elsewhere.

John Burton Cleland was born at Norwood, South Australia, on 22nd June, 1878. He was the elder son of William Lennox Cleland (1847-1918), who at that time was in private medical practice. Not long afterwards W. L. Cleland was appointed Resident Medical Officer (i.e. Medical Superintendent) of the Parkside Lunatic Asylum, as it was then called, and moved into residence there with his family.

At an early age, J. B. Cleland developed a love of natural history, an interest no doubt fostered by his father, who, apart from being a medical practitioner specializing in psychiatry, lectured at the university level in materia medica, and on occasions, in botany. Additionally, in both 1898 and 1899, as President of the Royal Society of South Australia, W. L. Cleland gave Presidential Addresses on anthropological subjects. He was also interested in geology, reading a paper on this to this Society in 1887 (Vol. 10).

Between the Asylum and the foothills of the Mount Lofty Ranges was open country with few houses. Every opportunity was at hand to study natural history, and at an early age J. B. Cleland had gathered together a small museum of stones, flowers and also sea-shore objects.

Initially Cleland was sent to a private school at Parkside, and later to Prince Alfred College. He commenced the study of medicine at the University of Adelaide in 1895, his teachers being Ralph Tate, Edward Rennie, William Bragg, Edward Stirling and Archibald Watson. In 1896 a dispute arose between the clinical teachers at the Adelaide Hospital and the South Australian Government. This came to a head in 1897 and the Honorary Teaching Staff all resigned. In consequence all students had to transfer to either Melbourne or Sydney to complete their courses. Cleland chose Sydney, as he had been advised that the natural history, particularly the birds, was better there, this being ascribed to the poorer soil and greater diversity of vegetation.

Cleland graduated in medicine in Sydney in 1900. After internship at the Prince Alfred Hospital and a period of work in pathology, he went as a ship's surgeon on a steam ship to northern Australian and far eastern ports. On stopping at Cairncross Islets on the Great Barrier Reef, he made some observations on the bird life, and later wrote an article, "Two hours on a coral island", which was published in the Sydney press. This was his first essay into writing on ornithology; as a schoolboy he had contributed an article on fungi to the school magazine.

In 1903 he travelled to the United Kingdom, getting further training in pathology, bacteriology and tropical medicine. On return to Australia in 1905 he joined the staff of the Public Health Department in Perth. As there was an outbreak of plague in Perth at the time, Cleland was able to make observations on rats and their ectoparasites as well as his more formal pathological duties. In 1907 he investigated the disease "Surra" in camels at Port Hedland, W.A., including collecting the ticks (*Hyalomma aegyptium*) and parasitic flies (Hippoboscidae) brought from India on the camels. Cleland's knowledge and efforts resulted in the identification and destruction of the infected camels.

In 1909 he transferred to the Government Bureau of Microbiology in Sydney, where he remained for 11 years. It was here that

Cleland was to make his two major contributions in the experimental medical field. The first of these was the establishment that dengue fever is transmitted by the mosquito *Aedes aegypti*. This was accomplished with his colleagues Bradley and McDonald in 1916, by the use of human volunteers. The other contribution made by Cleland with his colleagues was on the newly discovered "Australian X disease", which occurred in 1917 and 1918 in country towns of New South Wales, Queensland and Victoria. Virus strains were isolated by transmission to monkeys, also a sheep, horse and a calf. The nature of this virus-borne disease was not established until many years later, when a recurrence led to its being re-named Murray Valley encephalitis, found to be transmitted by culicine mosquitoes from an avian reservoir.

In 1920 Cleland was appointed Marks Professor of Pathology at the University of Adelaide, this being the foundation appointment. Cleland was very happy to accept this position, which brought him back into an academic atmosphere, with his horizons widened by working in other areas for a period of 20 years. This appointment marked the end of his experimental studies in epidemiology. However, apart from his routine pathological and teaching duties he was able to resume the role of a general naturalist, pursuing interests in botany and anthropology, as well as ornithology. He retired from this position in 1948, at the age of 70.

Botanical Studies

At quite an early age Cleland became interested in the fleshy agaric fungi, his fancy possibly having been taken by their striking coloration and elegant structure. Even in old age he could recall vividly a specimen of *Cortinarius archeri* with its purple cap and spider-web veil, its gills changing from purple to rusty-red. He was always fascinated by the colours of plants and other natural objects, including stained tissues. His interest in *Russula* led to the schoolboy article published in the "Prince Alfred College Chronicle" in 1893. He made attempts to preserve the colours and shapes of fungi, but these efforts were not successful. Following this, his father bought for him M. C. Cooke's (1892) "Handbook of Australian Fungi". Later Cleland was able to extend his interest in the larger fungi to other Australian states, and at the present time his two volumes (1934, 1935) on fungi in the South Australian handbook series are the nearest approach to a flora on these groups of Australian fungi. In due course he was able to solve some of the problems of recording the fugitive colours of fungi by enlisting the aid of Phyllis Clarke in Sydney, Rosa Fiveash in Adelaide, and others. In addition to his interests in the colours and morphology of the fungi he was interested in their edibility and possibly noxious effects. He would taste the fungi carefully, and ask others to do the same. An appreciation of Cleland's contributions to mycology was written by Hansford (1959), to which the reader may turn for more detail.

Cleland's interest in plants more generally was also to lead to a number of papers on distribution of vascular plants, particularly in South Australia. A sensitive appreciation of Cleland's contributions to vascular botany was made by Constance Eardley (1959), in the same commemorative series in the Transactions of the Royal Society of South Australia. Cleland was not a taxonomist in this field of biology, but mainly a collector and floristic surveyor, apart from his gathering of data on possible harmful effects of plants to man, and to a lesser extent, to other animals. As Constance Eardley's appreciation indicates, possibly Cleland's greatest contribution in vascular botany, apart from his thorough and systematic collecting wherever he went, was his support of John McConnell Black as a botanical taxonomist. Later, Cleland gave considerable promotion to the Second Edition of Black's Flora, after Black's death in 1951.

Cleland's final paper on the noxious effects of plants to man was by Cleland & Lee (1963), which epitomizes his previous efforts.

A ramble with Cleland was always an instructive experience. In his local woodlands there were few plants he could not recognize at sight. In addition he knew what knowledge was available of the aboriginal uses of the plant, and frequently a good deal of its taxonomic history.

Anthropology

As a child Cleland came in contact with mentally deranged Australian aboriginals confined at the Parkside Lunatic Asylum, leading to a sympathetic interest in them. At the University of Adelaide in the early 1920's, the Professor of Anatomy was Frederick Wood Jones, who included physical anthropology among his wide interests. Another colleague was Thomas Draper Campbell, later Professor of Dentistry, who also had a consuming interest in anthropology, particularly in aboriginal customs and some aspects of their material culture, apart from his professional interest in their dental anatomy. Cleland and Campbell joined Wood Jones in the formation of the Board of Anthropological Research at the University of Adelaide, and expeditions were made to Central Australia and remote areas of South Australia. Cleland was one of the original members of the Board, and became its Chairman in 1930, holding this position for many years.

Cleland's early interests in anthropology were in blood groupings, as well as in general ecological aspects such as the use of indigenous plants for native food materials and drugs. He took a considerable interest in the diseases of the aboriginals, contributing a number of papers on this subject. His more general studies were largely made in collaboration with the zoologist Thomas Harvey Johnston, the anthropologist Norman B. Tindale, and others.

Cleland's zeal for anthropology led to his being elected President of the Anthropological Society of South Australia on two occasions, 1945–6 and 1958. Additionally he was for a number of years a Member of the Aboriginal Affairs Board of the South Australian Government. An appreciation of his work as an anthropologist is given by T. D. Campbell (1959), in the commemorative series of appreciations in the Transactions of the Royal Society of South Australia, celebrating Cleland's 80th birthday.

Other biological interests

Mention has been made of Cleland's early interest in ornithology, and throughout his life ornithology remained a major interest. As a good general naturalist he had some knowledge of insects and marine animals, taking most interest in the toxic effects from their bites, stings, physical contact injuries, or ill-effects of ingestion. Even in old age these interests remained, resulting in effective collaboration in study of the toxic effects of plants and animals. Thus when Cleland broke his leg at the age of about 80 he began to put together notes on the effects of injurious marine animals and in due course this led to the publication of Cleland & Southcott (1965), a work dealing with the harmful effects of invertebrates to man in the Australian region. Cleland would think about a problem for many years, and enlist the aid of others where he could see an opportunity. A series of papers in collaboration with the writer on possible hypervitaminosis A among Australian aboriginals, Japanese and Australian fishermen and sailors, as well as Antarctic explorers, from the eating of carnivore liver, was the result of his puzzling for many years over a series of illnesses which first came to his notice in South Australia in 1935. The shed skin of the heel of one of the sufferers, which he preserved dried for many years, was analysed for arsenic, but only insignificant traces were found. Eventually it was possible to make a plausible hypothesis that these were all a manifestation of hypervitaminosis A. Recent analyses of the livers of Antarctic huskies have confirmed the hypothesis that Mertz and Mawson in 1913 suffered from this complaint, and although by then Cleland was almost completely blind, his intellect was quite unimpaired and he took a good deal of pleasure in the news.

Wild life conservation

Probably one of the most tangible ways in which Cleland was able to express his devotion to natural history was in his efforts in wild life conservation. In 1927, at the age of 49, he was President (for the first time) of the Royal Society of South Australia, and became *ex officio* one of the Commissioners of the National Park, as the title then was. At the time "The National Park" referred only to the Belair National Park, in the ranges behind Adelaide. In 1929, on a vacancy occurring, he was nominated in his own name. In 1936 he became Chairman of Commissioners and remained so until 1965, continuing on the Commission as Deputy Chairman until 1969, at the age of ninety.

Two major and recurring problems came before the Commissioners in their attempts to protect the fauna and flora under their care. The major of these was the constant threat of bushfires in the limited area at first placed under their jurisdiction. A wider problem, which for many years they were powerless to alter, was that of the constantly diminishing areas of native bushland, under the pressures of increasing population and industrialization on the one hand, and for greater food production on the other. For many years the Government of the day was unwilling to consider the setting aside of any possibly arable land for the apparently non-productive purpose of wild life conservation. Ultimately and belatedly the need became recognized, perhaps because the Government in part saw such reserves in the light of possible recreation or sports areas. The accelerated immigration programme of the 1950's brought into prominence how poorly Australia in general (and South Australia in particular) is provided with such reserves. Eventually it became recognized that wild life reserves are in fact what their name implies, and not reserves of land for sporting areas lightly disguised by a surrounding belt of bushland. The Commissioners came in time to have considerable land holdings placed under their care. Cleland, as Chairman of Commissioners, willingly accepted the heavy responsibility of advising the Government on the capabilities of the various areas offered from public or private sources as possible reserves. Contemporaneously with the establishment of the National Trust of South Australia, the National Park Act was amended to include nature reserves vested in the Commissioners who now became the Commissioners of the National Park and Wild Life Reserves. The original area at Belair, together with considerable additions in the Mt. Lofty Ranges, particularly at Para Wirra, and very large areas near the Victorian border and on Eyre Peninsula, were now under one authority.

Cleland spared no effort in promoting this cause, and made every attempt to preserve tracts of vegetation in their natural state. In the country districts often the only available natural areas were the roadside strips of mallee and other trees with their lower storey vegetation. Many rural land-holders wanted these strips removed, the usual reason given being that they harboured weeds and vermin. Some support was given to the land-holders at various official levels. On one occasion it was stated that the Bushfires Prevention Committee had two major problems to deal with, these being Professor Cleland and rabbits.

The apparently diverse controls of the various bodies with interests in fauna and flora preservation was not actually as diverse as it at first appears, when it is realized that Cleland served on various of these semi-government bodies, such as the Fauna and Flora Board, administering Flinders Chase, Kangaroo Island, and the Flora and Fauna Advisory Committee, advisory to the Minister of Agriculture of South Australia. No doubt in these activities Cleland was able to get at least some semblance of a common policy.

In 1957, at the age of 79 Cleland was able to make a trip to New Guinea. His forensic interests were stimulated when he was given a collection of recipes for the cooking of human flesh. In New Guinea he travelled to a number of widely scattered centres, including Port Moresby, the Fly Delta, Goroka and Lae—air transport making such travelling possible for an elderly, even though active man. Later he was able to make a trip to the Fore country, where the newly discovered disease "kuru" had been recorded by Gadjusek and Zigas. Although it was not known at the time, this disease is apparently largely perpetuated by cannibalism.

His loss of sight in his late 80's was a considerable hardship, preventing him from reading the early accounts of Australian and other exploration, as well as early medical and biological texts in which he took so much pleasure. Nevertheless he bore this blow stoically, accepting it as part of the ageing process.

Apart from his active participation in the affairs of the Royal Society of South Australia (see further below) and the bodies mentioned earlier, he was a member of a number of medical and scientific societies. He had served as President for a number of these, including the Royal Society of New South Wales, the Royal Australasian Ornithologists' Union and the Medical Sciences Club of South Australia, being one of the founding members of the last-named.

Cleland always strove for complete intellectual honesty. As an illustration of this, the writer remembers Cleland in 1947 telling how he had recently been on a trip to the Coorong in company with Julian Huxley and some other eminent biologists. Cleland stated that in telling his colleagues about the habits of birds there was a natural tendency to embellish the account, which had to be kept rigidly in check.

Cleland was made C.B.E. in 1949, and was knighted in 1964. For those who had known him for many years it was difficult to change from "Professor Cleland" to "Sir John" in addressing him. With his natural modesty he seemed to prefer the title by which he had so long been known. Another well-deserved honour was the naming after him of the Cleland Wild Life Reserve, later re-named Cleland National Park, on the western slopes of Mt. Lofty. This will be a lasting memorial to his efforts in the field of wild life conservation. He was commemorated also in the names of several plants and animals. A comparatively minor honour which Cleland valued was having a kindergarten in the neighbouring suburb of Beaumont named after him.

At the time of his death Cleland was the oldest member of the Royal Society of South Australia, and the one with the longest membership, having joined in 1895. On returning to South Australia in 1920 he was able to participate actively in the Society's affairs. He served on the Council from 1921–1926, 1932–1937, and as Vice-President for 1926–1927 and 1941–1942. He was elected President on two occasions, 1927–1928 and again 1940–1941. He was awarded the Verco Medal in 1933, and was elected to Honorary Fellow in 1949.

R. V. Southcott.

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